

# Surgical Treatment for Falcotentorial Meningiomas

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Among intracranial meningiomas, falcotentorial meningiomas, occurring at the junction of the falx cerebri and tentorial dural folds, are extremely rare. Because of their deep location, they are surrounded by critical structures, and have been regarded as one of the most challenging lesions for surgical treatment. In this study, we describe our surgical strategy for falcotentorial meningiomas and provide a review of our experience.

**Key Words:** Meningiomas, venous infarction, operations, craniotomy

## INTRODUCTION

Meningiomas arising from the falcotentorial junction are rare, and constitute about 1% of all intracranial meningiomas.<sup>1-3</sup> Two types of meningiomas can occupy the pineal region: the first type is the velum interpositum meningioma, while the second type is the falcotentorial meningioma. There has been some controversy concerning the definition of falcotentorial meningiomas. However, it is generally accepted that falcotentorial meningiomas arise from the dura of the tentorium cerebelli and posterior part of the falx. These meningiomas have dural attachment, and secondarily invade the pineal region. Meanwhile, velum interpositum meningiomas arise from the velum interpositum, the double layer of pia mater that forms the roof of the third ventricle, and are free lying in the third ventricle without dural attachment.<sup>4-7</sup> Falcotentorial meningiomas are mainly supplied by the tentorial branch of the meningohy-

pophyseal trunk. However, most velum interpositum meningiomas are distinguished from falcotentorial meningiomas in that they receive their main blood supply from the medial posterior choroidal arteries.<sup>1,8,9</sup>

## MATERIALS AND METHODS

Of the 2983 meningiomas we encountered from October 2001 to January 2014, we operated on 11 patients with falcotentorial meningiomas, which accounted for about 0.3% of all intracranial meningiomas (Table 1). Preoperatively, all patients underwent magnetic resonance imaging (MRI) and cerebral angiography to determine the appropriate approach trajectory and craniotomy size.

### Surgical approach

Our main surgical approach was an occipital transtentorial with or without transfalcine approach. Moreover, we favored the three quarter prone position, except in one case, since we believed this position to be safer, providing lower risk of air embolism during the prolonged operative time. In patient positioning, airway patency and jugular venous pressure are the most important factors determining positive outcomes. Therefore, we were very careful to maintain an adequate airway and venous pressure when we elevated, rotated, and flexed the patient's neck.

For determination of bone flap size and location, as well as

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Table 1. Summary of 11 Patients with Falcotentorial Meningioma

Case No.	Sex/age (yrs)	Symptoms	Duration of symptoms	Follow up period	Preoperative KPS score	Last follow-up KPS score	Extent of resection	Pathology	Postoperative complication
1	M/45	Headache, dizziness, visual field defect	2 months	150 months	80	100	GTR	Fibrous	Homonymous hemianopsia <sup>†</sup>
2	F/72	Headache	5 months	44 months	90	100	GTR	Transitional	No
3	M/53	Visual field defect	6 months	37 months	80	100	GTR	Meningothelial	No
4	F/68	Gait disturbance	6 months	35 months	90	60	GTR	Meningothelial	Occipito-Cbll., hemorrhage
5	F/51	Headache	6 months	35 months	90	100	GTR	Meningothelial	No
6	F/43	Diplopia	2 months	20 months	80	100	GTR	Meningothelial	Homonymous hemianopsia <sup>†</sup>
7	F/60	Gait disturbance	60 months	19 months	80	100	GTR	Transitional	No
8	F/32	Gait disturbance, general weakness	6 months	15 months	70	100	GTR	Transitional	Diplopia <sup>†</sup>
9	M/55	Gait disturbance	1 month	15 months	90	90	STR*	Transitional	No
10	M/55	Headache	2 months	9 months	90	100	GTR	Atypical	No
11	M/48	Visual field defect, diplopia	18 months	3 months	90	80	GTR	Atypical	PCA infarction <sup>†</sup>

M, male; F, female; KPS, Karnofsky performance scale; GTR, gross total resection; STR, subtotal resection; PCA, posterior cerebral artery.

\*This patient underwent gamma knife surgery due to re-growing of the tumor. <sup>†</sup>All these signs were transient. <sup>‡</sup>This resulted in visual field defect.

for identifying which side of the patient was to be upward, we thoroughly reviewed preoperative imaging studies. The location, size, and growth direction of the tumor were all important factors in determining the surgical approach. We compared those factors with surrounding normal brain parenchyma using a three-dimensional (3D) concept with the help of 3D simulation software (3D volume viewer version 1.2.3, released 14th August 2007, RMR systems, East Anglia, UK, www.rmrsystems.co.uk). The approach site was determined based on the shortest pathway from normal brain cortex to the tumor, and the patient's position was set so that the approach axis was parallel to the microscopic view. An occipital bone flap was made over the main bulk of the tumor considering possible exploration area through axis for surgical access. We could remove the tumor totally via a single, relatively small bone flap (Fig. 1). Craniotomy sizes are summarized in Table 2.

At the early stage of surgery, cerebrospinal fluid (CSF) drainage was imperative in most cases. With the aid of a navigation system, CSF was drained through the catheter into the ventricle or cisternal space. In half of the cases, the gravity-dependent position was helpful for gentle retraction of the occipital lobe.

To understand the relationship between the tumors and deep venous structures, pre-operative imaging studies, including thin-sectioned T2-weighted MRI and cerebral angiography with late venous phases, were performed. The vein that drained from the tumor was coagulated with minimal cerebral blood hemodynamic compromise. However, throughout the whole surgery, we tried to preserve physiologic veins. After central debulking of the tumor mass, we predicted the exact course of the deep venous structures and proceeded to remove the tumor, while maintaining the arachnoidal dissection plane. Gradual removal of the tumor in a piecemeal fashion allowed us to identify and save the deep venous structures around the tumor.

In cases in which the tentorium and falx had acted as an obstacle to the tumor, we made incisions on the tentorium and falx. In one case, we ligated and cut the transverse sinus on the non-dominant side to acquire wide exposure of the tumor (Fig. 2). In that case, although we divided the non-dominant transverse sinus, the patient had experienced complications of delayed occipito-cerebellar hemorrhage. The possible adverse effects of the transverse sinus ligation and resection will be discussed later.

## RESULTS

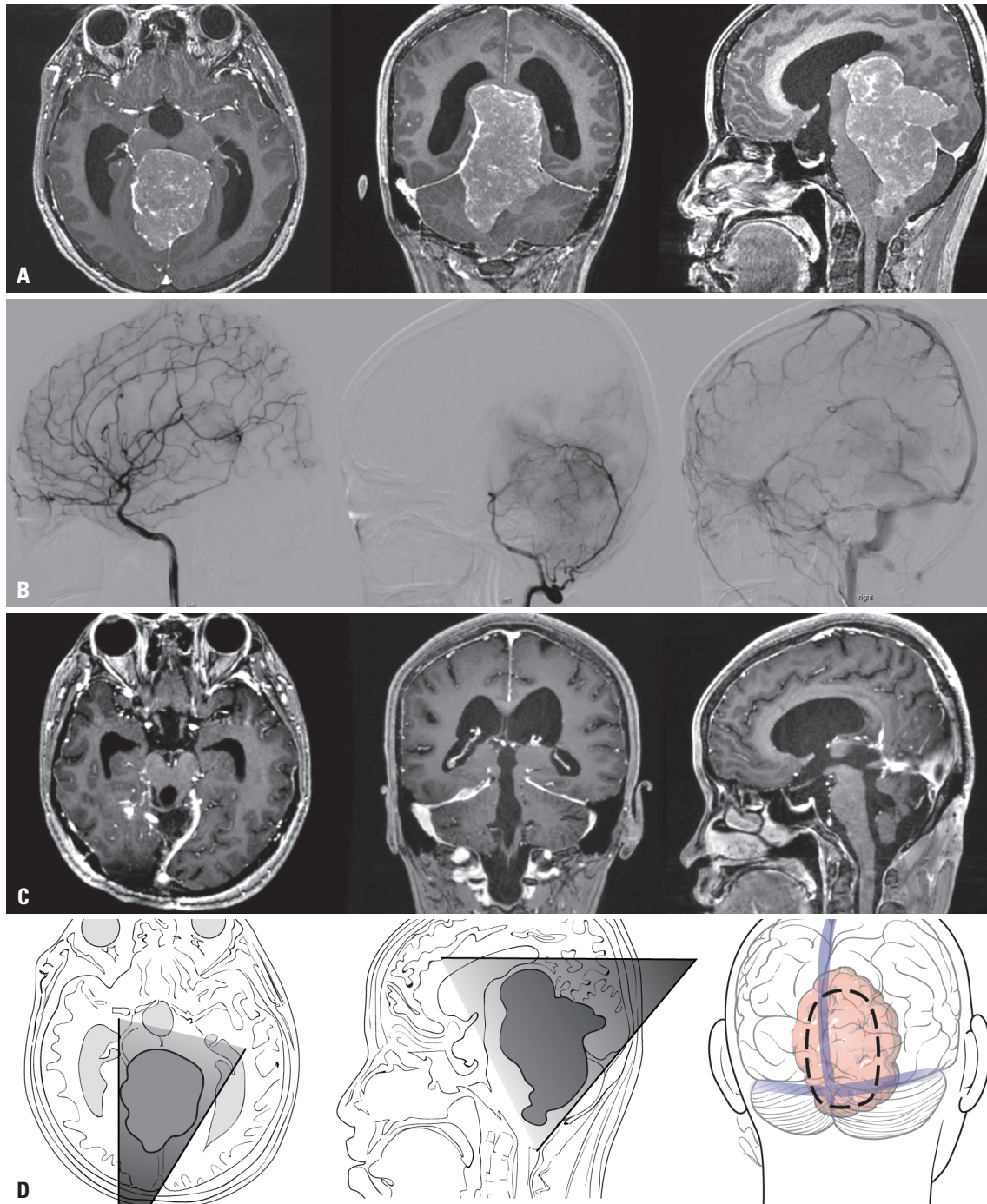
Five of these patients were men and six were women, with a mean age of 52.9 years (ranging from 32 to 72 years). The mean follow-up period was 35 months (ranging from 3 to 150 months). The main symptoms included headache in four patients, visual field defects in three patients, and gait disturbance in four patients. The average duration of symptoms was 10.3 months. The mean Karnofsky Performance Scale scores in the

preoperative phase and at last follow-up were 84.5 (range, 70 to 90) and 91.8 (60 to 100), respectively. The clinical features of the 11 patients are presented in Table 1.

**Imaging studies**

Like other intracranial meningiomas, the margins of the tumors

were relatively distinct from surrounding brain tissues on gadolinium-enhanced T1-weighted images. The average dimensions of the tumors were 4.1×3.4×4.6 cm (anteroposterior×transverse×vertical). Cerebral edema around the tumor was found in four patients, and preoperative hydrocephalus was noted in two patients.



**Fig. 1.** (A) Preoperative T1-weighted contrast-enhanced magnetic resonance images demonstrating a huge falcotentorial meningioma compressing brain stem and deep venous system. (B) Preoperative angiography showing feeders from meningeohypophyseal trunk (the artery of Bernasconi-Cassinari) and posterior meningeal artery from vertebral artery. Venous phase shows occlusion of inferior sagittal sinus and basal vein of Rosenthal. (C) Postoperative T1-weighted contrast-enhanced magnetic resonance images revealing complete tumor removal. (D) Artist's drawing showing possible access area through the relatively small bone flap. View in axial plane, sagittal plane and posterior view.

**Table 2.** Summary of Tumor Locations and Surgical Approach

Case No.	Tumor size (cm)	Classification by Asari, et al. <sup>10</sup>	Classification by Bassiouni, et al. <sup>1</sup>	Surgical approach	Patient position	Craniotomy size* (cm)	Op. time (hr)	Blood loss (mL)
1	4.3×3.1×3.2	Anterior, central	I	Bioccipital transtentorial	Three quarter prone, Rt. side up	6.5×7.2	6.0	300
2	3.4×2.7×3.1	Superior, lateral	III	OTT, Lt.	Three quarter prone, Rt. side up	4.8×3.6	6.5	350
3	5.0×4.6×4.6	Superior, lateral	III	OTT, Rt.	Three quarter prone, Lt. side up	3.2×3.6	7.2	350
4	3.3×2.8×3.7	Inferior, central	II	OTT, Lt. (transverse sinus cutting)	Three quarter prone, Lt. side up	3.9×5.5	6.4	400
5	2.5×2.2×2.5	Anterior, central	I	Occipital, Rt. (transtentorial, transfalcine)	Three quarter prone, Lt. side up	4.6×5.1	5.7	630
6	4.2×4.1×4.1	Anterior, central	I	Occipital, Lt. (transtentorial, transfalcine)	Three quarter prone, Rt. side up	6.5×4.3	10.0	450
7	4.5×4.6×4.8	Inferior, central	II	Occipital, Rt. (transtentorial, transfalcine)	Three quarter prone, Rt. side up	5.9×7.8	7.5	1200
8	6.3×5.0×9.3	Inferior, central	II	OTT, Rt.	Three quarter prone, Rt. side up	4.7×4.1	13.0	1500
9	3.8×2.9×3.9	Inferior, central	II	Occipitoparietal, bilateral	Three quarter prone, Lt. side up	6.5×5.2	7.5	300
10	2.9×2.8×3.1	Anterior, central	I	Occipitoparietal, Rt.	Three quarter prone, Rt. side up	3.4×4.4	7.5	650
11	5.2×2.9×8.1	Posterior, lateral	IV	Occipital, Lt.	Prone	6.8×7.8	9.5	800

Lt., left; Rt., right; Op., operation; OTT, occipital transtentorial.

\*Craniotomy size indicates the largest diameter.

Using the classification that Asari, et al.<sup>10</sup> published in 1995, the growth directions of the tumors were categorized into four types. There were four anterior-type tumors, two superior-type tumors, four inferior-type tumors, and one posterior-type tumor. Using classification published by Bassiouni, et al.,<sup>1</sup> there were four type I, four type II, two type III, and one type IV tumors (Table 2). Preoperative and postoperative coronal T1-weighted contrast-enhanced magnetic resonance images of all 11 patients are shown in Fig. 3.

A summary of the preoperative angiographic findings is presented in Table 3. Considering the benefit-to-risk ratio of preoperative embolization, the embolization procedure was only performed on three patients.

### Operative results

The operative results are summarized in Table 1. Ten patients had gross total resection (Simpson grade 1) confirmed by a postoperative MRI study, while one patient had subtotal resection (Simpson grade 4). There was one case of recurrence where subtotal resection was performed. That patient underwent gamma knife surgery at 6 months after the operation, and there was no evidence of regrowth after 12 months of follow-up.

There were no cases of surgery-related mortality in our series.

Most preoperative symptoms (9 of 11 cases in this series) were improved postoperatively. However, one patient, in whom we performed transverse sinus ligation and cutting, experienced delayed occipito-cerebellar hemorrhage that required additional ventricular drainage and an extended recovery time. Moreover, this was the only patient to receive placement of a post-surgical ventriculoperitoneal shunt. One other patient experienced a posterior cerebral artery infarction resulting in visual field defects. All other complications, including the visual field defect and diplopia, were transient and either resolved or improved over several postoperative weeks.

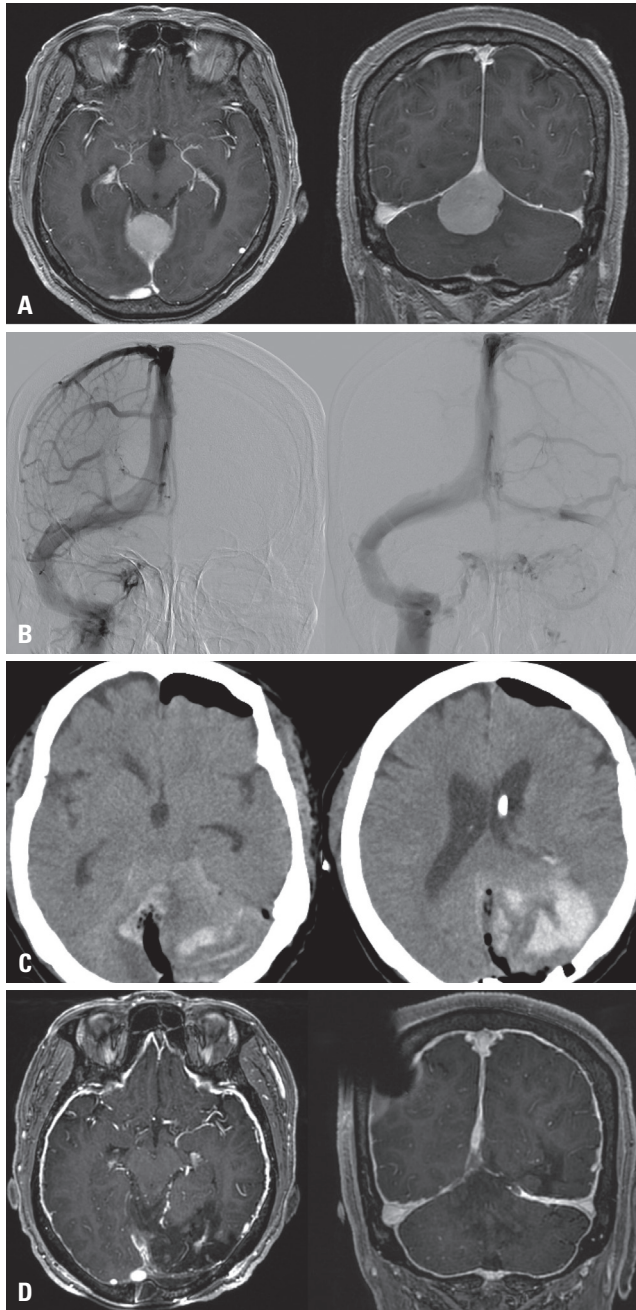
## DISCUSSION

### Clinical features

The average age of our patients at the time of operation was 52.9 years and this was similar to the reported average ages of patients with meningiomas at all locations.<sup>11,12</sup> Furthermore, we could not find gender predominance in our series (five male patients, six female patients).

In general, cortical blindness is the main postoperative problem encountered via the occipito-transtentorial approach, and





**Fig. 2.** (A) Preoperative T1-weighted contrast-enhanced magnetic resonance images demonstrating a falcotentorial meningioma abutting both transverse sinus. (B) Preoperative angiography showing right side dominant transverse sinus. (C) Postoperative CT scan showing delayed occipito-cerebellar hemorrhage. (D) Follow up T1-weighted contrast-enhanced magnetic resonance images showing complete tumor removal.

this is likely due to prolonged retraction of the occipital lobe. However, many studies have reported improvements in patient vision on discharge and, further, that vision often recovers to preoperative baseline levels on follow-up. In our series, we frequently relaxed the occipital lobe during operations, and no patient complained of visual field deterioration during their normal daily activities.

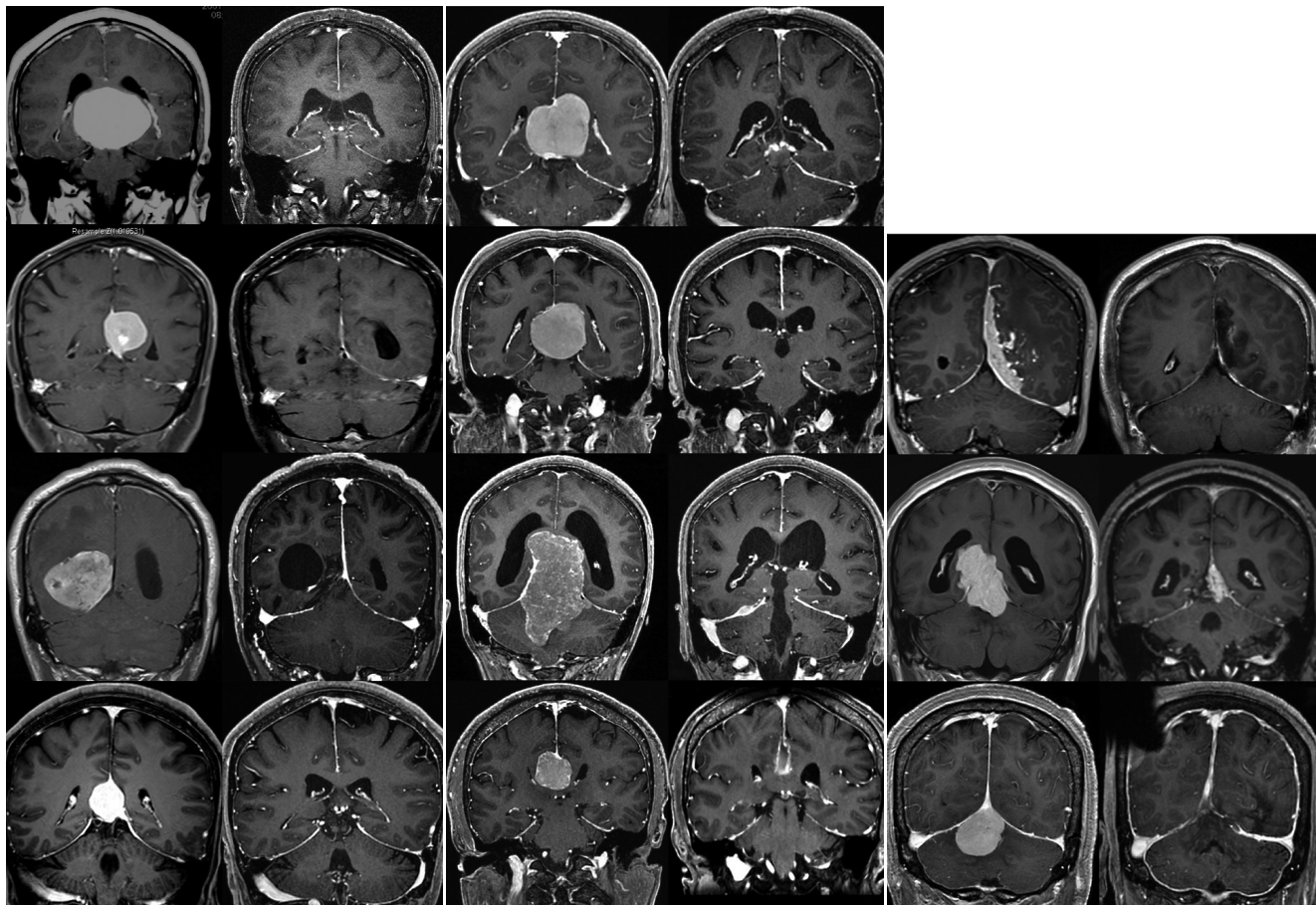
Commonly reported symptoms of falcotentorial meningio-

**Table 3.** Summary of Preoperative Angiographic Findings

Case No.	Feeder*	Degree of staining	Displacement of vessels		Occlusion or stenosis of deep venous structures	Preoperative embolization
			Arteries	Veins		
1	PMA	Homogeneous, faint	PCA, downward	Not definitive	GVG	No
2	No staining	No	PCA, downward	ICV, downward	ISS, BVR	No
3	MHT <sup>†</sup>	Homogeneous, strong	PCA branches, downward	Not definitive	Straight sinus, ISS	No
4	PMA, MMA	Faint	PCA, splaying	Not definitive	GVG, ICV	Yes
5	PMA	Faint	PCA, splaying	ICV, downward, straight sinus, upward	GVG, straight sinus	No
6	PCA branches	Faint	PCA, downward	ICV, downward	ISS, GVG	No
7	PMA	Homogeneous, faint	PCA, splaying	Not definitive	GVG, straight sinus	No
8	MHT <sup>†</sup> , PMA, MMA	Heterogeneous, strong	PCA, splaying, downward	ICV, upward	ISS, BVR	Yes
9	MHT <sup>†</sup> , PMA	Heterogeneous, strong	PCA, splaying	ICV, downward	GVG, straight sinus	No
10	MHT <sup>†</sup> , MMA	Homogeneous, faint	PCA, downward	ICV, downward	ISS	Yes
11	MHT <sup>†</sup> , ACA, PMA, MMA	Heterogeneous, strong	Not definitive	ICV, downward, straight sinus, posterior	ISS, BVR	No

ACA, anterior cerebral artery; BVR, basal vein of Rosenthal; GVG, great vein of Galen; ICA, internal cerebral artery; ISS, inferior sagittal sinus; MHT, meningohypophyseal trunk; MMA, middle meningeal artery; PCA, posterior cerebral artery; PMA, posterior meningeal artery; SSS, superior sagittal sinus.

\*The first line is the main feeder. <sup>†</sup>The marginal tentorial branch of MHT is the Bernasconi-Cassinari artery.



**Fig. 3.** Total 11 cases' preoperative and postoperative coronal T1-weighted contrast-enhanced magnetic resonance images showing gross total tumor removal in 10 out of 11 cases.

mas include headache, visual deficits, gait disturbances, mental deterioration, and cognitive impairment.<sup>2,10</sup> Our findings were similar to these previous reports. Ataxic gait is a common result of an inferior extension of the tumor into the cerebellum.<sup>5</sup> In our series, four patients had gait disturbances, and all of their tumor locations and growth directions were inferior or posterior. Upward gaze palsy, a component of Parinaud's syndrome, occurs less frequently in falcotentorial meningiomas than other pineal region tumors.<sup>13,14</sup> Asari, et al.<sup>10</sup> explained that this is the falcotentorial meningioma mainly exists in the cistern and grows slowly so that there is less compression and destruction of the periaqueduct and posterior part of the third ventricle. In our series, there was no symptom of upward gaze palsy.

### Angiographic findings

Various feeding arteries have been reported in falcotentorial meningiomas. Feeding branches from the internal carotid artery include branches of the meningohypophyseal trunk (especially the Bernasconi-Cassinari artery), inferolateral trunk, and anterior choroidal artery. Moreover, there have been some reports that the feeding artery involves ophthalmic artery branches and/or the muscular branch of the vertebral artery.<sup>10,15,16</sup>

Although not as common, branches of the external carotid

artery can supply falcotentorial meningiomas, and this was observed in our series.<sup>14,16</sup>

### Surgical approach

Several surgical approaches have been described to treat falcotentorial meningiomas. These include infratentorial supracerebellar, suboccipital, occipital transtentorial, and combined supratentorial and infratentorial approaches.<sup>2,3,9</sup> Nowadays, occipital transtentorial and infratentorial supracerebellar approaches are regarded as the standard techniques to treat pineal-region meningiomas.

There are two main issues in treating falcotentorial meningiomas. One is selecting the surgical approach, which includes design of the bone flap. The other main issue is whether main venous structures will be sacrificed for a radical tumor resection. In all of our cases, we tried to make an adequately sized bone flap, even when the tumor was quite large (Fig. 1D). Some authors have insisted on performing wide craniotomies for large falcotentorial meningiomas. For example, Quiñones-Hinojosa, et al.<sup>8</sup> described a bilateral occipital transtentorial/transfalcal approach for large falcotentorial meningiomas. They ligated and cut the transverse sinus after checking the patency of the occluded sinus, and used permanent aneurysmal clips to



ligate the vein of Galen when the straight sinus was occluded. The area above and below the tentorium can provide wide exposure and reduce occipital lobe retraction during prolonged operation times. Moreover, this approach may allow surgeons some form of intraoperative flexibility in terms of their surgical plan.

It should be noted that we do not suggest routine application of wide craniotomies, such as the combined supratentorial and infratentorial approach. This is because wide craniotomies may increase the total amount of bleeding, prolong the operation time, and increase the risk of cerebral cortex injury. Moreover, it is possible to completely remove huge falcotentorial meningiomas without neurological deficit via relatively small craniotomies. In the current set of craniotomies, a catheter for CSF drainage was inserted into the ventricle or cisternal space through the safest area in each patient. We also designed small craniotomies through which the possible access area covered the entire tumor territory. Thus, if a CSF drain is possible, then appropriately designed small craniotomies are sufficient to achieve complete tumor resection without cortex injury.

There are some reports that have described usage of ligation and sectioning of the transverse sinus with or without reanastomosis.<sup>9,17</sup> Although many authors have reported safe ligation of the transverse-sigmoid sinus, some complications have been described.<sup>18,19</sup> In one of our cases, in which we ligated the non-dominant transverse sinus, we experienced delayed occipitocerebellar hemorrhaging and a prolonged patient recovery period (Fig. 2). Therefore, from our experience, every venous structure should be preserved even if they seem to lack significant function. This will help prevent complications associated with delayed lobar parenchymal hemorrhage that can be attributed to venous infarction.

In conclusion, surgical approaches should be tailored to each patient according to the origin and direction of tumor growth, feeding arteries, and the surrounding venous drainage system. In our series, we found that a relatively small craniotomy was sufficient to completely remove each tumor. Moreover, we found that the most important factors for avoiding surgical complications were to preserve vital deep neurovascular structures, as well as flow through the venous sinuses. Our results showed that falcotentorial meningiomas could be cured via single-stage operations without complications by applying careful perioperative planning and a delicate microsurgical technique.

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