Interhemispheric Precuneus Retrosplenial Transfalcine Approach for Falcotentorial Meningiomas: Anatomic Study and Clinical Series

The Neurosurgical Atlas
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BACKGROUND: Falcotentorial meningiomas are surgically challenging. Currently accepted approaches include occipital interhemispheric and supracerebellar infratentorial approaches, which have documented drawbacks.

OBJECTIVE: To propose an alternative approach to the posterior tentorial incisural space, the interhemispheric precuneus retrosplenial transfalcine approach (IPRTA).

METHODS: A total of 6 colored-silicone-injected adult cadaveric heads were dissected. We measured the interval between bridging veins and studied computed tomography venography scans of 20 subjects to confirm the feasibility of the IPRTA. Bony landmarks, the region's bridging veins, and the anterior and posterior borders of the approach were identified. The surgical corridor widths (veins' interval) and lengths were compared between alternative midline approaches. We also reviewed 4 consecutive clinical cases using this approach.

RESULTS: The IPRTA provides the shortest distance to the anterior and posterior limits of the posterior tentorial incisura. Moreover, it is the only approach that provides direct visualization of the anterior and posterior limits of falcotentorial junction meningiomas. In all specimens and patients, a minimum 30-mm interval between the anterior and posterior parietal veins was found in at least one of the hemispheres. Tumor removal was successful in all 4 patients but resulted in mild paresthesia in the lower extremities of 2 patients and temporary foot drop in 1 patient.

CONCLUSION: The IPRTA offers the shortest and most direct corridor for falcotentorial meningiomas and provides excellent visualization of most of the critical structures in the region. Detailed preoperative evaluation of the deep and superficial venous structures is recommended.

KEY WORDS: Falcotentorial, Interhemispheric, Meningioma, Parietal, Pineal, Retrosplenial

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Falcotentorial meningiomas are considered one of the rarest meningioma types and constitute approximately 0.3% to 1.1% of all intracranial meningiomas.[1-4] These meningiomas account for 2% to 8% of all tumors located in the posterior incisural area.[2,5,6] Traditional operative approaches to the posterior tentorial incisura include the occipital interhemispheric approach, supracerebellar infratentorial approach (SIA), and a combination of these 2 approaches for large lesions, namely, the bilateral occipital transtentorial/transfalcine approach.[3,7-13] Other possible routes can be tailored to the morphology of the target lesion, including the parieto-occipital interhemispheric/transcallosal approach, posterior transcortical approach via the angular gyrus/lateral ventricle, and posterior subtemporal approach.

Several authors[14-17] have emphasized the importance of considering the location of the deep venous structures when selecting the surgical approach. In general, meningiomas that

ABBREVIATIONS: AITA, anterior interhemispheric trans-splenial approach; **ANOVA,** analysis of variance; **APV,** anterior parietal vein; **IPRTA,** interhemispheric precuneus retrosplenial transfalcine approach; **PCA,** posterior cerebral artery; **PPV,** posterior parietal vein; **SIA,** supracerebellar infratentorial approach

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displace the internal cerebral veins and the vein of Galen superiorly are better suited for a supracerebellar approach, whereas inferior displacement of the deep venous system calls for a more favorable supratentorial approach. The occipital interhemispheric approach is the most accepted supratentorial route to the posterior incisural space given the lack of bridging veins on the occipital segment of the superior sagittal sinus.[18] The anterior interhemispheric trans-splenial approach (AITA) was recently proposed as an alternative route for selected falcotentorial meningiomas; the lack of bridging veins anteriorly is a benefit of this approach, but a posterior third callosotomy is required.[19]

We propose here another supratentorial approach for the resection of falcotentorial meningiomas, the interhemispheric precuneus retrosplenial transfalcine approach (IPRTA), as an alternative to the occipital interhemispheric and anterior interhemispheric trans-splenial approaches. We used anatomic, imaging, and clinical studies to address several questions related to the proposed approach.

METHODS

Anatomic Study

A total of 6 adult human head specimens were injected intravascularly with colored silicone rubber and preserved in 75% alcohol. Each head underwent a computed tomography (CT) scan for neuronavigation (Stryker, Kalamazoo, Michigan) to confirm bony landmarks and neuroanatomic structures. Standard surgical instruments were used in all craniotomies (using a CORE Sumex drill, Stryker) and dissections. Microsurgical anatomy was studied under microscopic magnification and illumination (model VM900 surgical microscope, Möller-Wedel, Wedel, Germany). After the IPRTA was completed, the whole bony and dural layers of the skull convexity were removed, and the distances between bridging veins of the parietal and occipital regions were measured bilaterally at their sinus entry point in all 12 hemispheres. In addition, the depths of the surgical corridor to the surgical target (pineal gland and falcotentorial junction) were measured and compared between the IPRTA and the occipital interhemispheric, supracerebellar infratentorial, and anterior interhemispheric trans-splenial approaches.

Imaging Study

Contrast-enhanced CT venography scans (slice thickness, 0.625 mm) of 20 patients without relevant pathology were evaluated, and the distances between adjacent bridging veins anterior to the cuneus were measured on both hemispheres. The surgical corridor depths of the occipital interhemispheric, supracerebellar infratentorial, and anterior interhemispheric trans-splenial approaches and the IPRTA were measured. For this measurement, the pineal gland was used as a reference point. Also, the spatial correlation between lambda and the parieto-occipital sulcus was studied to determine whether lambda is a reliable landmark for this approach.

Surgical Technique

Heads were rotated 90° with their long axis parallel to the floor with the craniotomy side down to allow retraction by gravity. A linear coronal skin incision was made 3 cm superior to lambda. After the scalp was retracted, a rectangular unilateral or bilateral craniotomy was performed while keeping the sagittal sinus on the midline. Burr holes could be placed directly on the sagittal suture or on each side to enable epidural dissection of the sagittal sinus. We used 3-dimensional (3D) reconstruction images of the bridging veins to avoid venous lakes and chose the side of the approach accordingly. After the dura was opened, arachnoid membranes were dissected carefully up to the adjacent bridging veins on both sides. After arachnoid dissection, additional retraction of the hemisphere is not generally needed, because the pull of gravity is sufficient (Figure 1).

An important landmark for this approach is the splenium of the corpus callosum, which should be identified. Superior to the splenium is the inferior sagittal sinus, and inferior to the splenium is the vein of Galen; both venous structures drain into the straight sinus, which is posterior to the splenium (Figure 2). Tumor debulking should be performed after careful identification of these landmarks. In our anatomic dissections and the surgeries, we defined the anterior limit of the IPRTA as the splenium and the pineal cistern contents. The posterior limit was defined as the vein of Galen and falcotentorial junction. The falx can be incised to facilitate access to the contralateral side. When needed, the tentorial incision must be performed after the identification of deep venous structures (Figure 2).

Statistical Analysis

Statistical analyses were performed using SPSS Statistics Base 20.0 (SPSS Inc, IBM, Armonk, New York). The Shapiro-Wilk test rejected the assumption of normality of distribution for the quantitative variables of interest. An independent-samples *t*-test was used to determine whether the difference between the occipital interhemispheric approach and the IPRTA, in terms of the distances between bridging veins, is statistically significant. A 1-way analysis of variance (ANOVA) test was performed to compare the surgical corridor lengths of all 4 approaches. The alpha value was set at 5% and P values of $<.05$ in all tests were deemed statistically significant.

Institutional review board/ethics committee approval and patient consent were neither required nor sought for this study.

RESULTS

Anatomic Findings

Cranio-Cerebral Relationships

CT images of 20 patients showed that the parieto-occipital sulcus was anterior to lambda in 18 (90%) patients and posterior in 2 (10%) patients. The maximum anterior distance of the parieto-occipital sulcus to lambda was 11 mm, whereas the maximum posterior distance was 4 mm (mean, 6.5 mm, anterior). These results indicate that lambda is a reliable bony landmark for identifying the parieto-occipital sulcus, which represents the posterior limit of the surgical approach (Figure 3).

Bridging Veins

The posterior parietal vein (PPV) approximately coincides with the parieto-occipital sulcus. This vein was consistently identified as the posterior limit of the IPRTA. We found a hemispheric difference in the distribution of the anterior and PPVs in 5 of

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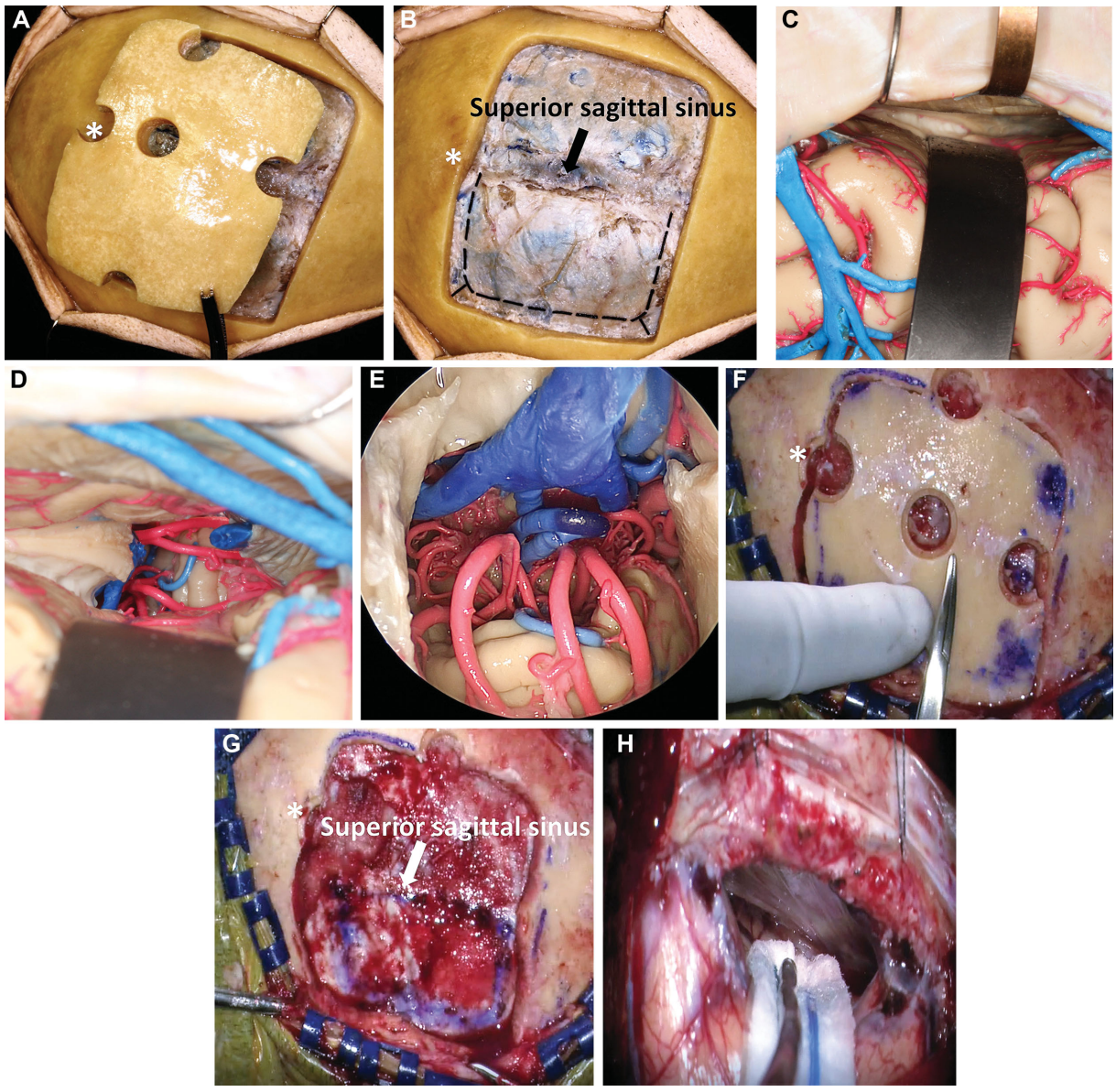


FIGURE 1. *Cadaveric dissection* **A** *to* **E** *and operative* **F** *to* **H** *photographs show the bone flap after craniotomy was performed* **A** *and* **F** *and lambda as the posterior border of the craniotomy (asterisk).* **B** *and* **G**, *Superior sagittal sinus and lambda (asterisk) after the bone flap was removed (the dural incision is marked with a dashed line).* **C**, *Bridging veins draining to the superior sagittal sinus become extra-arachnoidal when they are close to the sinus.* **H**, *An operative photograph shows that after removal of arachnoid membranes, surgical space is wide enough for the approach and to preserve the bridging veins.* **D**, *A dissection photo shows the view after cutting the posterior falx and vein of Galen to expose the 2 posterior cerebral arteries (PCAs) and basal veins.* **E**, *An endoscopic view from the supracerebellar infratentorial approach shows arrangement of the PCA, basal veins, and vein of Galen, which usually adhere to the tumor.*

the 6 specimens and 16 of the 20 CT scans. In cases of joint drainage of the anterior parietal vein (APV) with more anterior veins, in particular the postcentral vein, a wider surgical space for the IPRTA was found as the distance between bridging veins increased. In contrast, an independent drainage pattern of the APV resulted in a narrower surgical space in the precuneus area (Figure 4).

In regard to the availability of sufficient surgical space for performing the IPRTA, all 6 specimens and all 20 patients had a minimum 30-mm distance between the posterior and APVs in at

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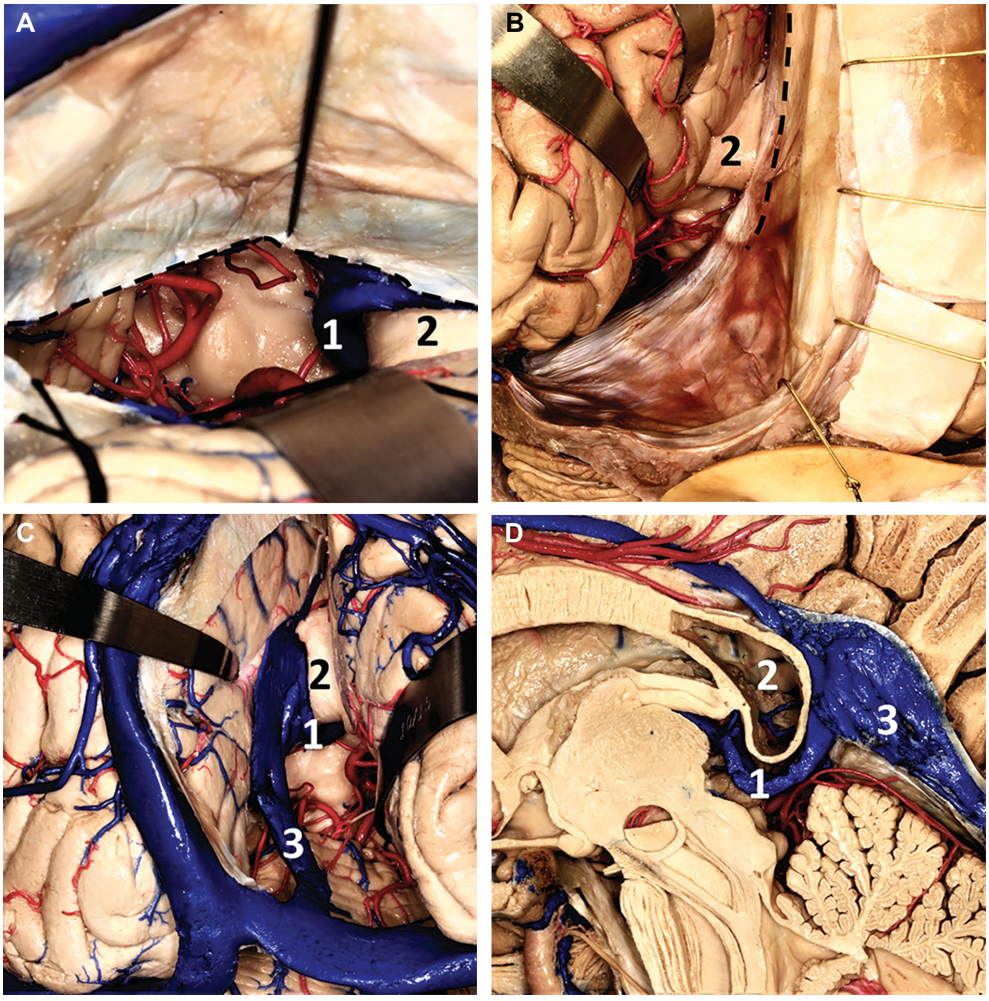


FIGURE 2. *The vein of Galen (1) is expected inferior to the splenium (2), draining to the straight sinus (3).* **A** *and* **B**, *A falx incision (dashed line) should be performed after careful definition of venous structures.* **C**, *The vein of Galen (1), straight sinus (3), and splenium after removal of the arachnoid membranes and dural layers.* **D**, *The vein of Galen (1), splenium (2), and straight sinus (3) from the sagittal view. The splenium was particularly excised to show its relations with the surrounding neuroanatomic structures.*

least 1 hemisphere. In addition, 3 (50%) specimens and 8 (40%) subjects had a more than 35-mm distance between these veins in at least 1 hemisphere (Figure 4). The mean distance between bridging veins for the IPRTA was 32 ± 11 mm, whereas the mean distance between the last occipital vein (OV) and torcula for the occipital interhemispheric approach was 46 ± 9 mm. The *t*-test results showed that the occipital interhemispheric approach had a statistically and significantly wider surgical space in between bridging veins ($P < .001$).

Surgical Corridor Length

The mean surgical corridor lengths for the occipital interhemispheric, supracerebellar infratentorial, and anterior interhemispheric trans-splenial approaches and the IPRTA were 77 ± 5 mm, 73 ± 4 mm, 85 ± 5 mm, and 76 ± 3 mm, respectively. One-way ANOVA results ($P < .001$) and post hoc comparisons indicated that only the AITA has a statistically significant longer surgical corridor length (Figure 5).

Clinical Findings

See Table 1 for the clinical data. The average age of our patients (2 men and 2 women) was 55 yr. The average tumor size was 4.9 cm in maximal diameter. A total of 3 patients underwent near-total resection, and 1 underwent gross total tumor resection. A total of 2 patients suffered from sensory changes in their

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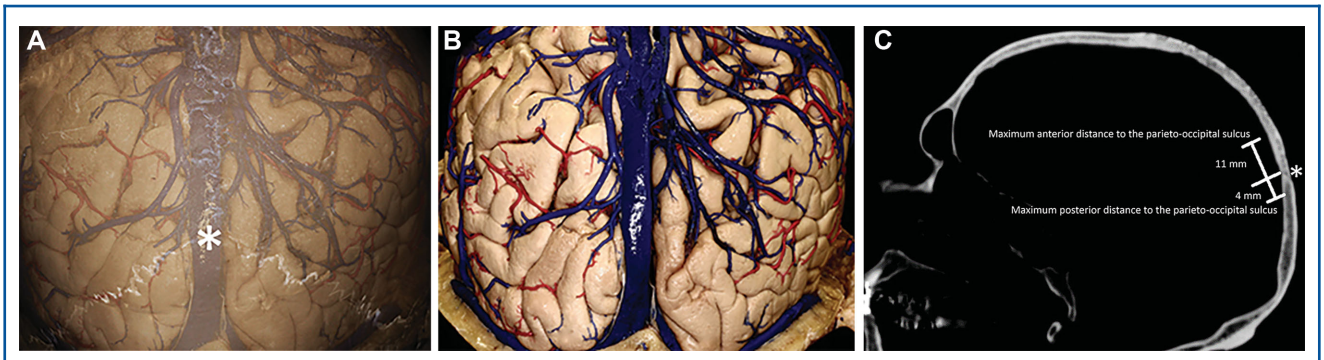


FIGURE 3. **A** *and* **B**, *The parieto-occipital sulcus was anterior to lambda (asterisk) in 18 (90%) patients and posterior to lambda in 2 (10%) patients.* **C**, *The maximum anterior distance of the parieto-occipital sulcus to lambda was 11 mm, whereas the maximum posterior distance was 4 mm.*

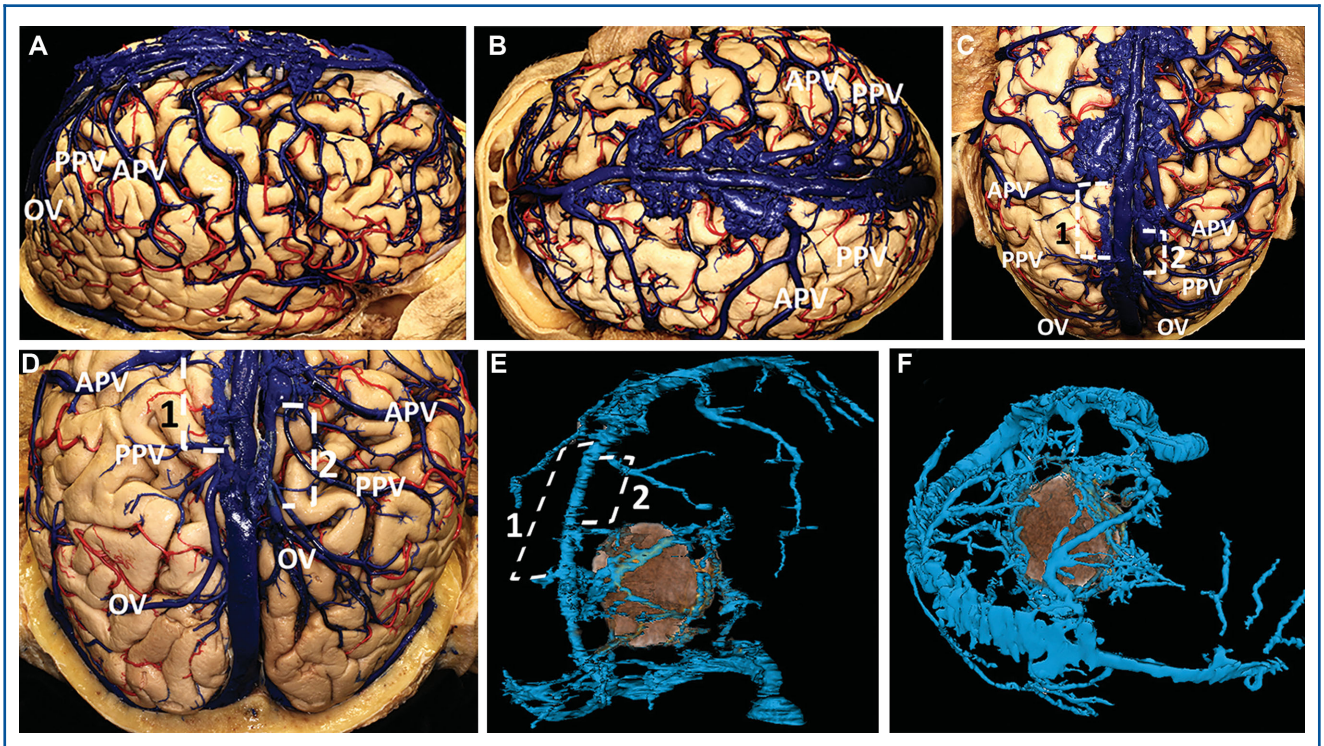


FIGURE 4. **A** *to* **D**, *The occipital vein (OV) was identified in our dissections. Space between the posterior parietal vein (PPV) and anterior parietal vein (APV) (1 and 2) was sufficient for providing a feasible corridor for performing an IPRTA. Variations in the drainage pattern of the APV were observed to be related to hemispheric distribution differences (1 and 2). In cases of joint drainage of the APV with more anterior veins (as seen in the left hemisphere of the cadaver), there was a wider surgical space for the IPRTA (1) as the distance between the bridging veins increased.* **E** *and* **F**, *In contrast, an independent drainage pattern of the APV (as seen in the right hemisphere of the cadaver) resulted in a narrower surgical space (2) anterior to the cuneus. Imaging studies before the surgery are essential for identifying the correct side of the approach. 3D reconstruction of the cerebral veins was performed on the freeware 3D Slicer platform (www.slicer.org).*

lower extremities, and 1 patient suffered from transient foot drop.

In all cases, the IPRTA allowed generous exposure of the tumor borders with excellent and early visualization of most vulnerable cerebrovascular structures involved. The posterior portion of the falx was incised to allow a bilateral reach to remove the tumor efficiently and as completely as possible; the only restriction for complete tumor resection was adherence of the tumor to the deep veins. In each case, the status and location of the parasagittal and deep veins in preoperative imaging guided our operative plan.

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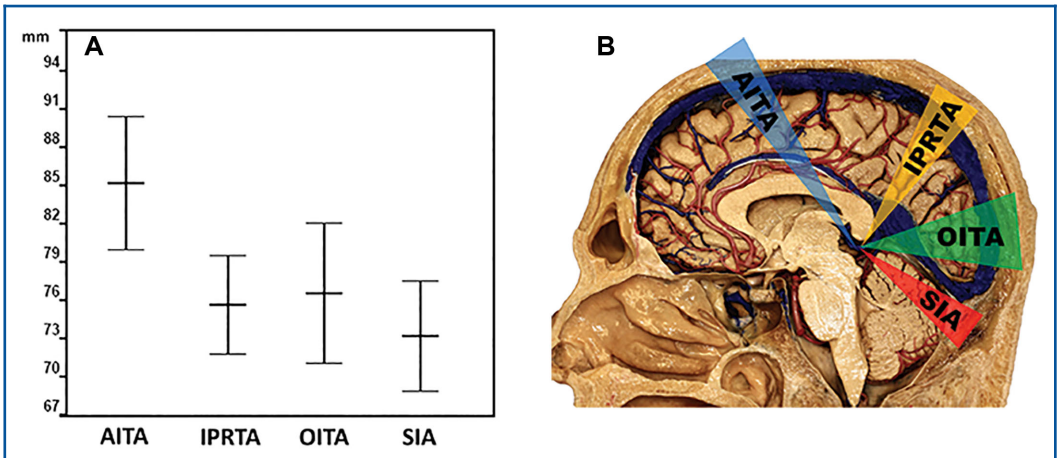


FIGURE 5. **A**, *One-way ANOVA results ($P < .001$) and post hoc comparisons indicated that only the anterior interhemispheric trans-splenial approach (AITA) has a statistically significant longer surgical corridor length.* **B**, *The occipital interhemispheric trans-falcine approach (OITA), supracerebellar infratentorial approach (SIA), and IPRTA have similar surgical corridor lengths. Note that these calculations were performed by targeting the pineal gland. Surgical corridor length will be longer when reaching the anterior extension of tumors in posterior approaches and posterior extension of tumors in the AITA.*

TABLE 1. Patient Characteristics

Age (yr)	Sex	Predominant symptoms	Tumor size (cm)	Other finding	Complication
76	Male	Gait and memory difficulty	3.5	Near-total resection	None
69	Female	Numbness and mild weakness on right side	3.3	Near-total resection	Numbness of right leg
47	Female	Headache and vomiting	4.8	Gross total removal	Leg numbness
28	Male	Headaches and memory difficulty	8.0	Near-total resection	Temporary foot drop

ILLUSTRATIVE CASE

A 28-yr-old man was diagnosed with an 8-cm falcotentorial meningioma during workup for headaches and memory difficulty (Figure 6A-6C). CT venography revealed a wider surgical window between the bridging veins on the right side (Figure 6D). A unilateral parasagittal parietal craniotomy eccentric to the right side was performed, followed by an interhemispheric approach. A portion of the posterior falx was coagulated and incised to expose the contralateral side. The tumor was debulked internally to allow room for dissection. The splenium was exposed, and the tumor capsule was dissected out and followed back until the deep veins were identified (Video). Postoperatively, the patient showed evidence of right foot drop that resolved within 1 wk after surgery. Three months after surgery, the patient noted relief of all his preoperative symptoms. Postoperative magnetic resonance imaging (MRI) showed near-total removal of the tumor (Figure 6E and 6F).

DISCUSSION

We demonstrated that the IPRTA is likely to provide a surgical space larger than 3 cm on at least 1 side. Also, we found that the IPRTA and the occipital interhemispheric and SIAs have approximately similar surgical corridor lengths when the pineal gland is targeted; however, the AITA has a significantly longer surgical corridor depth.

Moreover, our radiological investigation found lambda to be a reliable bony landmark for identifying the posterior limit of the craniotomy in the IPRTA, which is the parieto-occipital sulcus. Our results are in concordance with those of previous craniometric studies.[1] Numerous laboratory and clinical investigations confirmed the short- and long-term cytotoxic effects on brain parenchyma caused by the disruption and occlusion of cerebral veins.[20-30] We recommend performing a detailed presurgical radiological study to determine the side of the approach and to measure the distance between bridging veins.

Our results suggest that the occipital interhemispheric approach and its combinations confer a significant advantage regarding surgical freedom between bridging veins. However, the IPRTA, as proposed here, confers a distinct advantage; it provides the shortest distance to both the anterior and posterior limits of a falcotentorial junction meningioma, and it is the only approach that provides direct visualization of both the anterior (splenium and pineal cistern contents [basal veins, posteromedial choroidal

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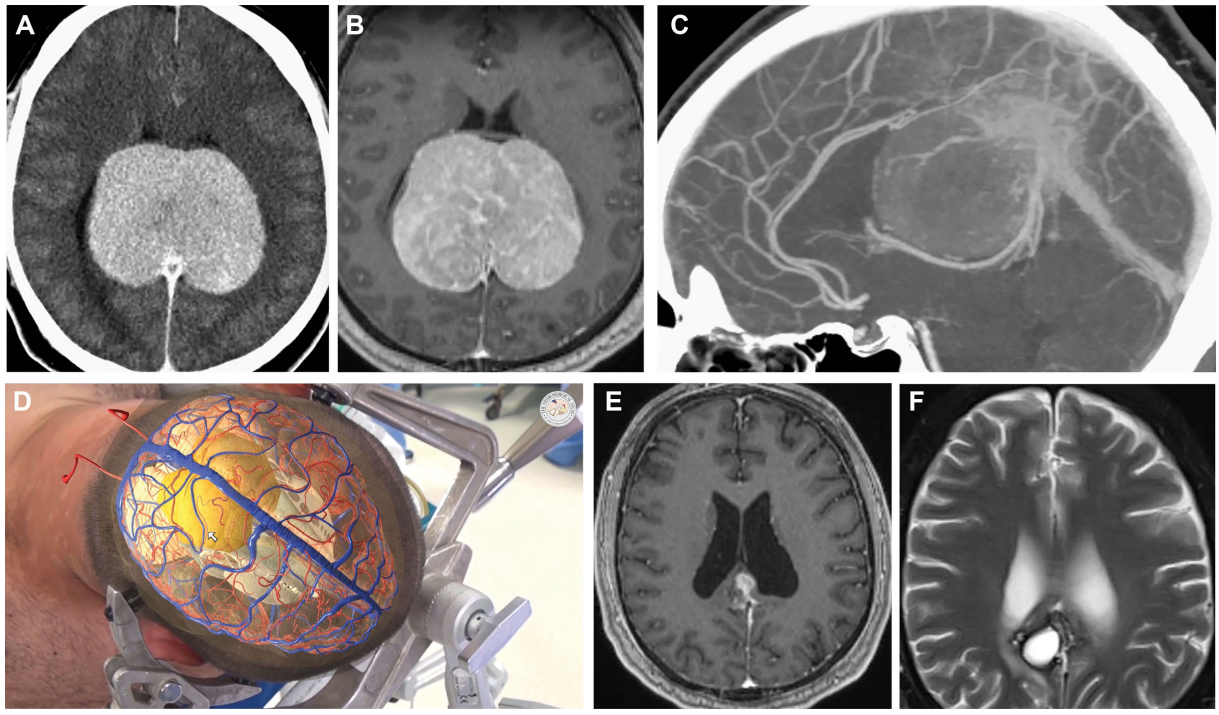
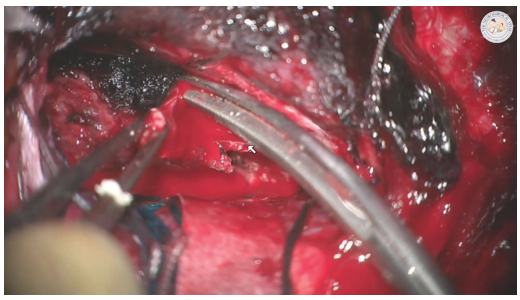


FIGURE 6. *Illustrative case. Preoperative CT and MRI images show a well-enhanced giant homogenous extra-axial tumor in the pineal area* **A** *with attachment to the falcotentorial dura* **A** *to* **C**. **D**, *A superimposed venogram on the head of the patient shows a better window for the interhemispheric approach on the right side.* **E** *and* **F**, *Postoperative MRI shows a small piece of tumor attached to the deep veins.*



VIDEO. *Summary and operative clip of our illustrative case. (Used with permission from The Neurosurgical Atlas by Aaron A. Cohen-Gadol, MD.)*

arteries, and tectal plate]) and posterior (vein of Galen and falcotentorial junction) limits. Although we found posterior midline approaches and the IPRTA to provide similar surgical corridor lengths, these lengths were measured by targeting the pineal gland without considering the anterior or posterior extension of meningiomas in the region. The surgical corridor length needed to reach the anterior margin of the tumor will be longer in posterior approaches.

Another potential complication related to the occipital interhemispheric approach is visual deterioration. Several authors have reported permanent or temporary hemianopsia or blindness in patients after occipital interhemispheric approaches.[7,11,14,16,31,32] Via the IPRTA, it is possible to avoid visual morbidity related to surgery but at the expense of a potentially increased risk of sensory-motor complications, given the proximity of the paracentral lobule and its draining veins. In 2 of the 4 cases presented here, the somatosensory evoked potentials on the contralateral side were lost, which was unrelated to any obvious vascular or cortical injury. We speculate that this event was related to displacement of the paracentral lobule, as required for the interhemispheric approach. To reduce this risk, we describe several relevant measures, such as a lateral position with the ipsilateral side down for gravity retraction and use of lumbar drainage, but other considerations include wide opening of the interhemispheric fissure to facilitate brain relaxation and gentle retraction, protection of exposed cortex, and avoidance of fixed brain retraction.

In a recent publication, Yağmurlu et al[19] proposed the AITA to the falcotentorial junction. Previous reports suggested that posterior callosotomy might cause personality changes and memory deficits.[17,33] Thus, as long as it is avoidable, we do not recommend performing a trans-splenial approach. In addition, as

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TABLE 2. Falcotentorial Meningioma Classifications According to Bassiouni et al[15]

Type 1	Originates between leaves of the falx above the junction of the great vein of Galen with the straight sinus, displaces the vein of Galen and internal cerebral veins inferiorly during growth, and suitable for the IPRTA in select cases.
Type 2	Originates from underneath the tentorium near the junction of the vein of Galen with the straight sinus, pushes the vein of Galen and its collaterals upward, and the IPRTA is not recommended for this type of tumor.
Type 3	Originates from the paramedian tentorial incisura, the vein of Galen could lie superomedial or inferomedial to the tumor, suitable for the IPRTA in select cases, but side of the vein of Galen and side of the dominant bridging veins must be investigated carefully before surgery.
Type 4	Originates from the falcotentorial junction along the straight sinus and displaces the vein of Galen and its collaterals to the contralateral side, and suitable for the IPRTA in select cases.

IPRTA, interhemispheric precuneus retrosplenial transfalcine approach.

found in our study, the AITA has a significantly longer surgical corridor, and the posterior extension of tumors in this region will be distant to the surgeon and dissected blindly.

As we have mentioned, superiorly displaced vascular structures are a contraindication for the IPRTA in falcotentorial meningiomas. Bassiouni et al[15] classified falcotentorial meningiomas in respect to their expansion direction and displaced veins of the region (Table 2). According to their classification, type 1, 3, and 4 meningiomas are eligible for the IPRTA. The vein of Galen tends to collapse by mass effect of the meningioma, and venous drainage is generally maintained via collateral venous structures.[2,5]

Limitations

A limitation of this study is the relatively low number of investigated specimens and patient CT images. Although we found a 100% chance of finding adequate surgical space (>30 mm) between bridging veins anterior to the cuneus, our sample is rather small for making general conclusions. For this reason, we strongly recommend detailed radiological study before surgery to identify the most advantageous corridor between the patient's anterior and posterior parietal bridging veins. From the results of this study, when the APV drains into the postcentral vein, the surgical corridor becomes wider.

CONCLUSION

The IPRTA offers the shortest and most direct corridor for reaching falcotentorial meningiomas and provides excellent visualization of most of the critical structures of the region. The interval between bridging veins provides sufficient working space for the approach, but potential risk to the somatosensory cortex exists. Detailed preoperative imaging evaluation is critical for identifying the displacement of deep venous structures and for deciding on the ideal corridor between bridging veins.

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Disclosures

The authors have no personal, financial, or institutional interest in any of the drugs, materials, or devices described in this article.

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