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ORIGINAL ARTICLE - TUMOR - MENINGIOMA

Modified unilateral approach for mid-third giant bifalcine meningiomas: resection using an oblique surgical trajectory and falx window

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Abstract

Background Utilizing the shortest available trajectory is the norm for excision of meningiomas. However, such an approach for the mid-third/central falcine meningiomas risks the adjoining draining veins and eloquent cortex. A larger size and bilaterality of such tumors adds to the surgical challenge. Herein, we report the surgical nuances of a modified unilateral approach in patients operated for giant bilateral symmetrical mid-third falcine meningiomas.

Methods Five such patients were operated. The clinico-radiologic data was studied at presentation and at the follow-up. The meningiomas were subclassified into those that were located in the anterior and posterior half of the central falx, and their surgical trajectory was chosen accordingly. The tumor was excised through an oblique anterior or a posterior trajectory instead of directly working over the major draining veins and eloquent brain. The falx was incised to create a surgical window and access the tumor on the contralateral side.

Results Four patients had meningiomas in the anterior half and one in the posterior half of central falx. Simpson excision was grade II in four patients. One patient showed small residual tumor and underwent stereotactic radiosurgery. The overall mean follow-up of the patients was 9.2 months. All the patients had good clinical outcome.

Conclusions Giant bifalcine meningiomas can be safely resected through a unilateral approach. Falx opening serves as a window to remove the tumor from the contralateral side. An oblique trajectory rather than an end-on access to these tumors minimizes the risk of venous and cortical injury.

Keywords Falcine · Falx · Bifalcine · Meningioma · Trajectory · Unilateral · Interhemispheric · Mid-third

Abbreviations

FM	Falcine meningiomas
MRI	Magnetic resonance imaging
SSS	Superior sagittal sinus

Introduction

The resection of falcine meningiomas (FM), especially over the mid-third region poses a surgical challenge [6, 16]. Firstly, these tumors are located in depth, and hidden by the eloquent brain surfaces [5]. The second reason is the densely populated major bridging veins draining this area [10, 11]. In general, one would prefer the shortest trajectory (end-on access) for removal of meningiomas [2, 5, 6, 9, 16]. However, in cases of mid-third/central FM, the shortest trajectory endangers the adjacent sensori-motor cortex and the venous drainage and may add to the postoperative morbidity [7, 9, 11].

The FM can have different growth patterns [2, 6, 10, 16]. At times, they present as large symmetrical mass on both sides of the falx extending into bilateral cerebral hemispheres, resembling a beetroot. In these, the bilaterality and large size of the tumors add to the surgical difficulty [2, 6, 16]. Accessing such tumors from both sides of the falx would double the risk of venous and retraction injuries to brain. Few authors have reported a contralateral transfalcine approach for small FM showing such growth pattern [2, 16]. In this manuscript, we describe our modified technique and its surgical nuances for the resection of giant mid-third/central falcine meningiomas through a unilateral approach using falx as the surgical

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window and utilizing an oblique surgical trajectory to avoid the major bridging veins and eloquent brain.

Methods and materials

From 2016 to 2018, we operated upon five adult patients of large mid-third/central bifalcine meningiomas using the technique described below. The preoperative magnetic resonance imaging (MRI) included T1, T2, and FLAIR sequence followed by T1-contrast-weighted sequence. All the patients had large globular/dumb-bell tumors that symmetrically extended to bilateral cerebral hemispheres. According to the recent classification by Zuo et al., they fall into the category IIIB [16].

Subclassification of mid-third/central falcine meningiomas

The coronal and lambdoid suture divides the antero-posterior extent of falx into anterior, middle/central, and posterior third region. We further subdivided the central FM into anterior-half and posterior-half tumors (Fig. 1). The purpose of this subdivision was to choose the appropriate surgical trajectory. A perpendicular line was dropped from the coronal suture. Another perpendicular was drawn from the lambdoid suture. The intersection of these two lines was marked. A bisector from the intersection point that extended into the cranial vault was used as the reference line. The meningiomas that were located predominantly anterior to this bisecting line were defined as anterior-half tumors of central falx. Those that were predominantly posterior to this line were subclassified as posterior-half tumors of central falx.

Surgical technique

The surgical trajectory depended on whether the tumor was located in the anterior half or posterior half of the central falx (Figs. 2 and 3). In the former, an anterior oblique trajectory close to the coronal suture was chosen and in the latter, a posterior oblique trajectory close to the lambdoid suture was opted. For meningiomas that extended almost equidistant from the bisecting line, the trajectory was decided based on the most prominent surfacing point of the lesion.

For anterior-half tumors of central falx, the patient was positioned supine, with head in midline and flexed to about 30°. The posterior-half tumors of central falx were operated in prone position. A Sugita head fixation device was used for stabilizing the skull. An L-shaped or horse-shoe incision was taken and subgaleal flap raised. For tumors located in the anterior half of central falx, the anterior edge of craniotomy extended about 2 cm anterior to the coronal suture and the posterior extent about 2 cm from the posterior tumor margin. The extent of craniotomy for posterior-half tumors of central falx was as follows: anteriorly about 2 cm from the anterior tumor margin and posteriorly about 2 cm beyond the lambdoid suture. Medially, the craniotomy reached up to the midline to expose the superior sagittal sinus such that adequate dural elevation was possible. Laterally, it was about 4 cm from the midline.

An interhemispheric approach on the non-dominant side was taken in all patients. For meningiomas of the anterior half of central falx, an anterior interhemispheric corridor was utilized. The trajectory was near the coronal suture where the likelihood of major draining vein was less. For the posterior-half tumors of central falx, a posterior interhemispheric route was performed. In these, the area spanning about 7 cm

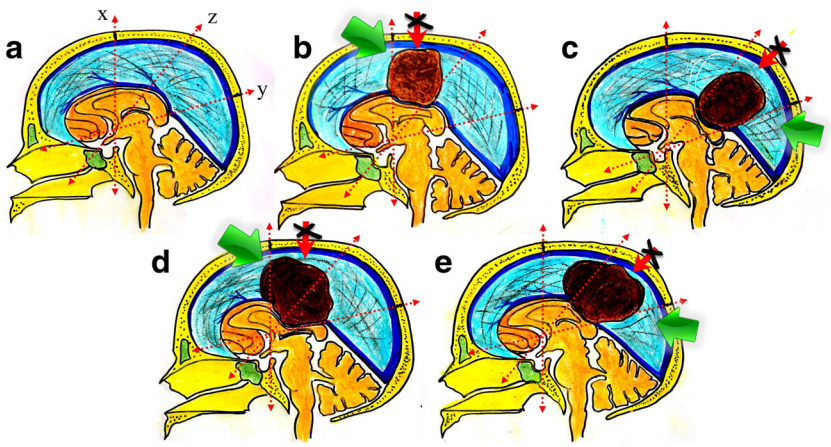

Fig. 1 Schematic diagram showing subclassification of meningiomas in mid-third (central) falx and the proposed surgical trajectories. **a** (*x*) and (*y*) indicate perpendicular lines drawn from the coronal and lambdoid sutures respectively. The line (*z*) which bisects the angle of intersection of *x and y* divides the central falx into anterior and posterior half. **b** Meningioma predominantly located in anterior half. **c** Meningioma predominantly located in posterior half. **d** Tumor extending into both sides of bisecting line and surfacing anteriorly. **e** Tumor extending into both sides of bisecting line and surfacing posteriorly. The proposed trajectories are shown in green arrow. The conventionally used trajectories (red arrow) may be shorter but endangers the major bridging veins and adjacent eloquent cortex

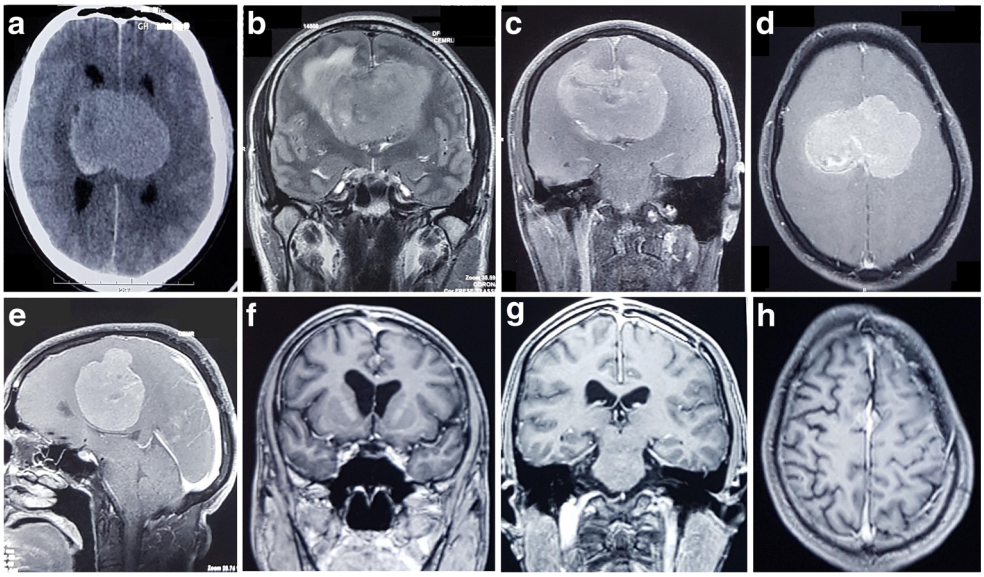

Fig. 2 Bifalcine meningioma in anterior half of mid-third (central) falx. Preoperative images (**a**–**e**). CT (**a**) depicts hyperdense mass in the falcine area. **b** T2-weighted MRI shows bifalcine meningioma with perilesional edema. **c**–**e** (Post contrast images) The tumor extends symmetrically on both sides of falx (**c**, **d**) and is located in anterior half of central falx (**e**). **f**–**h** Postoperative MRI demonstrates complete tumor removal. The tumor was excised through an anterior oblique trajectory

superior to the inion was chosen for the surgical trajectory. Once the dura was opened, the arachnoid adhesions over the superior sagittal sinus (SSS) were released. Since the working trajectory was either anterior or posterior (approximately 45°) to the tumor in the antero-posterior plane, the bridging veins that normally needs dissection over the mid-third were not of a major problem. Any minor bridging veins at the intended site of surgery were meticulously dissected. The initial brain retraction was using Swiss roll cotton patties to keep lobe retraction to the minimum. A Leyla retractor was reserved for the latter part of surgery. Once the tumor was visualized, an attempt was made to coagulate the attachment of the tumor margin to the falx so that the vascular feeders were disrupted. Next, the tumor was internally debulked, taking cautious effort to preserve the arachnoid plane all around. Tumors with soft to firm consistency were decompressed by CUSA and

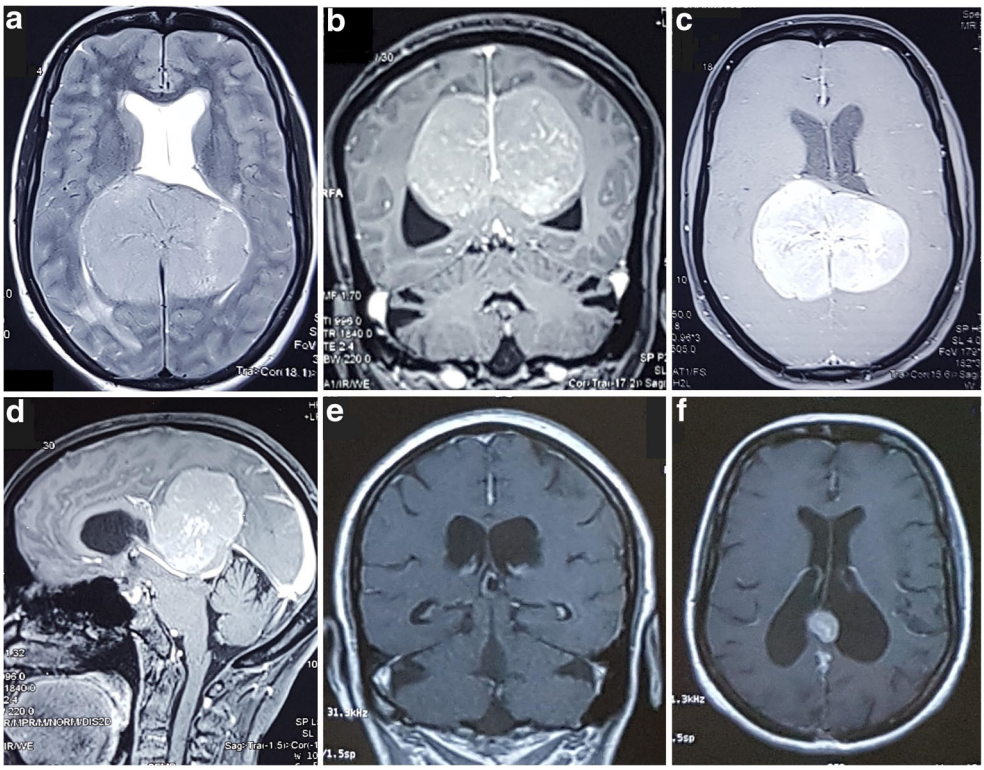

Fig. 3 Bifalcine meningioma in posterior half of mid-third (central) falx. **a**–**d** Preoperative MRI (**a**, T2-weighted, **b**–**d**, post contrast images). The tumor is located in the posterior half of central falx (**d**). **e**–**f** Postoperative MRI shows near total resection of meningioma. In this patient, the tumor was excised through posterior oblique trajectory

hard tumors by sharp dissection using microscissors. Once the ipsilateral tumor was sufficiently decompressed, we proceeded to remove the contralateral portion.

Falx window

Creating a falx window opens up the corridor for visualization of the tumor contralateral to the falx (Fig. 4). After the falx was coagulated and devascularized, it was incised using no. 11 knife blade. The central surface of the falx, away from the superior and inferior sagittal sinus, was chosen for the same. Initially, a horizontal incision was given in the antero-posterior direction for a length of about 2 cm with precaution to stay short of margin of SSS. Inferiorly, the incision was extended and the free edge of the falx was divided after coagulating the inferior sagittal sinus. The opening in the falx was utilized to decompress the tumor in the contralateral side. As the tumor was being decompressed, it started falling into the surgical field. Throughout the procedure, the dissection was carried out in an extra-arachnoidal plane, taking care to preserve the tumor capsule all around.

Follow-up

The patients were evaluated in the postoperative period and at follow-up for improvement in clinical status. Follow-up MRI was performed at 3 months and at 6-monthly interval.

Results

The clinico-radiologic data of patients is summarized in Table 1. Of the five patients, two were male and three were female. Four patients had meningioma located in the anterior half and one in the posterior half of central falx. The tumors measured minimum 5 cm size on at least any single dimension. Their size ranged from 5.2 to 7.6 cm. The commonest presenting complaints were headache and focal limb weakness. The mean age of patients was 56.2 years. The mean blood loss was approximately 800 ml and the operative time was about 4 h. In four patients, Simpson grade II excision was achieved. One had a residual tumor in follow-up MRI and required gamma knife radiosurgery. The mean follow-up was 16 months and all patients had good postoperative outcome. The postoperative histopathology showed meningothelial variety in all cases.

Discussion

FM are less frequently seen and represent approximately 9% of all intracranial meningiomas [5]. They originate from the falx surface and usually do not involve the superior sagittal sinus. Based on their relationship to the coronal and lambdoid sutures, Al-Mefty classified them into anterior (anterior to coronal suture), middle (between coronal and lambdoid), and posterior third (behind the lambdoid suture) [1]. The mid-third/central ones are the most common tumors [9].

Unlike the resection of convexity meningiomas, the surgical approach to the FM needs greater expertise. The usual hindrance to their surgical access is the overlying eloquent brain and major draining veins [4, 10, 11]. Also, the vascular supply of these tumors arises from the falx. Although an early devascularization can provide a relatively bloodless surgical field, it is not that easily achieved. Furthermore, the basic principle of adhering to an extra-arachnoidal dissection needs to be rigorously followed as a pial breach in the eloquent brain is less forgiving.

Knowledge of the relevant anatomical landmarks is necessary during surgery for the mid-third/central FM. The central sulcus demarcates the precentral gyrus (primary motor area) from the postcentral gyrus (primary somatosensory cortex) and is located about 3.5 to 4.5 cm behind the coronal suture [13]. Occasionally, the lesions might displace the pre- and postcentral gyri. Retraction of the precentral gyrus can produce contralateral hemiparesis. Damage to the primary somatosensory cortex can cause contralateral paresthesias and cortical sensory syndrome. An injury to the paracentral lobule

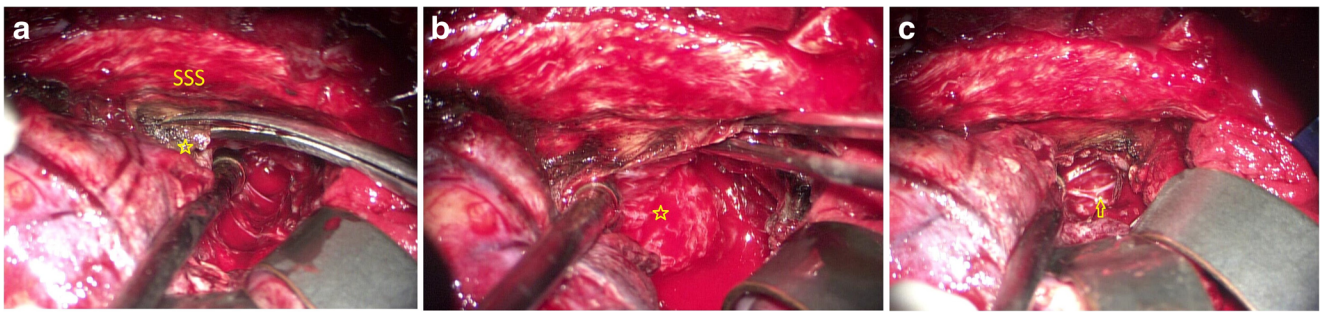

Fig. 4 Intraoperative photographs. **a** The coagulated falx (asterisk) is being cut. SSS, superior sagittal sinus. **b** Contralateral part of the tumor (asterisk) is visualized after creating falx window. **c** Arachnoid of the contralateral side (asterisk) is visible after tumor excision

Table 1 Clinical characteristics and treatment outcome of patients ($n = 5$)

	Patient 1	Patient 2	Patient 3	Patient 4	Patient 5
Age/gender	46/M	58/M	70/F	55/F	52/F
Clinical presentation	Raised ICP, weakness of limbs (L>R)	Weakness of left lower limb	Walking difficulty, urinary incontinence, frontal lobe involvement	Headache, left hemiparesis	Headache, subtle right-sided weakness, parietal lobe signs
Size (cm)	7.6 × 5.4 × 5.2	6.1 × 5.5 × 5.3	6.8 × 5.8 × 5.4	7.2 × 5.6 × 5.5	7.5 × 6.5 × 6
Disposition in mid-third (central) falx	Anterior half	Anterior half	Anterior half	Anterior half	Posterior half
Simpson excision	Grade II	Grade II	Grade III	Grade II	Grade II
Adjuvant treatment	–	–	GKRS	–	–
Follow-up (months)	17	7	8	4	10

ICP, intracranial pressure; *GKRS*, gamma knife radiosurgery

(extent of precentral and postcentral gyri onto the medial surface) can manifest as contralateral lower limb weakness, sensory loss, and bladder incontinence [13].

The superior sagittal veins which drain the superior and lateral cortical surfaces drain into the SSS [12]. Anatomical studies have shown that the major venous tributaries are concentrated in the mid and posterior frontal region within 2 cm anterior or posterior to the coronal suture. About 70% of the parasagittal venous drainage occurs within 2 cm posterior to the coronal suture and 30% occur within 2 cm anterior to suture line [14]. The central (Rolandic) vein drains the precentral and postcentral gyrus [12]. The superior anastomotic vein (vein of Trolard) that usually lies in the posterior central region connects superficial sylvian vein to SSS. Injury to these major bridging veins can cause venous infarction and hemiplegia [12, 14].

The surgical approach for FM is determined by the growth pattern of the tumors [2, 6, 16]. Though transcortical corridor is described, it is currently not favored and an interhemispheric approach is preferred [5]. For FM confined to unilateral cerebral hemisphere, an ipsilateral interhemispheric approach is used [5, 6, 9, 16]. In such tumors, few authors advocate contralateral transfalcine corridor that avoids manipulation of edematous brain on the side of the lesion [3, 8, 16]. In tumors with bilateral falx involvement with an asymmetrical extension, initially the meningioma is approached from the smaller side of the tumor. Then, the patient's position is adjusted (towards the side of larger bulk) to access the tumor on the contralateral side through a transfalcine approach [16]. Bilateral meningiomas with symmetrical extension are initially decompressed from non-dominant side and then the opposite side by transfalcine corridor [16]. Ausman et al. have described transfalcine excision for a patient with small bilateral asymmetrical meningioma [2]. He had suggested bilateral craniotomy though the excision was unilateral from the larger side of the tumor. The aforementioned studies have not discussed the surgical trajectory for the tumors.

All our patients showed symmetrical tumor extension on both sides of the falx. We did not face the necessity of a bilateral craniotomy in any of them. Despite the large size, the tumors could be successfully removed from unilateral side. We chose the side of non-dominant hemisphere for the initial tumor decompression so that any damage if incurred was kept to the minimum. The other approach could be removing the meningioma from the symptomatic/lateralizing side of the patient. Though we utilized the falx window to reach the contralateral portion of the tumor, the trajectory used was different from that of others [2, 16]. The traditional method which involves direct dissection over the major veins especially in large tumors with an overlying edematous brain puts the venous structures at risk. In contrast to the previous reports, we accessed the meningioma at an angle from either an anterior or posterior trajectory (Fig. 1). This way, the dissection over the bridging veins and the brain retraction was minimized. Though the initial part of decompression may be slightly difficult because of a narrow and deep corridor, the latter part becomes easy as the space is created and tumor starts falling into the surgical area.

Safe area for falx incision

One must be aware of the differences in the regional venous anatomy of falx before incising it. Anatomically, the falx is anatomically divided into anterior, middle, and posterior third in relation to the coronal and lambdoid sutures [15]. The anterior third shows venous channels which are localized close to the superior and inferior sagittal sinuses. The central part of anterior-third falx is relatively free of venous plexus and is a safe area for falx incision [15]. In the mid-third, the venous plexus can extend into the central surface from the adjacent venous sinuses. However, we did not face any significant trouble secondary to these veins while creating the falx window. The surface of the central portion of the falx has to be thoroughly coagulated before fenestrating it. In the posterior

third of falx, the veins were more concentrated in the lower margin and close to the straight sinus [15]. Therefore, the falx window has to be created close to the central surface and slightly towards the anterior aspect avoiding the area close to the junction of straight sinus.

Once the falx is incised, the surgical window can be horizontally enlarged depending on the antero-posterior extent of the tumor. Inferiorly, the inferior sagittal sinus may be coagulated and sacrificed to widen the vertical extent of the surgical corridor.

Conclusion

To summarize, we share our surgical nuances and experience in the management of giant mid-third/central falcine meningiomas. The unilateral approach is safe and effective even for such large meningiomas. An oblique anterior or posterior trajectory instead of an end-on approach lessens the chance of injury to the draining veins and the adjacent eloquent cortex and provides good outcome. Creating a falx window helps to reach the contralateral side of the tumor.

Compliance with ethical standards

The procedures performed were in accordance with the ethical standards of the institutional ethics committee and with the 1964 Helsinki declaration and its later amendments. For this type of study, formal consent is not required.

Conflict of interest The authors declare that they have no conflict of interest.

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