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Clinical Article

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Falx Meningiomas : Surgical Results and Lessons Learned from 68 Cases

Objective : The purpose of this study was to review the characteristics of falcine meningioma retrospectively and to identify the parameters associated with tumor recurrence.
Methods : The analysis included; age, sex, extent of resection, and radiologic and pathologic findings. Falcine meningiomas were classified by location as anterior, middle, or posterior as described for parasagittal meningiomas.
Results : Of the 795 meningioma patients treated between 1990 and 2004 at the authors' institution, 68 patients with meningiomas arising from the falx underwent craniotomies. There were 22 male and 46 female patients (1 : 2.1). Mean age was 55 years and ranged from 14 to 77 years. Locations of falcine meningioma were; the anterior third in 33 cases, middle in 20, and posterior in 15. Mean tumor volume was 42 cc and ranged from 4 to 140 cc. In 58 of the 68 patients tumors were totally removed. Additional surgery for recurrence was performed in 6 patients over 15 years. Of these 6 patients, only two patients underwent gross total tumor resection at first operation; the other four underwent subtotal tumor resection. Based on pathologic reports, the largest tumor subtype was transitional. There were four patients with a high grade tumor-three atypical and one anaplastic meningioma. Of the 68 patients, 59 achieved a good outcome (no neurological deficit or recurrence), six had temporary complications, two suffered new permanent postoperative deficits, and the remaining one died due to severe brain swelling despite postoperative intensive care. Extent of surgical resection was found to be significantly related to tumor recurrence.
Conclusion : Falcine meningioma accounted for 8.5% of intracranial meningiomas and the transitional meningioma was the most common subtype of falcine meningioma. Gross total resection of tumor was the single most important predictor of an improved surgical outcome.

KEY WORDS : Falcine meningioma · Surgical results · Histological subtype.

INTRODUCTION

Falcine meningioma, as defined by Cushing, is a meningioma arising from the falx cerebri and completely concealed by the overlying cortex[6]. Falcine meningioma tends to grow predominately into one cerebral hemisphere but is often bilateral, and in some patients the tumor grows into the inferior edge of the sagittal sinus. However, although much information is available regarding meningiomas, little is known about falcine meningiomas.

It has been reported that parasagittal and falx meningiomas recur more frequently than other intracranial meningiomas[13], and the authors suspect that these relative high recurrence rates are related to incomplete tumor removal. In this report, cases of falcine meningiomas are reviewed with respect to their clinical characteristics, the surgical techniques used, their histological subtypes, and surgical outcomes.

MATERIALS AND METHODS

Patient population

Between January 1990 and December 2004, 68 patients with a falcine meningioma underwent craniotomies at the authors' institution. All tumors were attached to the falx with either anterior or posterior extension and proven pathologically as meningiomas. The medical records, neuroradiologic findings, and videotapes of these 68 cases were reviewed retrospectively. Age *per se* was not a primary factor when deciding upon surgery. If a patient had good neurological function prior to symptom onset and a satisfactory medical status, surgical resection was considered. Patients who were diagnosed as recurred falx meningiomas after surgery or radiosurgery at other hospitals were excluded.

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Surgical technique

The operative techniques used differed according to tumor locations and degrees of sagittal sinus involvement. The interhemispheric approach through a midline crossing craniotomy was used most frequently to treat falcine meningiomas[1,10]. An anterior or middle third tumor type with a dumbbell shape required a bicoronal or linear incision, whereas for posterior third tumors, a U-shaped flap based inferiorly which was wide enough to allow for bilateral occipital craniotomy should suffice. The bone flap was created 2 to 2.5 cm from the midline on both sides. The dura was opened on the side of the non-dominant hemisphere or on the side of the larger component of a dumbbell-shaped tumor. This dural incision was extended to the lateral portion of the superior sagittal sinus, and the bleeding was controlled using hemostatic clips. In some cases, a bridging veins were freed from the cortex for a few millimeters to give the required exposure without sacrificing the vein; a self-retaining retractor was then placed. In the anterior third type of tumor, it was usually possible to take draining veins and the sagittal sinus, if required, to complete resection[15]. The medial surface of the hemisphere was gently retracted to identify the anterior and posterior limits of the tumor. Before internally decompressing a tumor, the anterior and posterior margins of the falx were divided from superior to inferior, preferably with a 1 cm or greater margin from the tumor edge, to interrupt blood supply to the tumor from falx arteries.

Statistical analysis

Statistical analyses were performed using PC-SPSS software (SPSS, Inc, Chicago, III). The Pearson Chi-square test was used to analyze the relation between extent of tumor removal and recurrence. A probability value of less than 0.05 was considered statistically significant.

RESULTS

Demographic and clinical manifestations

Falx meningioma constituted 8.5% of the 795 meningiomas treated during the 15 year study period. The 68 patients were aged from 14 to 77 years old, and peak occurrence was in the seventh decade. There were 22 male and 46 female patients. No familial tendency was found. Clinical follow-up periods ranged from 6 to 173 months (median, 36 months), and three cases were lost to follow-up.

At presentation, symptom durations were found to vary widely. Twenty-one patients (30%) presented with headache, and eleven (16%) with unilateral motor weakness. Five (7%) patients had a chief complaint of a seizure history. Five (7%) patients presented with personality change and four (6%) were asymptomatic and their brain tumors were detected incidentally.

Neuroradiologic characteristics

The majority of tumors were iso- or slightly hypointense relative to the cortex on T1-weighted magnetic resonance (MR) images, although signals on T2-weighted images were variable. About 60% of falcine meningiomas had a collar of thickened, enhancing tissue that surrounded their dural attachment (dural tail sign). The degree of peritumoral edema was mild. Mean tumor volume was 42 cc and ranged from 4 to 140 cc, and these were located along the falx in 48, 29 and 23% of the anterior, middle and posterior thirds. Cerebral angiography was performed in 41 cases and visualized as prominent radial or "sunburst" vascular pattern in 7 cases. Sinus involvement of the tumor (adjacent to the edge or occlusion of the sinus) was encountered in 7 patients.

Surgical results and recurrence

Gross total tumor resection (Simpson Grade[15] I or II) was achieved in 58 cases, and subtotal resection was performed in 10 cases. In 2 patients, in whom the anterior cerebral artery (ACA) was encased by the tumor, subtotal removal was attempted in accord with preoperative intent (Fig. 1), and in one patient the hard consistency of a mass attached to falx prevented total removal.

Gamma-knife surgery was performed as a postoperative adjunctive modality in 6 patients. There has been no evidence

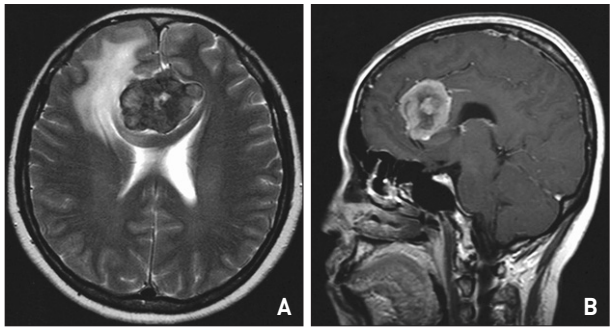

Fig. 1. Magnetic resonance image showing a lobulating mass attached to the falx. Mass with severe peritumoral edema compressing anterior cerebral arteries (ACA) on T2 weighted axial view (A). T1 enhanced sagittal view showing encasement of the ACA by the tumor (B).

Table 1. Extent of tumor removal and recurrence

	Non-recur	Recur	Total
GTR	54	2	56
STR	5	4	9
Total	59	6	65

Extent of surgical resection was found to be significantly related to tumor recurrence ($p<0.001$). GTR and STR mean gross total removal and subtotal removal respectively

of recurrence or regrowth in those 6 patients until median follow-up of 5 years.

Surgical outcome was assessed by tumor recurrence or progression of remaining tumor, and was verified primarily by gadolinium-enhanced MRI. Radiological evidence of tumor recurrence or progression was obtained in six patients (11.2%). Further surgery for recurrence was performed on 6 patients. Of the six, two patients had undergone gross total tumor resection (GTR) at first operations, and the other four subtotal resection (STR). At second operations, two of the six underwent subtotal tumor resection and the other 4 patients underwent gross total resection.

The relation between tumor recurrence and incomplete resection was found to be significant ($p<0.001$) (Table 1). However, age at first surgery, tumor location, and pathological subtype were found not to be related to recurrence ($p=0.841$, $p=0.465$, and $p=0.931$ respectively).

Of the four patients with a high grade tumor (3 atypical falcine meningiomas and one anaplastic falcine meningioma) two patients (one atypical and one anaplastic) received adjuvant radiotherapy after STR or GTR respectively. The patient who underwent GTR and radiotherapy has had no significant complication, and the other was unfortunately not followed due to transfer to another hospital. The other two patients (both with atypical falcine meningioma) did not receive adjuvant treatment and were not followed.

Histological results

Meningiomas of any histologic subtype can arise from the falx. In the present clinical series, the transitional subtype was the most common and accounted for 39% patients (26 of 67 patients). In summary, the meningothelial subtype accounted for 30% (20/67), the fibrous subtype 12% (8/67), and the atypical or anaplastic subtypes 6% (4/67). Several patients had a mixed histology meningioma, and were difficult to categorize by subtype.

Morbidity and mortality

Fifty nine of the 68 patients achieved a good outcome, with no neurological deficit or complications, six had temporary deficits, and two had new permanent postoperative deficit, i.e., contralateral lower extremity weakness and severe impairment of visual acuity, respectively. One patient died (1.4%). This patient was admitted through the emergency department due to sudden increase in intracranial pressure caused by transtentorial herniation of a left huge frontal mass attached to the falx. This patient underwent emergency craniotomy and tumor removal. A ruptured superior sagittal sinus around the parietal lobe and massive bulging of the brain parenchyme were observed intraoperatively.

DISCUSSION

Clinical manifestations

Cushing and Eisenhardt classified meningiomas based on surgical findings of a dural or bony site of origin[6], and concluded that falcine meningiomas arise, or appear to arise, from the cerebral falx concealed completely by overlying cortex, and that typically they do not involve the superior sagittal sinus[6]. Falcine meningiomas frequently have a dumbbell shape and invaginate into the medial aspects of both left and right hemispheres. They can be divided into anterior, middle, and posterior types, depending on their origin in the falx[2]. The anterior type extends from the floor of the frontal fossa to the coronal suture, the middle type from the coronal suture to the lambdoid suture, and the posterior type extends from the lambdoid suture to the torcular Herophili. On the other hand, Yasargil classified falcine meningiomas into outer and inner types[16]. The former arise from the main body of the falx in the frontal (anterior or posterior), central parietal, or occipital regions, whereas inner falcine meningiomas arise in conjunction with the inferior sagittal sinus.

Moreover, incidence of falcine meningioma is five to seven times less common than parasagittal meningioma, which accounts for about 20% of intracranial meningioma cases. The western literature has shown a maximum prevalence for falcine meningioma between the fourth and the sixth decades[5], whereas the present study revealed a peak prevalence in the seventh decade.

Preoperative and intraoperative evaluations

Multiplanar MRI is the current standard study for the preoperative evaluation of patients with falcine meningiomas. Coronal, sagittal, and axial T1-weighted gadolinium-enhanced sequences help define the anatomical locations, sizes, and medial hemisphere involvements of these tumors.

Cerebral angiography is necessary in patients with these meningiomas, and the pericallosal artery is often displaced and may actually be engulfed by the tumor. Arterial phase cerebral or MR angiograms should be studied to determine the relationship between tumor and ACA. Anterior falcine meningiomas are usually supplied by the ACA or by a tentorial branch of the ophthalmic artery. Venous phase cerebral angiography is important because it provides significant information about whether a tumor mass has invaded the sagittal sinus. Moreover, it provides information about the courses of many large drainers around a mass (Fig. 2A), which must be determined to identify trajectory to a falcine mass and to prevent postoperative venous infarction. It is also useful for determining sinus patency and for delineating

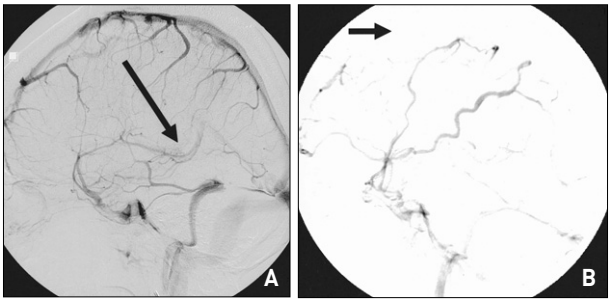

Fig. 2. Cerebral angiography showing downward displacement of internal cerebral veins (A). The superior sagittal sinus is almost totally occluded by the tumor (B).

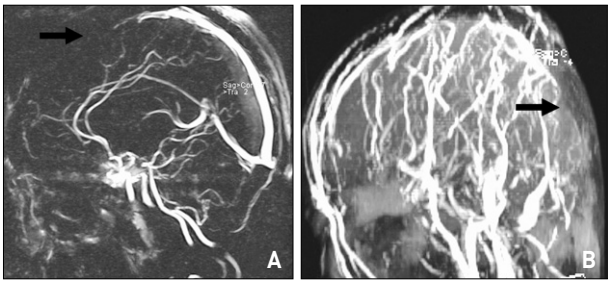

Fig. 3. Magnetic resonance venographs showing compression of a superior sagittal sinus by mass adjacent to the anterior (A) and posterior falx (B), respectively.

Table 2. Incidences of falcine meningioma histological subtypes (N=67)

Histologic subtype	Number of case (%)
Transitional	26 (39%)
Meningothelial	20 (30%)
Fibrous	8 (12%)
Anaplastic	4 (6%)
Others	9 (12%)

the anatomical location of the major cortical draining vein. Signs of venous occlusion include the disappearance of a segment of the superior sagittal sinus (SSS), a delay in venous drainage in the area of obstruction, and failure of the cortical vein to reach the sinus (Fig. 2B).

The majority of patients in the present study underwent preoperative cerebral angiography. MR venography in vertex view can be useful for demonstrating nearby parasagittal draining veins, which must be protected[3] (Fig. 3), but MRA alone seems to be inadequate in the lack of venous phase of cerebral vasculature around tumors.

Surgical technique

Cushing and Eisenhardt used a transcortical incision to expose most falcine meningiomas[6]. However, current microsurgical techniques and methods have improved intracranial compliance, including cerebrospinal fluid drainage, mannitolization, and hyperventilation, and a transcortical approach is rarely required. All cases in the present study were operated upon using the microsurgical technique, and thus, observed improvements in surgical outcome may be attributable to this type of microsurgery.

Histological subtype

Meningiomas arise from polyblastic and functionally multipotential arachnoid cells, and these characteristics result in histopathological variations. Transitional meningioma was found to be the commonest histological type in the present study (Table 2). JH Lee, et al., reported a significantly higher prevalence of meningothelial meningiomas in the midline skull base and in spinal locations[12], and discussed a significant association between meningothelial subtype and site of tumor origin. Others also have suggested that meninges covering the brainstem and spinal cord arise from a different embryological lineage than meninges of the cerebral convexity.

The authors consider that the results of the above mentioned studies and of the present study, support the possibility that differential leptomeningeal embryogenesis may result in the predominance of one cell type in certain locations (cap cells in the outer layer of the arachnoid membrane and trabecular fibroblasts in the inner layer).

Surgical outcome

In this series on falcine meningioma, 10 of the 68 patients underwent subtotal resection for several reasons. The majority who underwent subtotal tumor resection had a tumor that involved venous structures, such as, the SSS, torcula, and cortical draining vein, or were attached firmly to the falx. One patient underwent a staged operation due to dissection difficulties caused by severe adhesion to ACA. Giombini S., et al.[8] stated that 47% of parasagittal or falx meningioma patients were fit for work and that 5.6% were completely disabled postoperatively. However, much better surgical morbidity and mortality findings were found during the present study, which may have been attributed to more accurate presurgical tumor delineation and advances in microsurgical techniques.

Some consider that some meningioma histotypes are associated with an aggressive behavior, but the prevailing opinion is that recurrence depends, in most cases, on incomplete removal rather than on an intrinsic malignancy[8]. This concurs with our findings. In fact, in the present study, the 6 tumors that reappeared after removal belonged to the commonest types, and were histologically indolent according to first and second surgery specimens.

CONCLUSION

In our series, the falcine meningiomas accounted for 8.5% of intracranial meningiomas, and they were more frequent

in the anterior third of the falx. Of the subtypes the transitional falcine meningioma subtype was the most common.

With regards to the prognosis, the extent of surgical resection was found to be significantly related to tumor recurrence, and thus gross total tumor resection is presumed to be the single most important predictor of an improved surgical outcome. Moreover, adjuvant radiosurgery after STR of the tumor in cases of severe adhesion to ACA, SSS, or major veins may be considered to reduce the recurrence rates.

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