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Original article

The Dural Dark-Side Approach for falcine and tentorial meningioma: A surgical series of five patients

Approche transdurale pour la résection de méningiomes de la faux du cerveau et de la tente du cervelet : une série chirurgicale de 5 patients

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ABSTRACT

Introduction. – Falcine or tentorial meningioma can be complex to resect. When large meningiomas are located in eloquent areas, a direct ipsilateral surgical approach may cause brain injury and postoperative neurological deficits. In this series, 5 patients were surgically treated using a contralateral transfalcine or transtentorial approach to minimize brain retraction. This strategy was called the Dural Dark-Side Approach (DDSA). The aim was to analyze the quality of tumor resection and postoperative outcome.
Material and methods. – In our department, from June 2018 to January 2020, 5 patients underwent microsurgical DDSA for resection of 4 falcine and 1 tentorial meningioma. All tumors were selected on the following two criteria: large > 40 mm diameter tumor, with surrounding functional cortex. Clinical and radiologic data were retrospectively analyzed.
Results and discussion. – Mean follow-up was 20 months. No patients required use of a rigid retractor during surgery. Gross total resection was performed in 3 patients and near-total resection in 2. All patients had favorable neurologic outcome. Postoperative MRI showed no ipsilateral or contralateral brain lesions.
Conclusion. – This series suggested that meticulous DDSA allows excellent resection in selected large falcine or tentorial meningioma. The approach offered a safe and effective surgical corridor without injuring the surrounding healthy parenchyma.

Mots clés :
Approche transdurale
Transfalcoriel
Transtentoriel
Approche controlatérale
Chirurgie sans écarteur
Stratégie « *no touch* »

RÉSUMÉ

Introduction. – La résection de certains méningiomes falcoriels et tentoriels reste complexe. Lorsque de volumineux méningiomes se développent, en regard d'une aire anatomique éloquente, l'approche chirurgicale directe, homolatérale, risque d'entraîner une souffrance parenchymateuse, à l'origine d'un potentiel déficit neurologique postopératoire. Dans cette série, 5 patients ont été traités par une approche transdurale transfalcorielle ou transtentorielle, de manière à minimiser la rétraction cérébrale. L'objectif était d'évaluer la qualité de la résection tumorale et le résultat neurologique postopératoire.
Matériel et méthodes. – De juin 2018 à janvier 2020, 5 méningiomes (4 falcoriels, 1 tentoriel) ont été réséqués en utilisant une approche chirurgicale transdurale transfalcorielle ou transtentorielle. Les méningiomes sélectionnés avaient tous un grand axe supérieur à 40 mm et étaient tous recouverts par un cortex cérébral fonctionnel. Les données cliniques et radiologiques ont été analysées rétrospectivement.
Résultats et discussion. – Le suivi moyen était de 20 mois. Aucun écarteur autostatique n'a été utilisé durant la procédure chirurgicale. La résection tumorale était macroscopiquement complète dans 3 cas et subtotale dans 2 cas. L'évolution neurologique était favorable dans tous les cas. L'IRM postopératoire n'a pas montré aucune lésion parenchymateuse, ni homolatérale ni controlatérale.

Abbreviations: DDSA, Dural Dark-Side Approach; GTR, Gross total resection; MRI, Magnetic resonance imaging; mRS, modified Ranking Scale; NTR, Near gross total resection; PM, Parafalcine and parafalcorial meningioma.

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Conclusion. – Cette série suggère qu'une approche transdurale méticuleuse, transfalcorielle ou transtentorielle peut s'avérer pertinente pour la résection de certains méningiomes volumineux insérés sur la faux ou sur la tente. Cet abord offre un corridor chirurgical suffisant pour permettre une exérèse satisfaisante, tout en minimisant le risque de lésion du parenchyme cérébral homolatéral.

1. Introduction

Falcine meningiomas are defined as meningiomas arising from the falx completely surrounded by the overlying cortex that do not involve the superior sagittal sinus [1]. Falcine meningiomas generally grow bilaterally with a contralateral bulge in about 30% of cases. The incidence of falcine meningioma is 9% of all intracranial meningiomas. Tentorial meningiomas account for only 3% to 6% of intracranial meningiomas, but their location, particularly when projecting superiorly into the occipital lobe, often threatens the primary visual cortex [2].

The strategy for surgical resection of midline lesions alongside the falx or the tentorium has evolved over time. Initially, a transcortical approach was proposed. With regard to poor clinical outcome, the technique was quickly abandoned [3]. An interhemispherical ipsilateral approach was preferred for these tumors, as presented in the 1980s by Yasargil and Drake [3,4]. They suggested the approach would ensure direct access to these lesions by ipsilateral craniotomy. The strategy still remains the gold standard approach for resection of parafalcine and paratentorial meningiomas. In 2017, Murrone et al. presented a study of 95 patients operated on with an ipsilateral interhemispheric approach with good results and only new or worsened deficits in three patients [5].

The concept of a contralateral interhemispheric transfalcine approach was developed for vascular malformations [6–8]. In 1984, Machado de Almeida first published a contralateral parafalcine innovative approach for parasagittal arteriovenous malformations [8]. More recently, Burkhardt et al. developed the contralateral posterior interhemispheric approach to deep medial parietooccipital vascular malformations to minimize brain retraction [6]. The contralateral approach was also selected for intra-axial tumors or dysplasia [9–13]. In 1995, Goel published the first interhemispheric contralateral transfalcine approach for deep tumors near the falx in four cases: two gliomas, one choroid plexus papilloma and one abscess [9]. Mooney et al. described a transfalcine approach with asleep motor mapping for resection of metastatic lesions involving the medial precentral gyrus [12]. In 2018, Harput and Türe published the paramedian supracerebellar transtentorial selective amygdalohippocampectomy for mediobasal temporal epilepsy [10]. The extended contralateral transfalcine access to the mesial frontoparietal region and cingulate gyrus has been clearly demonstrated in a cadaveric feasibility study [11].

To our knowledge, few authors have reported some single cases and small series of tentorial or falcine meningioma resected by a transtentorial or transfalcine approach [14–19]. In 2012, Zuo et al. [20] proposed a scheme for the classification and surgical planning of falcine meningioma treatment. Six of the 20 patients were surgically treated using a contralateral transfalcorial approach, but the related clinical outcome was not precisely reported. Today, there is still no clear consensus on the strategy to adopt for resection of midline meningiomas inserted on the falx or on the tent.

In this series, we describe five cases of falcine and tentorial meningiomas successfully treated by a retractorless contralateral transfalcine or transtentorial approach. This approach has been called "the Dural Dark-Side Approach" (DDSA) in reference to the "dark side of the moon", highlighting the fact we used the "hidden" corridor that does not appear obvious at first glance (Fig. 1A). We restricted the indications to large complex meningiomas, which were surrounded by functional parenchyma. The main endpoint of this study was to report the technical notes and the clinical outcome of our patients, emphasizing our surgical strategy.

2. Material and methods

2.1. Patients

A retrospective review was performed to identify all relevant patients who underwent surgical resection for parafalcine and paratentorial meningiomas (PMs). PMs included parasagittal meningiomas, transverse sinus invading meningiomas, falcine and tentorial meningiomas. Falcine and tentorial meningiomas originated respectively from the falx and the tentorium but were surrounded by overlying cortex. Falcine and tentorial meningiomas did not involve the superior sagittal sinus or the transverse sinus. Over the last 10 year-period, 272 PMs were treated in our department. Between June 2018 and January 2020, four falcine and one tentorial meningiomas were operated on using DDSA by two senior authors (BB, SG) and were included in this series.

Clinical data (age, sex, presenting symptoms) and operative data (use of rigid retractor) were collected.

Preoperative MRI was essential to determine which patients were eligible for DDSA. All PMs were analyzed from the axial, sagittal and coronal MRI plans, in order to determine the operative corridor. PMs were treated by DDSA when they met the following two criteria: main diameter superior to 40 mm and ipsilateral surrounding eloquent cortex. When both criteria were not respected, the PMs were surgically treated by a classic ipsilateral approach and excluded from this study.

All meningiomas were classified according to the WHO classification [21].

In order to assess clinical evolution, the modified Rankin Scale (mRS) was used [22]. Initially developed for stroke pathology, the modified Rankin Scale (mRS) is now useful to analyze the clinical outcome after tumor surgery [23].

Postoperative MRI evaluated the quality of resection, the presence of brain damage secondary to the DDSA and the evolution of potential ipsilateral perilesional edema. The quality of the resection was defined as gross total resection (GTR), equivalent to Simpson I to III, or as near total resection (NTR) when tumor excision was superior to 90% with a thin layer of persistent tumor [24].

2.2. Surgical strategy

When the meningioma appeared to be highly vascularized, the patients underwent preoperative angiography to assess vascular mapping and embolize tumor arterial feeders if feasible. All surgical procedures were performed under neuronavigation. No external cerebrospinal fluid drainage was used in any patient.

According to the anterior or posterior location of the tumor, a transfalcine approach in supine or prone position was required for four patients with falcine meningiomas. The head was fixed in a Mayfield head holder. The head was turned nose down about 30°

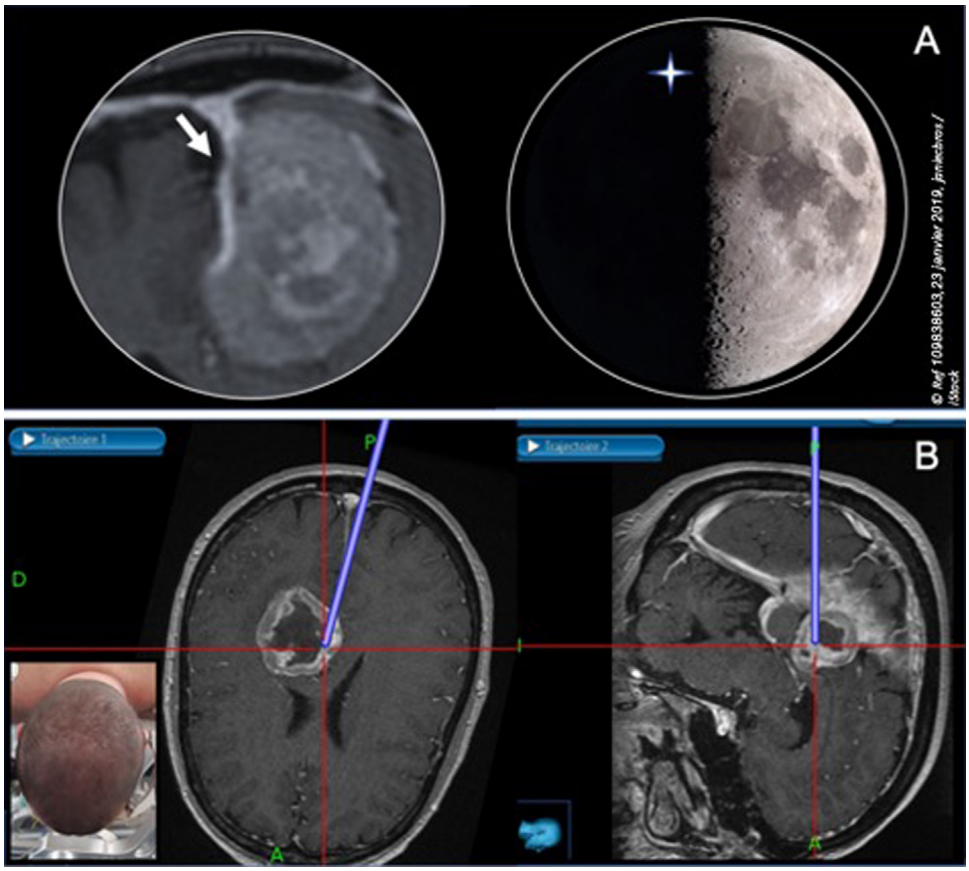

Fig. 1. Dural Dark-Side Approach. A. Concept of Dural Dark-Side Approach, highlighting the fact that the "hidden" corridor (white arrow, white star) does not appear obvious at first glance (photography from iStock, reference: 1098386032, 23/01/2019, janiecbros). B. Contralateral interhemispheric approach for a right deep parietal falcine meningioma (patient 2). Patient positioning (insert, in the lower left corner) and trajectory views obtained on the Stealthstation neuronavigation system. The head was fixed in a Mayfield head holder and turned nose down about 30° toward the floor, in order to take advantage of gravity and thus allow the brain to move away from the falx. Note that a direct interhemispheric approach could have induced ipsilateral damage.

toward the floor, in order to take advantage of gravity and thus allow the brain to move away from the falx (Fig. 1B). A contralateral craniotomy crossing the midline was performed. A transtentorial approach in sitting position was required for one patient with a left occipital tentorial meningioma. The head was fixed in a Mayfield head holder. A left occipital craniotomy crossing the lateral sinus was performed. The sitting position allowed the cerebellum to move away from the tentorium.

Arachnoid adhesions between the dura and the cortex were gently released, allowing meticulous dissection through the fissure, using gravity-assisted surgery. Cottonoids were placed, creating a persistent working corridor between the falx (or the tentorium) and the contralateral lobe. The dural opening through the falx or the tentorium was delimited with the help of neuronavigation. The dural window was tailored in order to expose most of the part of the tumor without exposing the ipsilateral brain. The dura was sectioned in a semicircular fashion and coagulated. The arterial feeders were coagulated and sectioned before tumor resection. The meningioma was then debulked with an ultrasonic aspirator, circumferentially dissected and removed.

3. Results

During the last 10 year-period, 272 PMs were treated in our institution. The majority of PMs were initially surgically treated by a classic ipsilateral approach but we recently changed our surgical strategy, following the current evolvement of "no touch" retractorless philosophy [25].

The characteristics of all 5 patients and postoperative data after surgery are provided in Tables 1 and 2. In the series, 4 women and 1 man were included, with a mean age of 56 years (range: 41–70 years). The mean follow-up was 20 months (range, 10–29 months). All patients were right-handed. At admission, all patients showed presenting neurological symptoms such as headache, gait instability, motor deficit, visual disturbances or cognitive disorders.

Three lesions were found in the left dominant hemisphere and two lesions were found in the right non-dominant hemisphere. PMs were in the rolandic area in one patient, the supplementary motor area in one patient, the deep parietal area in two patients and the occipital area in one patient. The mean tumor diameter was 49 mm (range: 45–51 mm).

Four patients underwent a contralateral interhemispheric transfalcine approach and one patient underwent a left supracerebellar transtentorial approach. No patient required a rigid retractor during DDSA. Mean postoperative day on discharge was at day 6 (range: 4–10 days).

Pathology confirmed grade I meningioma for four patients and grade II meningioma for one patient.

All patients improved postoperatively and recovered neurological function. Four patients completely recovered with a complete disappearance of their initial symptoms. At the last follow-up, mRS score was 0 for four patients and mRS score was 1 for one patient (patient 5 with persistent quadranopsia). No surgical complication – including postoperative hematoma, infection, transient neurological deficit or deep veinous thrombosis – was observed in the present series.

Table 1
Case summary of the 5 patients treated with DDSA.

Case	Age (y), sex (F/M)	Presenting symptoms	Preoperative MRI				Day on discharge
			Tumor location	Main diameter (mm)	Perilesional oedema	Type of DDSA	
1	41, F	Instability, low limb paresis	Left rolandic	48	–	Right interhemsipheric transfalcine	5
2	70, F	Headache	Right parietal	45	+	Left interhemispheric transfalcine	4
3	43, F	Quadranopsia, dysgraphia, aphasia	Left occipital	51	+	Supracerebellar transtentorial	10
4	69, M	Gait instability, cognitive disturbance, aphasia	Left supplementary motor area	51	–	Right interhemispheric transfalcine	4
5	55, F	Gait instability, low limb paresis, quadranopsia	Right parietal	48	+	Left interhemispheric transfalcine	5

DDSA: Dural Dark-Side Approach; F: female; M: male; Y: year; mm: millimeters; MRI: magnetic resonance imaging.

Table 2
Postoperative data after DDSA.

Case	Histology/grade	Follow-up(months)	Clinical outcome/mRS	Quality of resection	Contralateral injury (Yes/no)	Perilesional edema
1	Meningothelial/II	29	Favorable/0	NTR	No	–
2	Fibroblastic/I	21	Favorable/0	GTR	No	Decreased
3	Microcystic/I	28	Favorable/0	GTR	No	Decreased
4	Transitional/I	11	Favorable/0	NTR	No	–
5	Transitional/I	10	Favorable/1	GTR	No	Decreased

DDSA: Dural Dark-Side Approach; mRS: modified Ranking score; GTR: gross total resection; NTR: near total resection.

Postoperative MRI showed GTR in three patients and NTR in two patients. Radiological analysis confirmed the absence of contralateral brain damage secondary to DDSA. When present before surgery, ipsilateral perilesional edema decreased in each patient (patients 2, 3 and 5).

3.1. Illustrative case No. 2

A 70-year-old woman with no significant medical history presented with a falcine meningioma accidentally discovered in 2014. Initially, clinical and radiologic monitoring was decided. In December 2018, she presented with a severe headache. MRI showed an increase of tumor volume with appearance of a large central necrosis and perilesional edema, located deep in the right parietal lobe. A surgical indication was agreed on (Fig. 2a–c). DDSA was decided and a left rectractorless interhemispheric transfalcine approach was performed. Complete resection was achieved. Discharge was at day 4. Pathology confirmed a grade I fibroblastic meningioma. Six months after surgery, the patient totally recovered with mRS score = 0. MRI confirmed GTR, no cortical injury, and complete disappearance of the perilesional edema (Fig. 2d–f).

3.2. Illustrative case No. 3

A 43-year-old woman presented right homonymous superior quadrantanopia, aphasia and dysgraphia. Preoperative MRI showed a 51 mm diameter occipital meningioma inserted on the tentorium of the cerebellum, associated with moderate perilesional edema (Fig. 3a–c). DDSA was decided. A retractorless left supra-cerebellar transtentorial approach was carried out in sitting position. A complete resection was performed and the patient discharged at day 10. Histologic analysis confirmed a grade I microcystic meningioma. The patient fully recovered with a mRS score at 0. Postoperative MRI confirmed GTR. The occipital lobe was intact and preoperative perilesional edema disappeared, as illustrated in Fig. 3d–f.

4. Discussion

4.1. Selection of patients eligible for DDSA

The majority of the 272 PMs treated in our institution were not directed towards DDSA. The classical ipsilateral approach is most of the time associated with excellent rates of resection and favorable outcome [5,26]. In case of parasagittal meningiomas, or small falcine and tentorial meningiomas without perilesional edema, a direct ipsilateral interhemispheric approach was obviously chosen. In these indications, the direct conventional approach took advantage of a pre-existing anatomic natural corridor. Nevertheless, in case of deep and large lesions located in eloquent areas, the use of a rigid retractor and brain retraction is often necessary to expose the meningioma. In a study of 95 falcine menigiomas, resected with a classic ipsilateral interhemispheric approach, Murrone et al. [5] experienced three new or worsened neurologic deficits (lower extremity weakness, hemiparesis) after surgery, related to surgical manipulation around the motor strip. Functional brain retraction induced direct traumatic injury or secondary lesions due to increased edema or venous ischemia.

Large PMs located in functional areas are more challenging to resect without injuring the adjacent cortex, which is why DDSA was chosen for patients with the two criteria we previously described. Both criteria were defined according to the preoperative MRI: large eloquent tumor with a main diameter of > 40 mm and surrounding functional cortex. For these selected tumors, we assumed that the classical surgical approach greatly increased the risk of ipsilateral brain injury and postoperative neurologic deficits. After applying

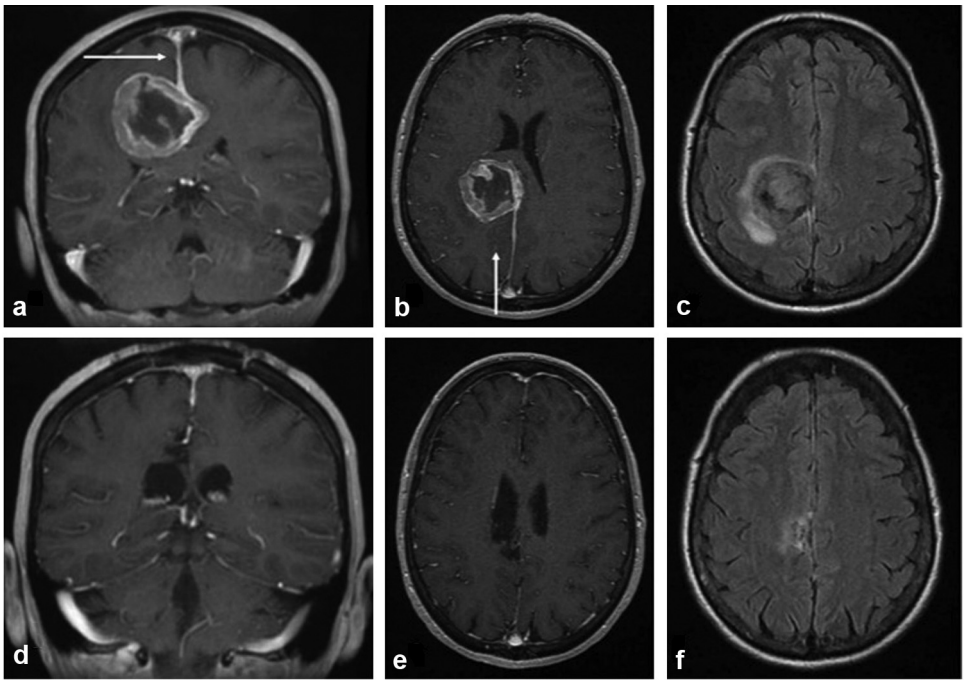

Fig. 2. Magnetic resonance images for patient 2: a and b: preoperative postcontrast T1 coronial and axial, enhancing meningioma measuring 45 mm diameter along the falx, located deep in the right parietal lobe, with a large central necrosis. The lesion was surrounded by healthy parietal cortex (white arrows); c: preoperative FLAIR T2 axial, hyperintense mass with perilesional oedema; d and e: postoperative postcontrast T1 coronial and axial, demonstrating gross total resection; f: postoperative FLAIR T2 axial, showing that ipsilateral and contralateral functional parietal cortex was respected with decrease of perilesional oedema.

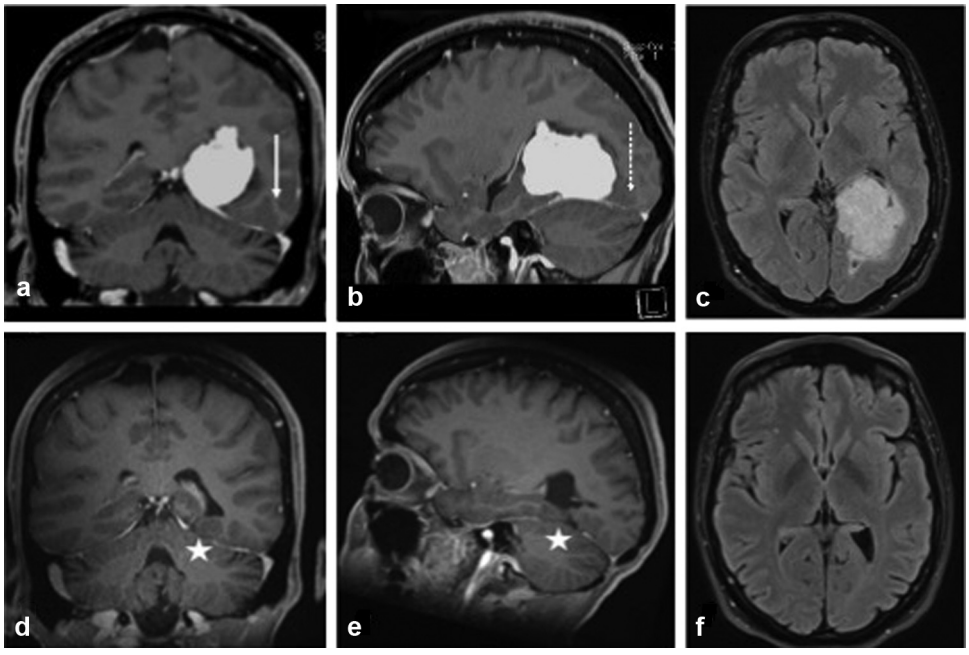

Fig. 3. Magnetic resonance images for patient 3: a and b: preoperative postcontrast T1 coronial and sagittal, avidly enhancing meningioma measuring 51 mm anterior posterior along the tentorium. The lesion was surrounded by entire normal left temporal lobe (white arrow) and occipital lobe (white dotted arrow); c: preoperative FLAIR T2 axial, hyperintense mass with mild perilesional edema; d and e: postoperative postcontrast T1 coronial and sagittal, postsurgical changes demonstrating gross total resection. Note: the section of the tentorium was limited and did not extend beyond the tumor insertion (white asterisk), in such a way that the eloquent the occipital lobe was not initially exposed; f: postoperative FLAIR T2 axial, highlighting intact ipsilateral and contralateral cortex after tumor resection.

the two selection criteria, five PMs were resected with a DDSA. This approach is almost exclusively described in case reports.

4.2. Surgical technique

This approach provided access to the tumor without significantly increasing the distance between the surface and the lesion, compared to the ipsilateral interhemispheric approach. Although some authors have advocated the use of drainage of cerebrospinal fluid [6,14,15], this procedure was not necessary to create a safe surgical corridor in our series.

In our experience, the contralateral craniotomy should be extended across the midline or across the transverse sinus in order to increase dural mobilization and optimize the surgical corridor.

Using gravity-related to head position, spacing of the contralateral lobe allowed spontaneous opening of the interhemispheric or intertentorial fissure. Bridging veins were identified, dissected and preserved. Progressive releasing of arachnoid adhesions was essential to protect the contralateral healthy lobe. Most authors have taken all the possible advantage from gravity the head is usually positioned with the falx in a horizontal orientation [6,27]. In theory, the more gravity is used, the more the surgical corridor is optimized. In clinical practice, our experience is that a progressive corridor spacing with a wide gentle arachnoid dissection and a meticulous positioning of tailored cottonoids allows an optimal access to the falx without injuring the contralateral healthy brain. Moreover, when the patient is placed in this position, the surgical area is approached with a superior angle of view, which obviously improves comfort and ergonomics for the neurosurgeon. In our experience, turning the head with the nose down about 30° toward the floor, gentle arachnoid dissection and maintaining the corridor with cottonoids was sufficient to work safely without using a rigid retractor.

A window was made in the falx or in the tent, and the lesion was exposed. In order to reduce the risk of recurrence, some authors have advocated the removal of all the invaded falx [28,29]. Mooney et al. concluded that increased extent of resection including, whenever possible, a clear margin of falx surrounding the tumor base was associated with the best long-term outcomes [29]. On the other hand, the large transdural window can damage important structures such as veins, arteries, surrounding sinuses and contralateral cortex. Maximum resection can be complicated by arterial or venous infarction, and lesions of eloquent areas [30]. In their series of 126 parafalcine meningiomas, Kong et al. reported that GTR was only achieved in 13 patients (10%) and NTR in 109 patients (86%) [31]. Aggressive resection of the falx is technically possible but we believe that a gentle and limited manipulation of the falx should be preferred to protect the ipsilateral swollen hemisphere. We tailored the dural opening with the neuronavigation in such a way that the ipsilateral brain was not exposed through the transfalcine or transtentorial window. One horizontal incision and two vertical incisions were performed at the limits between the meningioma and the brain. Hence, about 90% of the invaded dura was initially resected. All arterial feeders were coagulated before tumor resection, which minimized blood loss and improved tumor debulking. The tumor was resected in an extracapsular fashion. When the major part of the meningioma was removed, the residual part of tumor insertion was tangentially resected through the same trap door. The final surgical step was to remove the surrounding persisting infiltrated dura without taking the risk of injuring the superior longitudinal sinus or the lateral sinus. The entire invaded falx was removed in this way in three patients.

In our series, GTR was performed in three patients and NTR in two patients. This decision was taken intraoperatively according to the risk-benefit evaluation. The dural attachment involving the inferior part of the superior longitudinal sinus was respected in two patients. It appeared obvious that the superior longitudinal sinus could not be sacrificed. In terms of extent of resection, GRT was therefore obtained in all patients whenever possible, which is in accordance with the previous reported surgical series describing the ipsilateral or contralateral approach [5,14–17,19]. No grade III meningiomas was observed on pathological analysis. For this reason, in 2/5 of patients with subtotal resection, no radiotherapy nor radiosurgery was proposed immediately after surgery. The tumor residue was evaluated on MRI at 3 months after surgery and then every 6 months. To our own experience, for grade I or II meningiomas, we recommend to propose radiotherapy in case of tumor recurrence only.

4.3. Postoperative outcome

We reported a small retrospective series of five PMs treated with a DDSA. The short mean follow-up was 20 months (range, 10–29 months), which may underestimate the rate of radiologic progression or recurrence of the tumor. Obviously, the long-term radiologic recurrence could not be evaluated in the present report. However, all patients showed favorable clinical and radiologic outcomes after surgery. Our illustrative cases suggested that a direct conventional approach could have induced neurologic deficits, such as hemiparesis, hemianopsia or aphasia. Both patients were not only stable, but also recovered entirely 6 months after surgery. Perilesional edema decreased in both patients. Our postoperative data appear sufficient to assess the safety of the surgical procedure: we had no postoperative complications with a complete respect of the contralateral healthy brain. The capacity to respect the ipsilateral swollen brain with no new retractor-related lesion was demonstrated.

The main limitation of DDSA was the potential complication of bilateral eloquent brain injury. Identifying and respecting the venous structures was the key point of this surgery. It was crucial to create a meticulous and retractorless corridor during DDSA, as previously described [17].

Taking into account the real current trend to develop mini-invasive procedures, transfalcine and transtentorial strategies have been proposed in the last decade for arteriovenous malformations [6], aneurysm clipping [27], mediobasal temporal lobe resection [10] and more recently deep tumor resection [9,14,16]. The “Dural Dark-Side Approach” aims to share the same common philosophy to reduce brain retraction and protect ipsilateral hemisphere. DDSA could be extended to all large lesions located near the falx and near the tentorium regardless of their histological classification.

5. Conclusion

We retrospectively analyzed clinical and radiologic data in a consecutive series of five patients with falcine or tentorial meningiomas who were treated in our department. The surgical choice between a classical direct approach and DDSA was decided according to tumor size, tumor location and anatomic relationships with the bordering functional areas. In selected PMs, DDSA preserved surrounding eloquent cortex and allowed total or near total tumor resections with low morbidity.

We recommend that DDSA should be considered for any parafalcine and paratentorial lesion, as previously proposed [6,10,16]. This approach could be regularly included in new “no touch” retractorless surgical strategies currently developed for minimizing the risk of brain injury [17,25,27].

Human and animal rights

The authors declare that the work described has been carried out in accordance with the Declaration of Helsinki of the World Medical Association revised in 2013 for experiments involving humans as well as in accordance with the EU Directive 2010/63/EU for animal experiments.

Informed consent and patient details

The authors declare that this report does not contain any personal information that could lead to the identification of the patient(s) and/or volunteers.

Disclosure of interest

The authors declare that they have no competing interest.

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Author contributions

All authors attest that they meet the current *International Committee of Medical Journal Editors* (ICMJE) criteria for Authorship.

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