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Original research article

Surgical treatment of parasagittal and falcine meningiomas invading the superior sagittal sinus

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ARTICLE INFO

Article history:
Received 30 January 2014
Accepted 15 May 2014
Available online 24 May 2014

Keywords:
Parasagittal meningioma
Superior sagittal sinus
Microsurgical resection
Tumour recurrence

ABSTRACT

Objective: We present our experience with surgery of parasagittal and falcine meningiomas invading the superior sagittal sinus with special consideration of the surgical complications and the incidence of tumour recurrence.

Materials and methods: The analysis included 37 patients with parasagittal and falcine meningiomas invading the superior sagittal sinus. In 13 cases, the sinus was ligated and resected with tumour. In 14 cases, the sinus was entered with the goal of tumour resection and the sinus was reconstructed, while in 10 patients the sinus was not entered and the remaining residual tumour was observed for growth.

Results: Out of 13 patients after radical resection of the tumour and invaded part of sinus, 9 revealed haemodynamic complications: venous infarction (4), significant brain oedema (3) and hypoperfusion syndrome (2). 2 out of 14 patients after resection of the tumour from the lumen of the superior sagittal sinus with subsequent sinus repair developed venous infarction after surgery. Among 27 patients after radical tumour excision the remote follow-up revealed recurrence in 2 patients. There were no significant haemodynamic complications in none of 10 cases, in which the residual tumour was left after surgery in the superior sagittal sinus. In this group, 3 cases were subjected to early post-operative radiotherapy and local recurrence was observed in 4 patients.

Conclusions: The aggressive surgical treatment of meningiomas infiltrating the superior sagittal sinus is associated with a high surgical risk. The incidence of recurrence of these tumours increases significantly in the case of non-radical excision of the tumour.

1. Introduction

Meningiomas are usually benign, slow-growing and macroscopically well-circumscribed tumours. Parasagittal and falcine meningiomas are the second most common group of intracranial meningiomas and a frequent subject of the neurosurgical practice [1–3]. The most important feature of these meningiomas is their location in the immediate vicinity of the superior sagittal sinus and the presence of large

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http://dx.doi.org/10.1016/j.pjnns.2014.05.003

cerebral veins that enter the sinus in the proximity of these tumours [1,3–5]. The infiltration of the superior sagittal sinus and the large veins draining the cerebral hemispheres and directing the blood into the superior sagittal sinus impede the safe and complete removal of the tumour. The high risk of damage to the cerebral venous system, when making an attempt to perform radical resection, results in the high percentage of cases of incomplete removal of the tumour and consequently, in some studies this group of meningiomas is described as the one having the highest percentage of tumour re-growth [6,7]. On the other hand, the attempt of radical resection of the tumour increases the risk of damage to the cerebral venous system and severe neurological complications [2]. The optimal surgical strategy in the treatment of meningiomas invading the superior sagittal sinus is still the subject of debate.

The aim of the study is to retrospectively evaluate the results of the treatment of parasagittal and falcine meningiomas invading the superior sagittal sinus with particular emphasis on the surgical complications and the risk of tumour recurrence, depending on the adopted management.

2. Material and methods

In the years 1991–2010, at our centre, 152 patients with a diagnosis of parasagittal and falcine meningiomas underwent surgery. 37 cases were diagnosed with the tumour invading the superior sagittal sinus and the above patients were analysed. The diagnosis of meningioma was based on the result of the histopathological examination. Table 1 shows the characteristics of meningiomas in the study group.

Table 1 – Location of tumours, tumour size, type of sinus invasion and tumour histology.

Parameter		No. of patients (%)
Location of tumours	Parasagittal	29 (78)
	Falcine	8 (22)
Location of tumours according to portion of sinus invaded	Anterior	11 (30)
	Middle	21 (57)
	Posterior	5 (13)
Tumour size	<3 cm	4 (11)
	3–5 cm	23 (62)
	>5 cm	10 (27)
Type of sinus invasion according to Sindou and Alwernia classification scheme	Type II	11 (30)
	Type III	11 (30)
	Type IV	6 (16)
	Type V	3 (8)
	Type VI	6 (16)
Tumour histology	Meningioma, WHO Grade I	33 (89)
	Meningioma, WHO Grade II	3 (8)
	Meningioma, WHO Grade III	1 (3)

The characteristics of the tumour growth were based on the analysis of the pre-operative brain magnetic resonance imaging (MRI) and the intraoperative findings. There were 29 parasagittal meningiomas and 8 patients had falcine meningioma with bilateral growth overgrowing both blades of the falx; 21 meningiomas were located in the middle part of the superior sagittal sinus. The radiological diagnostics in all cases included MRI. Digital subtraction angiography (DSA) and magnetic resonance angiography (MRA) were performed in order to evaluate the patency of the superior sagittal sinus (DSA in 31 patients, MRA in 6 patients). The results of DSA and MRA in 9 cases showed occlusion of the superior sagittal sinus and in 28 patients the sagittal sinus was patent in varying degrees. A degree of the superior sagittal sinus invasion was evaluated according to the Sindou and Alwernia classification scheme [8] based on the brain MRI, the vascular examinations (DSA and MRA) and the intraoperative findings.

Table 2 presents the patient characteristics. The patient age ranged from 19 to 73 years (mean 47 years). The study group consisted of 27 women and 10 men. Epileptic seizures and limb paresis were usually the first symptoms of the disease.

The management depended on the preference of a surgeon. 13 patients underwent resection of the superior sagittal sinus together with the tumour: the superior sagittal sinus was ligated at the proximal and distal ends of the involved sinus and then cut. In seven of above cases the flow through the superior sagittal sinus was still preserved, in 6 patients the superior sagittal sinus was completely obliterated by the tumour. In 14 cases, meningioma was excised from the lumen of the superior sagittal sinus with subsequent sinus reconstruction. In 10 patients, the part of the tumour was left in the invaded superior sagittal sinus.

The scope of resection was evaluated based on the intraoperative observation and the result of brain MRI imaging (made 3 months after the operation). The condition of the patients was assessed at discharge from the clinic and during the long-term follow-up (conducted in the hospital or outpatient clinic) based on the neurological examination and the MRI imaging studies. The postoperative outcome was analysed using the Karnofsky Performance Status (KPS) to measure the degree of disability [9]. The postoperative

Table 2 – Demographic data and first signs of tumour in studied patients.

Parameter		No. of patients (%)
Age	<40	8 (22)
	40–65	26 (70)
	>65	3 (8)
Sex	Women	27 (73)
	Men	10 (27)
First sign	Headache	3 (8)
	Limb weakness	11 (30)
	Epileptic seizures	14 (38)
	Visual disturbance	6 (16)
	Cognitive disturbance	3 (8)

follow-up period ranged from 24 months to 19 years (mean 7.3 years), with the follow-up data obtained in 33 out of 34 discharged patients (97%).

3. Results

3.1. *Intraoperative and immediate perioperative complications depending on the extent of resection of the tumour invading the superior sagittal sinus are shown in Table 3*

The haemodynamic complications most often occurred in the cases of resection including the part of the invaded superior sagittal sinus, although in most cases, the cutting of the fragment of the superior sagittal sinus was performed within 1/3 anterior part of the sinus. Four patients had postoperative cerebral infarction with a venous origin, three manifested extensive brain swelling, and two patients developed postoperative intracranial hypotension (the hypoperfusion syndrome). Of the four patients with cerebral venous infarction two patients died (in these patients invaded but still patent 1/3 anterior portion of the sinus was resected without venous flow reconstruction), and one had serious permanent neurological deterioration. In one of three patients with brain swelling (in this case the tumour had been removed through resection of completely obliterated middle portion of the superior sagittal sinus) the patient was discharged with severe neurological deficit. All of the patients with intracranial hypotension syndrome recovered with a few days of intravenous fluid therapy and patients positioning ''flat'' use.

When the superior sagittal sinus was entered during tumour resection and subsequently reconstructed two patients developed postoperative venous infarction, one intraoperative air embolism (following which the patient died) and in three cases there were focal neurological deficits resulting from the surgical manipulations around the motor strip. The highest risk of the treatment was associated with the operation of meningiomas located in the middle 1/3 portion of the sinus.

The occurrence of venous infarction caused neurologic deterioration, in both cases: one patient had transient neurological deterioration and a slight permanent postoperative neurological deficit, while the other was discharged with deep hemiparesis. Of three patients with postoperative focal deficits associated with the surgical manipulation around the motor strip, one patient suffered from permanent slight paralysis of the distal part of the lower limb, but the patient moves smoothly and is independent. The cases of focal deficits related to the surgical manipulation around the motor strip and the cases of deficits resulting from the cerebral haemodynamic disorders after surgery were differentiated on the basis of the postoperative brain CT images and the clinical outcome observed in the postoperative period.

In the cases of tumour resection leaving tumour invasion in the superior sagittal sinus, 2 patients manifested transient postoperative hemiparesis associated with the operation in the vicinity of the motor cortex. Apart from that, the other patients had the uneventful postoperative course.

3.2. *Results stratified according to the extent of resection of the tumour invading the superior sagittal sinus are shown in Table 4*

Among 13 patients with the tumour removed through complete resection of invaded superior sagittal sinus unsatisfactory results (KPS score < 70) were achieved in nearly 1/3 of patients, mortality was 15%, and very good outcome (KPS score 90–100) was found in 40% of patients. Better outcome was seen in cases of the superior sagittal sinus invasion removed with subsequent sinus reconstruction (7% mortality, 70% of very good outcome). All 10 patients when tumour invading the sinus was left in place had KPS scores of at least 80.

3.3. *Postoperative radiotherapy.*

In cases of radical tumour resection postoperative radiotherapy we used to apply due to the presence of atypical or anaplastic meningioma, and in cases of the tumour invasion of the cranial vault bones (Table 5). In the cases of tumour resection together with a part of the infiltrated superior sagittal sinus, in two patients postoperative conformal radiotherapy was applied. In one case, the histopathological examination revealed the presence of atypical meningioma, while in the second patient radiotherapy was used because the tumour infiltrated the cranial vault bones, in spite of displaying the mild histopathological image (meningioma meningotheliale).

In the group of patients who underwent the removal of the tumour from the superior sagittal sinus, in one case postoperative conformal radiation therapy was applied because of the diagnosis of anaplastic meningioma.

After resection of the tumour, which left meningioma invasion in the superior sagittal sinus, postoperative conformal radiotherapy was applied in 2 cases due to the presence of atypical meningioma and in 1 patient because of benign meningioma with the invasive growth. The other 7 patients were observed using serial MRI imaging.

3.4. *Recurrence rate*

Tumour recurrence was noted in 6 patients (Table 5). Median time to recurrence was 3.8 years. The re-growth of the tumour on the verge of the already resected superior sagittal sinus was observed in one patient. In the case of anaplastic meningioma removed from the superior sagittal sinus, in spite of the use of early post-operative radiotherapy, there was the further tumour growth and after a year the patient died. In the group of patients who had meningioma infiltration left in the superior sagittal sinus in four cases the tumour progressed. Among 6 patients who had been treated with postoperative radiotherapy further one atypical and one anaplastic meningioma recurred. Of the 6 patients with tumour recurrence 4 had undergone surgery followed by radiotherapy. Due to the severe deterioration of the general and neurological condition two patients were not eligible for the further treatment. In the follow-up four patients died because of further tumour progression.

Table 3 – Incidence of operative complications according to the type of sinus invasion and the surgical strategy used.

Extent of tumour resection	Location of tumour along sinus	Type of sinus invasion[a]		Haemodynamic complications				Intraoperative air embolism	Surgical manipulation deficit
		Patent sinus	Complete sinus occlusion	Venous infarction	Brain oedema	Hypoperfusion syndrome	Intracranial haematoma		
Tumour resection including the part of invaded sinus (13 patients)	Anterior	7 (Type III) – 6 (Type IV) – 1	–	2	1	1	–	–	–
		–	2 (Type VI)	1	1	–	–	–	–
	Middle	–	2 (Type V)	1	1	–	–	–	–
	Posterior	–	2 (Type V) – 1 (Type VI) – 1	–	–	1	–	–	–
Tumour resection with subsequent sinus reconstruction (14 patients)	Anterior	2 (Type II) – 1 (Type III) – 1	–	–	–	–	1	–	–
	Middle	10 (Type II) – 8 (Type III) – 2	–	2	–	–	-	1	3
	Posterior	2 (II)	–	–	–	–	–	–	–
Tumour invasion left in sinus(10 patients)	Anterior	-	–	–	–	–	–	–	–
	Middle	6 (Type III) – 1 (Type IV) – 5	–	–	–	–	–	–	2
		–	2 (Type VI)	–	–	–	–	–	–
	Posterior	–	1 (Type VI)	–	–	–	–	–	–
		1 (Type III)	–	–	–	–	–	–	–

[a] According to Sindou and Alwernia classification.

Table 4 – Postoperative KPS[a] scores according to the surgical strategy used.

Extent of tumour resection	Location of tumour according to portion of sinus involved	Outcome (according to KPS scale)			
		90–100	80	40–70	0
Tumour resection including the part of invaded sinus (13 patients)	Anterior	5	2	–	2
	Middle	–	–	2	–
	Posterior	1	1	–	–
Tumour resection with subsequent sinus reconstruction (14 patients)	Anterior	2	–	–	–
	Middle	6	2	1	1
	Posterior	2	–	–	–
Tumour invasion left in sinus (10 patients)	Anterior	–	–	–	–
	Middle	6	2	–	–
	Posterior	2	-	–	–

[a] KPS = Karnofsky Performance Status.

Table 5 – Radiotherapy efficacy.

Extent of tumour resection	Postoperative radiotherapy	Recurrence
Tumour resection including the part of invaded sinus (13 patients)	1 Meningioma WHO Grade II	1 Meningioma WHO Grade I with no postoperative radiotherapy
	1 Meningioma WHO Grade I with invasive growth	
Tumour resection with subsequent sinus reconstruction (14 patients)	1 Meningioma WHO Grade III	1 Meningioma WHO Grade III after postoperative radiotherapy
Tumour invasion left in sinus (10 patients)	2 Meningioma WHO Grade II	1 Meningioma WHO Grade II after postoperative radiotherapy
	1 Meningioma WHO Grade I with invasive growth	3 Meningioma WHO Grade I with no postoperative radiotherapy

4. Discussion

The surgical treatment of parasagittal and falcine meningiomas is associated with the risk of cerebral haemodynamic complications. The tendency of meningiomas of this location to invade the superior sagittal sinus and encase or adhere to the large veins significantly hinders the ability to safely and completely removes the tumour. The risk of damage to the cerebral venous circulation system during the attempt of radical resection causes that meningioma invasion of the superior sagittal sinus is considered by some authors as a contraindication to the complete removal of the tumour [4,10]. Hence, in some studies, this group has the highest recurrence rate among all meningiomas [6,7]. On the other hand, the attempts of radical resection of the tumour performed in order to reduce the risk of recurrence have the increased risk of damage to the cerebral venous system and a consequence of severe neurological complications and the patient's death due to cerebral venous infarction [2]. This makes it necessary to develop tactics for the surgical treatment of parasagittal and falcine meningiomas invading the superior sagittal sinus, which would eliminate the clinical signs of the disease and in the best possible manner control the growth of the tumour and prevent deterioration of the patient's neurological status after the treatment. The main issues in the parasagittal and falcine meningioma surgery are the consequences of damage to the venous circulation within the superior sagittal sinus and its inflows. The bridging veins entering the superior sagittal sinus may be damaged when the associated tumour (encasing or closely adjacent) is removed. Sacrifice of a bridging vein promotes thrombosis within the injured vessel by causing focal venous engorgement and decreased vascular flow that encourages venous stasis [11,12]. The involvement of the large draining veins in thrombosis causes congestion of the brain and the development of venous infarction. Damage to the bridging veins could also promote venous sinus thrombosis, especially in the 1/3 frontal area of the superior sagittal sinus. Thrombosis occurs when the blood flow into the superior sagittal sinus decreases, because apart from the damaged bridging vein, there are no other large draining veins in this region of the superior sagittal sinus [13]. The ease of forming venous thrombosis in patients with intracranial meningiomas also arises from their ability to secrete tissue thromboplastin and its clinical consequences [14]. Another important issue is the role of venous collateral circulation under the circumstances of the superior sagittal sinus obliterated by the tumour [15]. When meningiomas invade the superior sagittal sinus which is still patent the collateral circulation is gradually formed. When the patency of the sinus is still preserved, collateral circulation may be inefficient and the closing of the sinus may lead to venous infarction. It is necessary to perform

the pre-operative evaluation of the collateral circulation using digital subtraction angiography (DSA). The following features prove the existence of collateral circulation: (1) nonvisualization of a segment of the superior sagittal sinus, (2) the cortical veins do not reach the superior sagittal sinus, (3) delayed emptying of veins in the region of obstruction, (4) the reversal of the blood flow in the collateral veins connecting the sinus with the other venous outflow channels [16]. The collateral venous circulation includes: (1) anastomoses between cortical veins and deep ventricular and cisternal veins, (2) end-to-end anastomoses of superficial cortical veins, (3) anastomoses with meningeal veins, (4) anastomoses with scalp veins [17,18].

The main aim of the treatment of parasagittal and falcine meningiomas is the control of the tumour growth with maintaining the good neurological condition. On the one hand, the therapeutic strategy can be based on the pursuit of radical tumour resection with reconstruction of the superior sagittal sinus and its inflows [4]. Using such management Sindou [8] reported the recurrence rate of only 4% (half of the cases were meningiomas of a higher grade), 3% mortality and 8% of the significant permanent neurological deterioration. A second strategy consists of partial resection while awaiting for sinus occlusion by residual tumour and promotion the development of collateral venous outflow [19]. However, the adoption of this method of treatment may be misleading as to secure the control of the tumour growth, which can progress along the course of the sinus and thus preserve its patency for a long time. Also, the complete occlusion of the superior sagittal sinus does not ensure the safety of tumour resection. It is assumed that gradual sinus obliteration secondary to tumour growth leads to the development of venous collateral circulation [18,20,21] and therefore the resection of the tumour obstructing the superior sagittal sinus is safe and does not require reconstruction of the sinus. However, the failure of the collateral circulation may be difficult to avoid, because it is formed in the dura matter at the planned opening surgical sites [20]. Based on the analysis of the material coming from 100 patients with meningiomas invading the major venous sinuses, Sindou [8] reports that all deaths and 5 out of 8 cases of the severe neurological complications occurred after resection of the tumour infiltrating the superior sagittal sinus without reconstruction of the venous system. The complications included swelling of the brain and the symptoms of venous infarction.

Our experience indicates that the aggressive treatment of the tumour invading the superior sagittal sinus is associated with a high risk of serious neurological complications, especially when the sinus demonstrated patency and was ligated and resected with tumour. The risk exists despite the use of such a treatment modality only for meningiomas located within the anterior 1/3 part of the superior sagittal sinus.

In the alternate approach (used by our centre presently) as much tumour as possible is removed, while major cortical veins are preserved and tumour remnants that significantly involve the sinus are left. In this approach, the residual tumour can be treated with radiosurgery to reduce the risk of tumour recurrence [13]. Sughrue et al. [22] propose that when the sinus invasion is minor and there is no need for sinus reconstruction the tumour should be removed using microsurgical dissection, with homeostasis obtained using Gelfoam, fibrin glue and Weck clips. In cases of more significant sinus invasion the tumour was subtotally resected, the exposed attachments coagulated, and the remnant tumour left in the sinus for observation; early postoperative stereotactic radiosurgery was used only in some cases. There was no difference in rates of tumour control for patients who received subtotal resection for a WHO Grade I tumour, followed by close observation, compared with those undergoing gross-total resection. Using the above tactics resulted in only one case of venous infarction and one case of cerebral oedema (out of 135 patients). Many authors regard as safe and recommend the resection of the involved portion of the superior sagittal sinus [13,22,23]. In patients with complete obliteration of the sinus Di Meco et al. [23] recommend total resection of the portion of sinus involved and preservation cortical veins that offer important collateral venous drainage. When there is patency, they perform as radical resection as possible following by a close observation and use of early postoperative radiosurgery only in the cases of meningiomas of a higher grade or the recurrence of the tumour remnants; also other authors recommend this approach [13]. However, in the case of the resection of the superior sagittal sinus obstructed by the tumour, he reported the cases of brain swelling, but none of them led to the permanent severe neurological deficits or death. Our observations confirm the safe postoperative course of the method based on the leaving of tumour invasion in the superior sagittal sinus; however, the high recurrence rate of this procedure inclines us to recommend the use of early postoperative stereotactic radiosurgery (gamma knife, LINAC).

5. Conclusions

1. The radical resection of parasagittal and falcine meningioma and invaded portion of the sinus poses a high risk of the haemodynamic complications. At the same time, the risk of recurrence of the tumour is very low.
2. It seems that the current possibilities of using stereotactic radiosurgery may help to control the fragment of the tumour deliberately left in the superior sagittal sinus and thus reduce the risk of postoperative complications.

Conflict of interest

None declared.

Acknowledgement and financial support

None declared.

Ethics

The work described in this article has been carried out in accordance with The Code of Ethics of the World Medical Association (Declaration of Helsinki) for experiments involving

humans; EU Directive 2010/63/EU for animal experiments; Uniform Requirements for manuscripts submitted to Biomedical journals.

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