

Microsurgical Treatment of Meningiomas Invading the Sagittal or Transverse Sinuses

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OBJECTIVE To analyze our management strategy and results of treating patients affected by meningiomas invading the sagittal or transverse sinuses.

METHODS Review of data from 35 patients with pathologically confirmed meningiomas (29 of the sagittal sinus and 6 of the transverse sinus) surgically treated between from July 1999 and June 2003, including clinical manifestations, mode of diagnosis and curative effect of microsurgery etc. For our surgical decision-making, meningiomas were classified into six types based on the degree of sinus involvement.

RESULTS A Simpson's Grade I resection was achieved in 27 cases (77.1%), Grade II in 6 (17.1%) and Grade III in 2 (5.7%). No patients died after the operations. The recurrence rate in the study overall was 2.9%, with a follow-up period from 3 to 6 years.

CONCLUSION Application of microsurgical techniques, protection of the sinus, avoidance of damages to the cerebral cortex, veins of the central sulcus, as well as other veins from the tumor, are the major factors for increasing the rate of total resection, reducing complications and improving the quality of life for the patients with meningiomas invading the sagittal or transverse sinuses.

KEYWORDS: sagittal sinus, transverse sinuses, meningioma, microsurgery.

INTRODUCTION

In meningiomas involving the major dural venous sinuses (superior sagittal sinus, transverse sinus, torcular), the treatment is problematic. If total removal is accomplished in these types of meningiomas, and venous sinuses and afferent veins cannot be spared, catastrophic complications may occur^[1-3]. Complete data from 35 patients with meningiomas invading the sagittal or transverse sinuses were analyzed. These patients received their first treatment during the period from July 1999 to June 2003, and comprised 35.3% of the total inpatients with meningioma in our hospital during the same period.

MATERIALS AND METHODS

Clinical data

There were 35 patients in our study, 14 males and 21 females, with ages ranging from 11 to 72, and a mean age of 51.4±4.3. The longest course was 15 years, and the shortest 14 days, averaging 3.4 years.

Clinical manifestations included symptoms such as headache, nausea and vomiting as well as optic disc edema in 18 cases,

epilepsy in 13, dyskinesia of lateral movement in 8, anandia in 2, lateral sensory disturbance in 6 and disturbance of urination and defecation in 1.

Neuroradiologic examination

A cephalic MRI plain scan and intensified examination were conducted for all the cases, among which craniocerebral CT was performed in 19 cases. Six cases showed changes such as hyperostosis and destruction of bone by cerebral X-ray examinations. A left-side tumor was found in 19 cases and a right-sided tumor in 16. In the 29 patients of the parasagittal meningioma, the tumors at the anterior third of the SSS could be seen in 9, those at the middle one third in 14, and in the posterior one third, 6. The diameter of the tumors ranged from 2.4 to 9.8 cm, averaging 5.17 ± 1.75 cm. A magnetic resonance venography (MRV) examination was conducted in 6 cases, and DSA brain angiography in 9, showing a double blood supply for the internal and external carotid artery. Tumor staining was seen in most cases, and there was an angiectasis and thickening in the scalp, then a circuitry leading to the tumor site in 2 cases. After understanding the blood supply of the tumor, embolization of the afferent arteries was performed in 3 cases, with a complete obstruction of the anterior one third of the sinus cavity in 2 cases and partial obstruction of the postmedian one third of the cavity in 3. In the circumferential zone of most of the tumors, there were a compensated venous circuitry and reticulation after an end-to-end anastomosis, with recirculation into the superior sagittal sinus, sphenoparietal sinus and transverse sinus, respectively.

Treatment

A conventional frontal, frontoparietal or parietooccipital craniotomy was performed, with both the incision and bone flap overpassing the median line providing sufficient exposure of the superior sagittal sinus. There was a lateral exposure of 2 cm beyond the tumor edge for autogeneic repair of the dura mater. Tumor encroachment upon the cranial bone may result in osteoclasia or abnormal cranioaural thickening, e.g. one case with a cranioaural thickening of 2.4 cm in this study. Adhesion among the inferior part of the skull, the dura mater and the tumor occurred from time to time. After a careful dissociation of the bone flap by grinding, if it was difficult to pry the bone flap, a careful separation was conducted in order to avoid a hemorrhage resulting from prying the bone flap by force.

A microsurgical technique was employed in all the endocranial operations. Cerebral dura mater was cut open at 0.5 to 1 cm away from the tumor margin,

with sufficient protection of the veins from the tumor using a process of keeping the vein connected. First, an intracapsular subtotal resection was conducted, allowing a temporary residue of a little tumor tissue clinging to the sinus wall. After excision of the tumor, careful peeling was conducted microscopically to finally achieve the total resection. At the same time, a prosthetic treatment of the affected sinus wall was conducted.

For decision-making, meningiomas were classified into six types according to the degree of sinus invasion^[4] as follows: Type I, lesion attachment to the outer surface of the sinus wall; Type II, tumor fragment inside the lateral recess; Type III, invasion of the ipsilateral wall; Type IV, invasion of the lateral wall and roof of the sinus; and Types V and VI, complete sinus occlusion with or without one wall free, respectively.

Lesions with Type I invasion were treated by peeling the outer layer of the sinus wall and coagulation of the dural attachment. As coagulation of sinus and venous surface is conducted by fulguration, more attention must be paid to turning down the dipole power to sustain cooling. In cases of sinus invasion Types II to VI, two strategies were used: a nonreconstructive (the sinus wall is thoroughly dissected together) and a reconstructive one (suture, patch, or bypass). Dissection of the affected sinus was conducted in 8 cases, with a meningioma at the anterior one third of the SSS, in this group, without ill results and achieving the excision of a modified Simpson's 0 grade. Treatment of 10 cases with Type-II meningioma at the retral two thirds of the SSS or transverse sinuses was performed, with a direct suture of the sinus wall after resection of the lateral recess. The sinus wall was incised at a site 2 mm away from the tumor, and the tumor in the lateral recess was taken out together with the lump intruding into the sinus. Tip-curved blood vessel forceps or temporary arterial blocking clips were used for a parallel occlusion along the course of the sinus, then with an immediate suturing of the incised part. The sinus wall was cut off by a length ranging from 1 to 2 mm each time, with a step by step procedure until completion of the mending. Intraoperative procedure in combination with a controlling of the hypotension is the best way to reduce bleeding.

Appraisalment of the effect of the sinus wall excision on the venous return is needed during the surgical operation on Type-III and IV meningiomas. The excision or vascular anastomosis reconstruction should be cautiously conducted, if there are comparatively large draining veins in the affected sinus wall. If there are no large veins, resection and mending of the affected sinus wall can be conducted, while an attempt should be made to preserve the uninjured

sinus wall. Autologous dura mater, a cerebral falx, fascia temporalis or artificial patch were employed for the repair, and the absorption line was used for a continuous suture. Muscle and EC glue were used for hemostasis in hemorrhaging part. Sinus wall repair was applied in 6 cases with Type-III and 3 cases with the Type IV meningiomas, among 2 of these cases an anastomosis was constructed using a venous blood vessel.

Concerning treatment of the Type-IV and V meningiomas, rough information on obstruction in the SSS was available after a preoperative DSA or MRV examination, but an intra-operative reevaluation was still needed. A discussion for a sinus exploration of the Type-V meningioma was performed. If a healthy sinus wall existed on one side, the management would refer to the treatment method of Type-IV meningioma patients, and management for those without a normal sinus would be referred for therapy of Type-VI meningioma patients.

Concerning management of the Type-VI meningioma patients, the SSS was provisionally occluded by a temporary obstruction clip along the excisional SSS extremity, with an observation ranging from 15 to 20 min. The diseased SSS would be excised if there was no apparent engorgement of the superficial veins and cerebral swelling. Otherwise, it showed that partial functions still existed in this section of the SSS. After a total resection, vasotransplantation was needed for reconstruction of the SSS. Both broken ends of the sagittal sinus were taken away from the outflow of the cerebral superior anastomotic vein. In transfixion of the broken ends, excessive cauterization should be avoided in order to not produce a thrombogenesis that would influence the front and the rear compensated recirculation in the cerebral superior anastomotic vein. Resection of the affected SSS, with no reconstruction, was conducted in one case with the Type-V and two with the Type-VI meningioma in our group.

As the vein of central sulcus (Rolandic vein) was adhered with the tumor, microscissors must be used to microscopically cut out the arachnoid along the vein, and then to carefully dissociate the vein. After complete dissociation, the vein was protected with a cotton piece. The tumor then was dissected in order to minimize the gross tumor volume, allowing the veins of central sulcus to become flaccid from a stretched state, thus reducing the tension on this vein. In general, as a tension-free separation of the paraneoplastic envelope which has adhered to the Rolandic vein is conducted, the Rolandic vein will not be damaged, achieving a satisfactory protection of the vein. The Rolandic vein, suspended on the residual cavity after the tumor resection, easily develops a post-operative

thrombus owing to a stretch by gravity, however, it can be avoided by a gelatin-sponge tamponade for support of the residual cavity. Allowing for a low long-term patency rate in reconstruction of the Rolandic vein, a lamellar tumor had to be left in place in two cases due to special difficulty in separating the tumor away from the Rolandic vein.

The cerebral dura mater and cerebral falx thickened by tumor invasion should be excised together, so as to reach the modified Simpson's 0 grade. Repair of the dura mater with considerable defects was conducted using autogenous periosteum, femoral fascia or artificial dura mater. Those with a slight cranioaural involvement underwent a removal of the affected internal plate using brain forceps. Otherwise, bone flap decompression and titanium plate fixation were performed for primary repair of the skull.

Gamma-knife stereotactic radiotherapy was performed at three months after a resection of malignant Type-III meningioma in one case.

Follow-up

Follow-up visits were conducted until October 2006, with a follow-up period from 40 to 74 months (mean 54.6 years) and a follow-up rate of 94.3%.

RESULTS

Surgical outcome

According to the modified Simpson's grading system^[5], there were 9 cases of the Grade-0 resection, with a total resection of the tumor, attached cerebral dura mater (cerebral falx) and a dura mater with dural tail sign of over 2 cm, comprising 25.7% of the total; 20 cases of the Grade-I resection, with a total resection of the tumor, attached cerebral dura mater and cerebral falx, comprising 57.1%; 4 of Grade-II resection, reaching 11.4% and, 2 Grade-III resection cases, both of which were the remnant lamellar tumors at surface of the Rolandic vein, without coagulation, accounting for 5.7% of the total cases. Two cases with preoperative hemiplasia failed to achieve a complete recovery though there was a slight post-operative improvement. Eight patients with preoperative normal activity presented an early post-operative progressive hemiplasia or aggravation of a previously relieved hemiplasia symptom. Most of the patients returned to normal after hydration and hormone therapy, and only one still suffered unilateral paralysis of the upper extremities one month after operation.

Pathological diagnosis of the meningiomas included 11 meningothelial, 10 fibrous, 5 angiomatous, 5 psammomatous, 3 mixed type and 1 malignant meningioma.

Follow-up

One patient with unilateral paralysis of the upper extremities one month after operation returned to partial unilateral paralysis following a 6-month follow-up. Three cases with post-operative epilepsy received anti-epileptic treatment for a period ranging from 1 to 2 years. Reexamination with CT or MRI was performed half a year after operation, and at a 1 or 2-year interval between the reexaminations from then on. One patient died of a myocardial infarction 4 years after operation, and another one who suffered a recurrence 3 and a half years after surgical operation received γ -knife stereotactic radiotherapy. No tumor relapse was found in the rest of the patients, of which 32 went back to normal work.

DISCUSSION

Diagnosis and preoperative preparation

Parasagittal meningioma ranks second among the meningiomas, meningioma invading the transverse sinuses is rare^[1-4]. The focal symptoms related to the nervous system usually are absent in early parasagittal meningioma. With growth of the gross tumor volume, epilepsy and headache as well as focal localization signs (or positive focal signs) gradually occur. CT and MRI examinations can be used for identifying the site and size of the tumor, and especially, enhanced MRI can clarify the scope of the rat-tail sign, so as to instruct the scope of a modified Simpson's 0 grade resection. Digital subtraction angiography (DSA) of the brain has been regarded as the gold standard for judging a smooth blood supply, an unobstructive sagittal sinus and collateral circulation, while a brain MRA has advantages of being free of trauma, is relatively inexpensive, and is more convenient to employ clinically. Over the past few years, up-to-date technologies, such as magnetic resonance veinography (MRV) and magnetic resonance digital subtraction angiography (MRDSA) etc., have provided an institutional and reliable bases for clinical schedules and surgical treatment plans, which still have the value of further studies and applications^[6].

Since these tumors present with an abundant blood supply, oncothlipsis and invasion on the sagittal sinus resulting in partial or complete obstruction of the SSS, a compensatory venous return system is slowly formed, with a manifestation of abnormally thickened ramus anastomoticus between the cortical vein and adjacent superficial vein, and between the deep cerebral ventricle and cisternal vein, and even a venous return to the external jugular vein system via meningeal veins and diploic veins. Therefore, in the cases

with a complete obstruction in the sagittal sinus, careful protection of these compensatory thickened veins from the tumor should be made at operation, and an attention is even to be paid when planning an incision of the scalp and treating the cerebral dura mater because these compensatory veins play an important role in balancing the cerebral blood circulation. If these vital bypasses first are blocked-up during the operation, it will bring about an uncontrollable intra-operative hemorrhage or an intra- and post-operative brain edema^[2,7].

Microsurgical experience in resection of the tumor

Careful procedures for protection of the peripheral brain tissues should be conducted, based on the principles for tumor resection, i.e., the extra-sinus part of the tumor first, and then the antral-wall or intra-sinus tumor. Attention should be paid to protect the peripheral brain tissues. An intra-tumor Cavitron ultrasonic aspiration (CUSA) or fine brain tumor forceps should first be used for a separate dissection of the tumor with a large volume. After an apparent decrease of the intra-tumoral tension, a complete separation was conducted, along the space between the tumor wall and arachnoid, to take out the tumor envelope. The intra-tumoral and extratumoral procedures were repeated until exposure of the basilar part for cutting off the total blood supply. Then a parasinoidal separation continued, accompanied by a concurrent coagulation for hemostasis, along the cerebral falx, thus completely excising the tumor or extra-sinus part of the tumor envelope.

Autogeneic cerebral dura mater is the first choice of the materials for repairing the SSS, because of its firm and tenacious character, easy suturing and homologous tissue, and with convenience in sampling in the same operating field. Usually the normal dura mater beyond the operating field was used as the tissue, owing to adjacent arachnoid granulations at a space 1.5 cm by the sinus, a coarse inner surface and in the vicinity of the tumor. The materials for rebuilding the SSS include autogeneic veins, most of which are taken from the radial artery, vascular prosthesis and especially, the great saphenous vein which can provide the lateral branch for anastomosing the Rolandic vein etc. Although the long-term patency rate of these anastomoses is low, the progressive obliteration wins invaluable time for setting up the compensatory circulation^[8].

Numerous of the so-called "unpredictable" post-operative complications are likely to be related to the lack of prevention or non-recognition of venous problems, especially damage to the dangerous venous

structures such as the Rolandic vein and the large paraneoplastic draining vein. Therefore, to avoid injury in the area, to carefully preserve all the veins as much as we can, especially the Rolandic vein, are the keys for reducing post-operative brain swelling, severe intracranial hypertension and hemiparesis. These intra-operatively exposed and stimulated cortical veins easily develop a venous thrombosis, therefore, a moderate intra-operative and post-operative fluid expansion, cautious application of the hemostats and administration of post-operative low-molecular weight heparin are necessary to avoid formation of a thrombosis.

Tumors invading the superior sagittal sinus leave the surgeon confronted with a dilemma: leave the fragment invading the sinus and have a higher risk of recurrence, or attempt at total removal with or without venous reconstruction and expose the patient to a potentially greater operative danger. Sindou et al.^[2-4] point out that failure of a radical excision is the major cause of the recurrence following a surgical operation for meningioma, and the histological typing and grading of tumors are only a secondary cause or even is unrelated, thus stressing that reconstruction should only be conducted in a favourable condition, including a complete occlusion of the antral cavity. Schmid-Elsaessert et al.^[9] were opposed to waiting for a second-stage operation following a thorough occlusion of the SSS, and suggested that a radical excision would be impossible because the vital adjacent bridging veins had been invaded by the tumor, after a final complete occlusion of the sinus cavity. Also a tumor recurrence might occur, and occlusion of the sinus cavity did not happen after several operations. They suggested that a radical excision could be conducted concurrently with a reconstruction of the venous sinuses, without postoperative radiotherapy. Reports on crippling and death were relatively increased, though active surgical procedures may decrease the recurrence rate^[2-4,8,9].

With development of stereotactic radiosurgery, a safer therapeutic means is available for treating tumor residues. Caroli et al.^[10] reported on 328 patients with meningiomas that had infiltrated the superior sagittal sinus. They suggested that the risks of aggressive surgery, with sinus reconstruction, may be avoided, and conservative surgery for meningiomas that are infiltrating but not obliterating the superior sagittal sinus may be a reasonable choice. For instance, there was tight adhesion between the Rolandic vein and the meningioma in 2 cases of our group, with difficult separation. In order to avoid a venous thrombosis evoked by electric coagulation, coagulation was not applied for the lamellar tumor remaining on the vessel wall,

with only a Simpson's Grade III resection. However, one of the 2 cases had suffered post-operative monoplegia and was rehabilitated half a year later. So, we hold that if there is a close adhesion between the tumor and central veins, it is advisable for the surgeons not to dissect the tumor by force during the operation, but to leave a little of the tumor tissue or tumorous envelope. Coagulation of the tumor adhering to the wall of the central veins should be performed with special caution.

Prevention of a recurrence

To strive for a total resection of the tumor is an ideal goal to prevent a post-operative recurrence of the meningioma, and if possible, the tumor should be resected with the invaded tissues. Special attention must be paid to the possibility of failure of total resection, obvious paraneoplastic edema and malignant meningioma etc. The measures for clearing the residual lesion, including post-operative follow-up, regular imaging reexamination and stereotactic radiotherapy, ought to be used more, in order to improve the therapeutic effect, and to avoid or at least delay the recurrence of the tumor.

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