Venous Reconstruction in Surgery of Meningiomas Invading the Sagittal and Transverse Sinuses

Abstract—Surgery of meningiomas involving major dural sinuses leaves the surgeon confronted with a difficult dilemma: leave the fragment invading the sinus in place and have a higher risk of recurrence, or attempt a total removal with or without venous reconstruction and expose the patient to a potentially greater operative danger. The authors report a series of 47 meningiomas (41 of the sagittal sinus, 4 of the transverse sinus and 2 of the torcular) in whom gross total removal was achieved in all cases, and venous reconstruction (of various types) attempted in a majority. Thirty-nine patients had a good outcome and resumed their previous activities. There was a permanent neurological deficit in five due to infarction secondary to injury of central veins (all in the sagittal sinus midthird). Three patients died from brain swelling; all with meningioma totally occluding the sinus and in whom resection was achieved without sinus reconstruction. There were two recurrences in this series which has a mean follow-up of 7.5 years.

The authors' surgical experience led them to favor whenever possible, total removal with sinus reconstruction, using a patch for meningiomas with partial sinus invasion and a venous bypass for those with total sinus occlusion.

Postoperative propensity of meningiomas to recur is linked to the extent of surgical resection. Total removal of the tumor is more likely to achieve a cure than subtotal removal, regardless of the histological type. Therefore complete surgical resection is the optimal treatment.

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.

That is why two main typical approaches have traditionally been advocated when dealing with these meningiomas. Some authors consider invasion of the sinuses as a deterrent to complete removal; in their opinion the sinuses are to be respected in spite of a higher risk of recurrence. Other authors have adopted a more aggressive

approach advocating total removal and venous reconstruction to restore the venous drainage.^{1-5,10} The latter is our standpoint.⁷⁻⁹

MATERIAL AND METHODS

Out of a total personal series of 230 meningiomas operated on by the senior author, 47 involved the major dural venous sinuses, 41; the superior sagittal sinus, 4 the transverse sinus and 2 the torcular region. Age ranged from 15 to 79 years (mean 57 years) (Table 1).

The diagnosis of meningioma was done on CT scan and/or MRI images. All patients had a four-vessel selective angiography through the transfemoral route, with arterial phases to study the feeders, capillary phases to

Table 1. Clinical Results According to Location of Meningiomas

<i>Topography of Meningioma (NB Cases)</i>	<i>Clinical Results</i>		
	<i>Cure</i>	<i>Morbidity</i>	<i>Death</i>
SSS Anterior Third 17	16	0	1
SSS Middle Third 16	11	5*	0
SSS Posterior Third 8	7	0	1
Torcular 2	2	0	0
Transverse sinus 4	3	0	1
<i>Total 47</i>	39	5	3 [†]
100%	83%	10.6%	6.4%

*Four deficits were due to lesion of rolandic veins and one to cerebral hemorrhagic infarct.

[†]The three patients who died had a complete resection of the totally invaded portion of the sinus with no venous reconstruction (see Table 2).

evaluate the vascularization of the tumor, and venous phases to demonstrate the involvement of the sinus(es) and the development of collateral circulation.

The degree of invasion of the sinus was defined according to the following classification (Fig. 1), which is simplified from Merrem-Krause⁶ and Bonnal-Brotchi¹. According to this classification, there were nine type I, two type II, eight type III, ten type IV, and 18 type V or VI.

All tumors but six underwent a gross total removal. The six in whom a fragment was left, had the residual tumor (which was always less than 1 cc in volume) intensively coagulated.

The surgical procedure used on the dural venous system depended on the variety of the sinus involvement (Fig. 2). Surgery consisted of :

- Resection of outer dural layer and coagulation of dural attachment in nine cases;
- Resection of intraluminal fragment and repair of dural defect by suture in two cases;
- Resection of involved wall and sinus repair with patch (dura-mater, fascia temporalis, pericranium, fascia-lata) in nine cases, (illustration in Figs. 4, 5, and 6); and

- Bypass in 15 cases, with Gore-Tex in six and autologous vein graft in nine (illustration in Fig. 7);
- Coagulation of residual fragment in 6 cases; and
- Global resection of involved portion of sinus without any venous reconstruction in six cases.

RESULTS

Clinical Results (Table 1)

Thirty-nine patients (83%) had a good postoperative outcome with previous daily activity resumed.

Three patients died in the postoperative period (6.4%) from edema and venous infarction. One had meningioma in the anterior third, another one in the posterior third, the third one in the transverse sinus. All were of type V-VI and did not have sinus reconstruction.

Five patients had a neurological deficit aggravated after surgery due to infarction secondary to injury of the central rolandic veins. All had their meningioma in the midthird; three were of type III, one of type IV, and one of type V-VI. Complications according to surgical technique are summarized in Table 2.

Table 2. Complications According to Surgical Technique

<i>Patients</i>	<i>Surgical Technique</i>	<i>Morbidity</i>	<i>Death</i>	<i>Total</i>
9	Peeling of external layer	0	0	0%
2	Resection of intraluminal fragment in lateral recess + suture	0	0	0%
9	Resection of invaded wall + patch	0	0	0%
9	Bypass with autologous vein	2/9	0	22%
6	Bypass with Gore-Tex	1/6	0	16%
6	Coagulation of residual fragment	2/6	0	33%
6	Global resection of invaded portion of the sinus without reconstruction	0	3/6	50%

Figure 1. Classification of meningiomas according to the degree of dural venous sinus involvement. Type I: meningioma attached to outer surface of the sinus wall; Type II: lateral recess invaded; Type III: entire lateral wall and roof of the sinus both invaded; Type IV: lateral wall invaded; Types V and VI: sinus totally occluded, one wall being free of tumor in type V. This classification is a simplified one from Krause and Merrem⁶ and Bonnal and Brothchi¹ ones.

Follow-up ranged from 1 to 14 years (mean 8.5 years). Recurrence rate was 4.3%. The two patients who had a recurrence, did not have the contralateral aspect of the sinus explored. Reoperation achieved a successful removal without any complication or neurological aggravation.

Angiographic Results

Angiographic control by arteriography was performed after 2 weeks follow-up. Out of the nine patches performed, six were angiographically controlled. Five were patent. All six bypasses made with Gore-Tex thrombosed (one of which with acute and severe but reversible intracranial hypertension). Of the nine bypasses with autologous vein, seven were angiographically controlled af-

ter two weeks; four were patent; and three thrombosed without having produced any clinical symptoms.

DISCUSSION

Our surgical experience in meningiomas involving the major dural sinuses leads us to advocate total removal of the tumor whenever possible. This resulted in our series in a relatively low recurrence rate (4.3%). One can be sure of the absence of intrasinus fragment of tumor only if opening the dural sinus and carefully exploring its lumen. Then the sinus has to be reconstructed and venous circulation restored.

Indications for Dural Sinus Reconstruction

Venous reconstruction should be performed, in our opinion, whenever possible, even if the sinus is occluded by the tumor. In a significant number of cases, the occluded portion of the sinus cannot be resected safely because of the frequent necessity to sacrifice the collateral venous pathways encountered on the surgical approach, as illustrated in Figure 3. In our series, the three patients who died after surgery had a complete occlusion of the sinus prior to operation and did not benefit from sinus reconstruction.

Patches can be performed using locally harvested dura-mater or fascia. Bypasses must consist of autologous vein (saphenous or external jugular vein) and not of prosthesis. In our series the six cases who had a Gore-Tex bypass, thrombosed within the first week.

Immediate patency essentially depends on the driving pressure within the dural venous system. This was obvious in our observations.

Absence of long-term patency does not necessarily mean that venous reconstruction was not useful. Progressive occlusion of the venous repair would have given time for compensatory venous pathways to develop. In our series, only the sudden occlusion of a bypass performed with a Gore-Tex prosthesis was followed by a neurological aggravation. It was due to acute intracranial pressure which, although severe, was totally reversible after 2 month intensive care therapies.

We recommend the following procedures according to the type of meningioma:

- Type I: excision of outer layer, leaving a clean and glistening dural surface, and coagulation of dural attachment;
- Type II: removal of intraluminal fragment and repair of dural defect with patch (Fig. 4);
- Type III: resection of sinus wall and repair by patch (Fig. 5 and 6);
- Type IV: repair by patch or bypass with saphenous or external jugular vein;

Operative procedures performed according to the grade of the meningiomas. total : 47 cases

Figure 2. Operative procedures performed in the series (47 cases).

- Type V-VI: removal of involved portion of sinus and restoration by venous bypass. The site of the bypass is on the sagittal sinus for meningiomas involving the sagittal sinus, between the SS and the external jugular vein for meningiomas totally oc-

cluding the torcular (Fig. 7), between the TS and the external jugular vein for meningiomas involving the TS.

Of paramount importance is the fact that in any case, strategy decisions should be reevaluated during the surgical procedure. One should be ready to stop the operation if brain swelling occurs after having turned the bone and the dural flaps, which means that significant venous collateral channels have been impaired, after the resection of the tumor mass or its volumetric reduction, which means that anastomotic cortical veins have been compromised. The operation has to be completed later on after brain swelling disappears.

Technical Principles for Reconstruction

Surgery of meningiomas invading the dural venous sinuses and their surgical repair are greatly facilitated when the following technical aspects are respected.

The semi-sitting (lounging) position allows a good venous return, without increased intracranial pressure. Air embolism although possible, is not a frequent risk because of the relatively high level of the intracranial venous pressure in these patients. The problem can be avoided or safely controlled in experienced surgical hands.

Figure 3. Venous MRI. right parasagittal meningioma, totally occluding the posterior third of SSS (between arrows). The SSS is draining through intraosseous emissary veins which communicate with extracranial circulation (arrowhead).

Figure 4. Right parasagittal Grade II meningioma. Midthird of SSS. A: Preoperative coronal MRI.T1- sequence after Gadolinium. B: Preoperative carotid angiography. Venous phase. Lateral view. Meningioma (Star). C: Postoperative coronal MRI. T1 sequence. Bone flap extends across the midline. Total removal. D: Postoperative carotid angiography. Venous phase. Lateral view. SSS has been patched after removal of the invaded recess (Arrows) ; sinus patent.

Figure 5. Grade III parasagittal Meningioma. Midthird of SSS. A: Drawing before and after removal of extra and sinusal portions of meningioma. Sinus repaired using reflection of the falx. B: Postoperative carotid angiography. Venous phase. Lateral view. Patched portion of sinus (arrowhead) patent.

Figure 6. Meningioma of the torcular. A: Preoperative axial CT scan and AP venous phase of carotid injection. Defect at torcular level in the left transverse sinus (arrow) and total occlusion of the right transverse sinus. B: Postoperative examination. Total removal of meningioma along with venous restoration of left transverse sinus (arrow). Notice repermeation of right transverse sinus.

Figure 7. Grade VI parasagittal meningioma totally occluding the posterative third of the SSS. A: Preoperative external carotid angiography showing contribution of occipital branch to the tumor. B: Preoperative internal carotid angiography. Venous phase. Lateral view. Postoperative third of SSS is occluded (black arrow). An important collateral pathway (double open arrow) along the cerebral convexity toward the sigmoid sinus. C: Postoperative angiography. Venous phase. Oblique view. Cranial portion of the venous bypass (arrows) performed from SSS anteriorly to the meningioma, (which has been removed) to external jugular vein. D: Postoperative angiography. Venous phase. Oblique view. Cervical portion of the bypass followed throughout its entire course to join the external jugular vein.

The operative exposure should be as extensive as possible. Skin flap and craniotomy should extend across the midline to permit visualization of both sides of the sinus and some 3 cm outside the margins of the occluded sinus. However, such a large access should be reconsidered if there are scalp, pericranial and/or diploic collateral venous pathways, which may be impaired during the approach.

Because there are frequent discrepancies between images and anatomical findings, the sinus should be explored through a short incision to disclose any intrasinus fragment.

Temporary control of hemostasis is easily obtained by packing small pledgets of hemostatic material (Surgicel, Johnson and Johnson Medical, Viroflay, France) in the lumen and at the ostia of afferent veins. Balloons

should not be used because they do not pass easily through the sinus septa and may injure the sinus endothelium. Vascular clamps and aneurysm clips should be avoided as much as possible because they may injure the sinus walls and afferent veins.

Bridging veins, especially in the rolandic outflow area, should be preserved by dissecting them free from adjacent brain and tumor.

Venous reconstruction is performed using patches or bypasses, with two hemirunning sutures (Prolene 8.0, Laboratoire ETHNOR, Neuilly/Seine, France). Although the autologous vein would appear as the most suitable material for use as a patch, vein harvesting seems excessive for patching only. The locally situated dura-mater, fascia temporalis, and pericranium have a structure rigid enough for blood to flow inside and for use as patches. The graft should not be compressed by increased intracerebral pressure which reduces flow even further. To facilitate bypass patency after surgery, blood pressure, volume, and viscosity must be carefully monitored. Heparinotherapy (2 times control) is recommended for at least 21 days to avoid clotting the reconstructed sinus and to allow endothelialization of the sinus walls.

In conclusion, this paper advocates, total removal of meningiomas with venous restoration whenever possible not only in those meningiomas which partially invade the sinus and in whom the venous flow cannot be

interrupted, but also in those with total sinus occlusion to provide sufficient venous brain circulation.

REFERENCES

1. Bonnal J, Brotschi J. Surgery of the superior sagittal sinus in parasagittal meningiomas. *J Neurosurg* 1978;48:935-945
2. Bonnal J. La chirurgie conservatrice et réparatrice du sinus longitudinal supérieur. *Neurochirurgie* 1982;28:147-172
3. Hakuba A, Huh CW, Tsujikawa S, Nishimura S. Total removal of a parasagittal meningioma of the posterior third of the sagittal sinus and its repair by autologous vein graft. Case report. *J Neurosurg* 1979;51:379-382
4. Hakuba A. Reconstruction of dural sinus involved in meningioma. In: O. Al. Mefty, ed. *Meningiomas*. New York: Raven Press 1991:371-382
5. Hakuba A. *Surgery of the Intracranial Venous System*. Tokyo: Springer Verlag; 1996
6. Merrem G. Die parasagittalen meningeome. *Fedor KRAUSE-Gedächtnisvorlesung. Acta Neurochir* 1970;23:203-216
7. Sindou M, Mazoyer JF, Fischer G, Pialat J, Fourcade C. Experimental bypass for sagittal sinus repair. Preliminary report. *J Neurosurg* 1976;44:325-330
8. Sindou M, Mercier P, Bokor J, Brunon J. Bilateral thrombosis of the transverse sinuses: Microsurgical revascularization with venous bypass. *Surg Neurol* 1980;13:215-220
9. Sindou M, Hallacq P. Microsurgery of the venous system in meningiomas invading the major dural sinuses. In: *Surgery of the the Intracranial Venous System*. Hakuba A, ed. Tokyo: Springer Verlag; 1996:226-236
10. Steiger HJ, Reulin HJ, Huber P, Boll J. Radical resection of superior sagittal sinus meningioma with venous interposition graft and reimplantation of the rolandic veins. *Acta Neurochir* 1989;100:108-111