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# Venography and Venous Pressure Monitoring in Dural Sinus Meningiomas

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This study was undertaken to determine the impact of dural sinus venography and pressure measurements in the evaluation of patients with meningiomas involving the dural sinuses. Of three patients who had MR imaging, arteriography, and dural sinus venography, the latter method better delineated the site and extent of tumor invasion in all three patients. Pressure measurement in one patient reflected the severity of the hemodynamic compromise resulting from narrowing of the transverse sinus. In one patient, dural sinus venography confirmed patency of the superior sagittal sinus that was unsuspected on MR scans and arteriograms. A test occlusion of the area of stenosis in the third patient allowed the surgeon to sacrifice that segment of the sinus without deficit.

Dural sinus venography is a useful adjunct to arteriography and MR imaging in the evaluation of invasive meningiomas.

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Meningiomas are slow-growing tumors that arise from the dural lining of the brain. They may evolve as primary tumors inside a dural sinus or may invade the sinus as secondary growth [1, 2]. Complete surgical excision of the entire tumor is a desired goal to prevent tumor recurrence [2]. Resection en bloc of a functioning sinus can be associated with severe morbidity and mortality [3-5]. Traditionally, dural sinus invasion has been delineated by arterial [6] or digital venous [7-9] angiography. Recently, CT [10, 11] and MR [12-15] imaging have been reported useful in delineating dural sinus thrombosis. In this report we describe direct dural sinus venography (DSV) with test occlusion and pressure recording to more accurately assess the position of the tumor, the adequacy of venous collaterals, and the hemodynamic changes in three patients.

## Material and Methods

Three patients with meningiomas invading the intracranial dural sinuses were evaluated by MR imaging, digital arteriography, and DSV. One patient (case 1) had a recurrence after subtotal resection of a meningioma involving the superior sagittal sinus 6 years earlier. All patients underwent MR scanning in the axial, sagittal, and coronal planes with T1-weighted 600/20 (TR/TE), and T2-weighted, 2800/30, 80 sequences. The two patients (cases 2 and 3) with a meningioma involving the right transverse sinus had additional T1-weighted scans after administration of gadolinium (0.1 mmol/kg). In all three patients, digital subtraction angiography was performed after injecting the internal carotid, external carotid, and dominant vertebral arteries, as well as the invaded dural sinus. From a femoral vein access, a 7-French polyurethane catheter\* was navigated into the ipsilateral jugular vein. A systemic anticoagulant was given (5000 units heparin IV for a 70-kg patient) and a 3.2-French high-flow Tracker catheter† with a 0.016-in. platinum guidewire was placed coaxially through the 7-French catheter and was navigated through the sigmoid sinus and to the site of the invasion by the meningioma. Three milliliters of Omnipaque‡ 300 mg I/ml were hand injected over 2 sec through the Tracker catheter and a digital subtraction venogram was obtained in several

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\* Cook, Inc., Bloomington, IN.

† Target Therapeutics, San Jose, CA.

‡ Iohexol, Winthrop Pharmaceutical, New York, NY.

projections. In cases 1 and 3, venous pressure was recorded with a Datascope 200IA.<sup>5</sup> The venous pressures were recorded within the invaded segment of sinus in case 1 and just proximal and distal to the site of invasion in case 3. In case 2, a 0.25-in. guidewire was positioned across the area of stenosis and a 5-French Meditech<sup>†</sup> endhole balloon occlusion catheter was positioned at the stenosis. The balloon was inflated to produce complete occlusion and continuous neurologic monitoring was performed for 15 min. A venogram obtained with the balloon inflated confirmed complete occlusion. After these studies were made, the catheters were removed and the anticoagulation was reversed with IV protamine sulfate given slowly over 15 min (1 mg of protamine sulfate reverses approximately 100 units of circulating heparin).

## Representative Cases

### Case 1

A 66-year-old woman underwent partial resection of a meningioma involving the posterior third of the superior sagittal sinus 6 years prior to reevaluation. A follow-up MR scan (Fig. 1A) demonstrated tumor invasion of the posterior two thirds of the superior sagittal sinus and suggested tumor invasion and occlusion to the level of the torcula. Arteriography confirmed the occlusion and suggested thrombosis or tumor invasion to the level of the torcula (Fig. 1B). The surgeon was concerned that if the level of obstruction extended to the torcula, then en bloc resection would be complicated because of the proximity to the patent functioning transverse sinuses. Dural venograms (Figs. 1C and 1D) revealed tumor invasion and occlusion of the superior sagittal sinus, but the occlusion level was higher than demonstrated by MR imaging or arteriography. Venous pressure measurement in this segment was normal, distal to the obstruction. This knowledge of the slow venous drainage in a patent sinus altered the surgical treatment by allowing the surgeon to resect the occluded sinus while preserving the segment that still had antegrade flow. The patient then had radiotherapy for the remaining tumor.

### Case 2

A 37-year-old woman with headaches had MR imaging, which disclosed a tumor along the superior tentorium invading the right transverse sinus (Fig. 2A). Arteriography disclosed a filling defect in the right transverse sinus but, because of laminar flow, could not accurately assess the degree of stenosis and invasion (Fig. 2B). Dural sinography showed the spherical shape of the tumor (Fig. 2C). A test occlusion at the site of the tumor was performed and tolerated. This allowed subsequent surgical excision of the tumor and the involved dural sinus without deficit. A postoperative dural sinus venogram confirmed the complete occlusion of the right proximal transverse sinus.

### Case 3

A 66-year-old man with traumatic loss of vision in the right eye developed gradual visual loss in the left eye over several years, resulting in severe visual loss. The fundoscopic examination revealed papilledema. MR imaging with gadolinium revealed an enhancing mass invading the right proximal transverse sinus (Fig. 3A). Four-vessel arteriography revealed a hypoplastic left transverse sinus and a smooth extrinsic narrowing of the proximal right transverse sinus

(Fig. 3B). An external carotid injection revealed a dural-based hyper-vascular tumor suggestive of a meningioma. There was disagreement as to the significance and severity of the stenosis among consulting services, with some postulating the origin of the papilledema as secondary to pseudotumor cerebri and the tumor to be an incidental, unrelated finding. Therefore, a dural sinogram was performed to reveal the degree of stenosis and to measure any associated hemodynamic changes. This study revealed the compression and invasion of the right sinus (Fig. 3C). Pressure measurement proximal to the stenosis was 35–40 mm Hg (markedly elevated) and 2–3 mm Hg distally (normal), which confirmed the severe hemodynamic compromise secondary to the stenosis. It was thought that with this degree of hemodynamic stenosis in the dominant sinus that a test occlusion would not be tolerated and therefore was not performed. On the basis of these two studies, surgical resection of the right transverse sinus was not considered safe and the patient was referred for radiation therapy.

## Discussion

Dural sinus obstruction can result from a wide number of disorders, including trauma [12], hypercoagulable states [17], tumors [1–5, 18], dural fistulas, and inflammatory processes [19]. Abrupt occlusion of the superior sagittal sinus or the dominant transverse and sigmoid sinus is rarely tolerated without severe clinical sequelae. Meningiomas, however, with their slow growth, can invade and gradually occlude a major venous sinus, often with minimal or no symptoms [5]. If total sinus occlusion occurs as a result of tumor invasion, then adequate venous collaterals may develop, and tumor and sinus can often be excised without fear of venous infarction, providing the adjacent veins are not disturbed [5]. If, however, the sinus is invaded but still patent, the risk of sinus occlusion can be high, especially in the posterior two thirds of the superior longitudinal sinus or a dominant transverse or sigmoid sinus [3]. Adequate cortical collaterals can develop through scalp veins [20] or cortical venous collaterals to venous sinuses distal to the obstruction [21]. Patients who do not have adequate venous collaterals can develop neurologic deficits, elevated intracranial pressure, papilledema, visual loss, and dementia [22–24]. The definitive treatment of meningiomas involves neurosurgical excision, and total excision is a desired goal. Important considerations for the neurosurgeon are the location of the tumor, whether invasion of the sinus has occurred, and whether the sinus is occluded. Most of these clinical questions can be answered by employing noninvasive techniques such as CT scanning or MR imaging, particularly with the use of gadolinium. The meningiomas in our series were all visualized on standard MR images. In the two patients (cases 2 and 3) in whom gadolinium was administered IV, intense enhancement of the tumor was observed. Because of slow venous flow in the adjacent venous dural sinus, enhancement also occurred in slowly flowing blood, making discrimination of the tumor margins difficult. Slowly flowing or turbulent blood may produce a confusing signal that may be misinterpreted as thrombus or complete occlusion of a dural sinus. Recent MR techniques have been reported that reduce the artifacts associated with flowing blood [25, 26] and should greatly improve the evaluation of flow in the dural sinuses.

<sup>5</sup>Datascope Corp., Paramus, N.J.

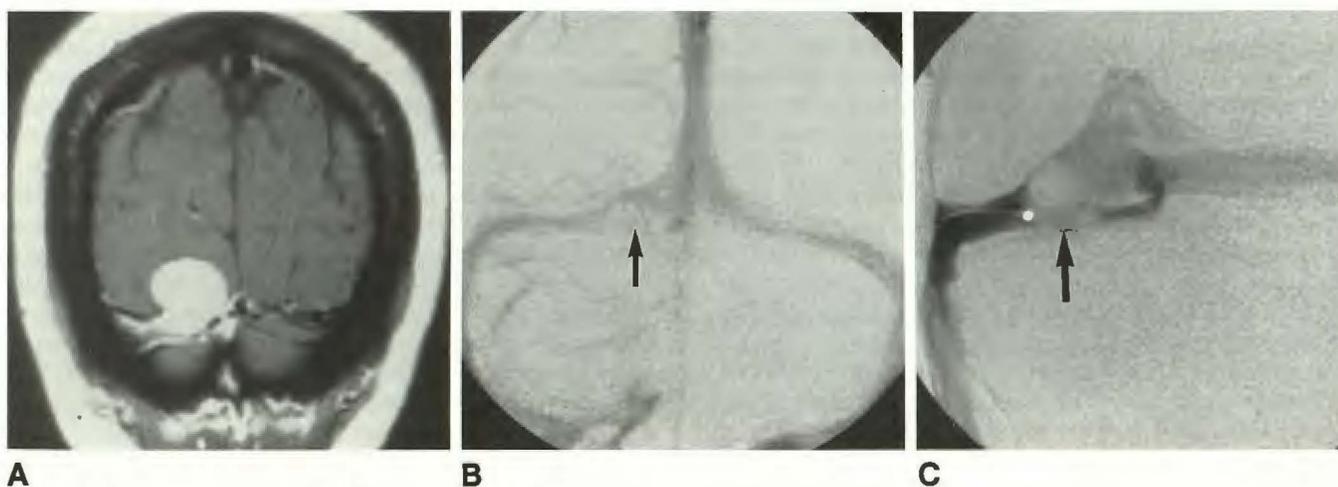
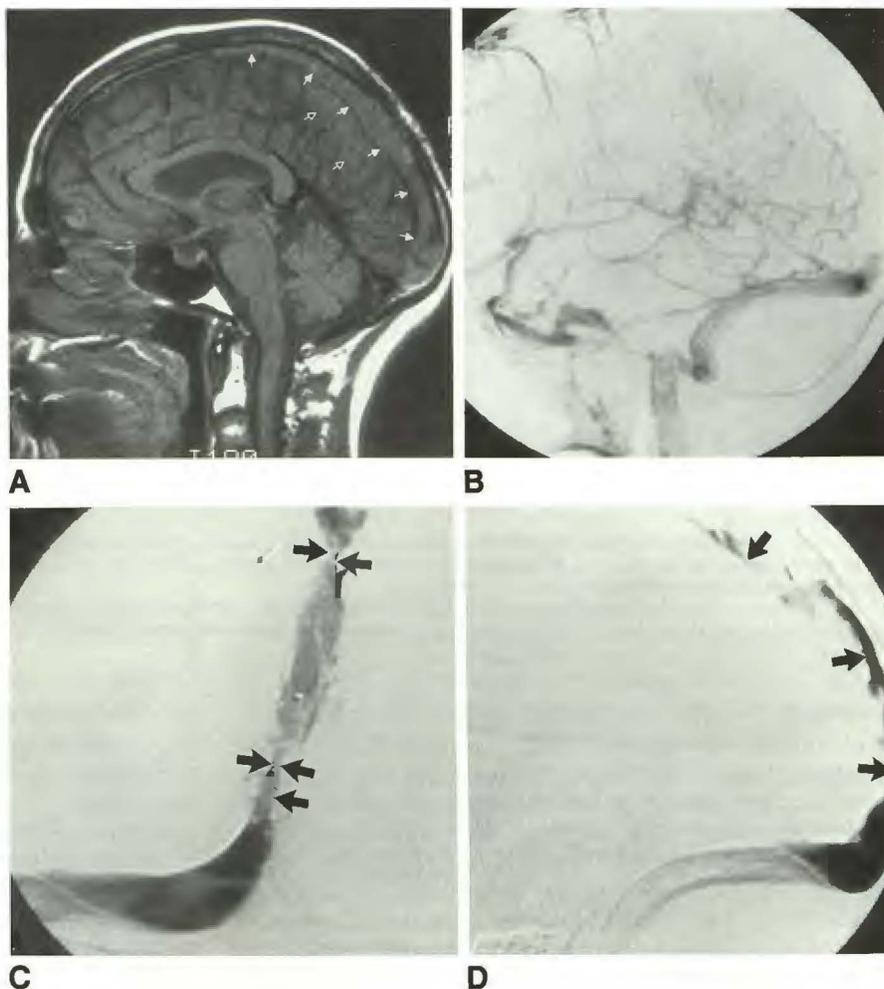
<sup>†</sup>Meditech, Watertown, MA.

**Fig. 1.—Case 1.**

**A,** Sagittal midline T1-weighted image (600/20) demonstrates tumor (closed arrows) involving posterior two thirds of superior sagittal sinus and extension into interhemispheric fissure (open arrows).

**B,** Right internal carotid angiogram, lateral view, venous phase, suggests complete occlusion of posterior superior sagittal sinus.

**C and D,** Superior sagittal sinus venograms, anteroposterior (C) and lateral (D) projections, demonstrate tumor invasion (arrows) of posterior third but patency of this structure distally with slow venous flow.



**Fig. 2.—Case 2.**

**A,** Coronal T1-weighted image (600/20) with Gd enhancement shows involvement at right transverse sinus.

**B,** Right internal carotid angiogram, Towne's projection, venous phase, shows a filling defect (arrow) involving right transverse sinus.

**C,** Transverse sinus venogram, right anterior oblique projection, shows spherical filling defect within transverse sinus. A test occlusion was performed and tolerated at site of arrow.

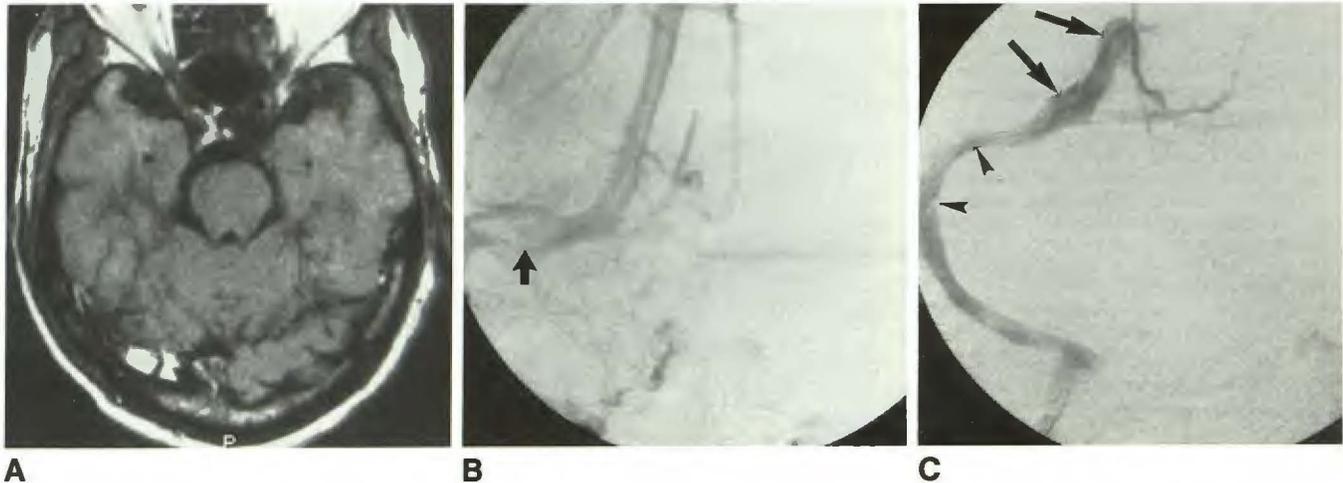


Fig. 3.—Case 3.

A, Axial T1-weighted image (600/20) with Gd enhancement shows enhancing tumor invading right transverse sinus.

B, Right internal carotid injection, anteroposterior projection, venous phase, demonstrates a narrowing of right proximal transverse sinus (arrow) and hypoplastic left transverse sinus.

C, Transverse sinus venogram, Towne's projection, delineates tumor invasion. Pressure recordings made by catheter in superior sagittal sinus and proximal transverse sinus (arrows) showed >35 mm of mercury. Pressure measurement distal to tumor (arrowheads) was <5 mm of mercury.

In case 1 both four-vessel arteriography with cross compression and spin-echo MR imaging suggested that tumor invasion extended to the level of the torcula, and that there was complete absence of flow in this segment of the sinus. Direct dural sinography confirmed the tumor invasion but demonstrated patency of this structure and persistent slow venous flow. This information markedly altered the surgeon's approach, as the procedure for an invaded but patent sinus is different from that for a totally occluded sinus. Traditionally, patients with invaded but patent sinuses require internal shunts during surgical resection [27] and repair of the sinus involved with tumor [28–33] rather than total sinus excision. In the transverse and sigmoid sinuses, complete sinus occlusion can be tolerated if the contralateral sinus is adequate to drain the diverted blood. By performing a test occlusion of the segment anticipated to undergo surgical excision, we were able to confirm in case 2 that the contralateral sinuses were adequate. While test occlusion of the internal jugular vein or jugular bulb distal to the meningioma is technically easier than occlusion at the site of the tumor, it is not as physiologic and predictive, because of added potential venous collaterals present distal to the obstruction.

In case 3, the patient's clinical syndrome of severe visual loss, papilledema, and increased intracranial pressure could have been a result of the tumor narrowing the proximal right transverse sinus, but it could also have been a result of idiopathic pseudotumor cerebri. As a diagnostic tool to differentiate between these two diseases, sinography with pressure measurements was performed, which revealed the hemodynamic severity of the stenosis.

Systemic anticoagulation was utilized in all three patients to prevent thrombus formation. Placing even the small Tracker catheter across a severe stenosis could induce thrombosis; therefore, anticoagulation is essential. One potential complication could be the dislodgment of fragments of the tumor,

which could metastasize to the lungs. Although uncommon in occurrence, spontaneous metastasis of an intradural meningioma to the lungs has been reported [34]. To minimize this potential risk, only soft-tipped catheters and guidewires were used to cross the site of tumor invasion.

Another potential concern could be the inadvertent passage of the guidewire or catheter system into a small draining vein, increasing the risk of venous rupture and resultant subdural or subarachnoid hemorrhage. To reduce this risk, arterial injections can be performed with roadmapping of the venous sinus. The soft guidewires and catheters can then be navigated upon the frozen image to the desired site. We have used dural venography in 25 other patients prior to transvenous embolization of their dural fistulas with excellent results [35, 36].

Jugular venography has been used for over two decades for the evaluation of invasive tumors at the skull base [37, 38]. Additional information can be obtained by utilizing venous pressure measurements. Although venous pressure has been measured in the superior sagittal sinus, both indirectly and directly [39, 40] by the use of surgically placed transducers and indwelling catheters, DSV is less invasive and, in addition, permits measurements at multiple locations. Venous pressure measurements were not obtained in case 2 because we were unsure at that time of the reliability of pressure measurements through a small microcatheter. Subsequently, Duckwiler et al. [41] have presented data confirming the reproducibility and accuracy of pressure measurements through a high-flow Tracker catheter in an animal model and in humans.

At present we recommend DSV in patients with poorly delineated tumor invasion on CT or MR scans or arteriograms. Pressure measurements can provide additional information on the severity of the stenosis. When sacrifice of the sinus is anticipated at surgery, a test occlusion at the stenosis can be a useful predictor of tolerance. When total sinus occlusion is

suspected by CT or MR imaging or arteriography, DSV can confirm the presence and location of the obstruction. In conclusion, dural sinography with test occlusion and pressure measurements can be a useful adjunct in the evaluation of invasive meningiomas.

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