Direct packing of the isolated sinus in patients with dural arteriovenous fistulas of the transverse–sigmoid sinus

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Object. The goal of this study was to evaluate the efficacy of direct packing of the isolated sinus (occluded both distally and proximally) in patients with dural arteriovenous fistulas (AVFs) of the transverse–sigmoid sinus.

Methods. Eight patients were included in this study. There were seven men and one woman, ranging in age from 47 to 75 years (mean 60.4 years). Five patients presented with intracranial hemorrhage or venous infarction, one with convulsions, and two with pulsatile tinnitus. Prominent retrograde cortical venous drainage due to sinus occlusion was angiographically demonstrated in all patients. All patients were treated by a small craniotomy and direct sinus packing with microcoils; the procedure was performed with the aid of digital subtraction angiography. Five patients were pretreated with transarterial embolization to reduce arterial inflow before the procedure, and intrasinus pressure and sinus blood gases were monitored throughout the operation. Postsurgery, the dural AVF was completely obliterated in all patients. The sinus pressure was 29 to 58% of systemic blood pressure, and sinus blood gas levels were purely arterial before packing. There was no morbidity related to direct sinus packing; however, one patient died as a result of acute myocardial infarction. Over a follow-up period ranging from 1 to 5 years, a faint asymptomatic dural AVF recurred in one patient on the cortex adjacent to the occluded sinus but regressed spontaneously within 1 year.

Conclusions. Direct sinus packing was found to be highly effective for the treatment of dural AVFs that empties into the isolated sinus. Measurement of changes in sinus pressure and sinus blood gas levels was useful for monitoring the progress of direct sinus packing.

KEY WORDS • dural arteriovenous fistula • sinus thrombosis • transvenous embolization

The cause of dural arteriovenous fistulas (AVFs) remains unknown; however, these lesions are known to be acquired and to behave aggressively depending on their pattern of venous drainage. Several recent classifications of this disease, based on venous draining patterns, have clarified which groups of patients are at high risk of intracranial hemorrhage. Drainage into leptomeningeal veins with occlusion of the affected sinus at proximal and distal sites is associated with a high risk of bleeding. In spite of recent advances in treatment modalities, including endovascular, microsurgical, and radiosurgical techniques, some patients with dural AVFs are still difficult to treat. Previously we described a successful radical treatment that was used in a patient with this type of “isolated” sinus whose multiple dural AVFs drained into the leptomeningeal veins. In the present paper, we report the results of combined endovascular and surgical treatment with direct dural sinus packing in eight consecutive patients who had dural AVFs that emptied into the isolated transverse–sigmoid sinus.

Clinical Material and Methods

A total of 21 patients with dural AVFs involving the transverse–sigmoid sinus have been treated at our institution since 1981. All of these patients underwent conventional angiography or digital subtraction angiography (DSA) to categorize the lesion. In eight of the patients, occlusion of the affected sinus at both proximal and distal sites (isolated sinus) and prominent retrograde cortical venous drainage were detected on the angioram. Seven of the eight patients were men; they ranged in age from 47 to 75 years (mean 60.4 years). Four patients presented with supratentorial subcortical hemorrhage or hemorrhagic infarction, one with cerebellar infarction, one with generalized convulsions, and two with pulsatile tinnitus and vascular bruit in the retromastoid region. In seven of the eight patients, addition of a contrast agent prior to obtaining computerized tomography (CT) and magnetic resonance (MR) images revealed many enhanced vessels around the cerebral cortex, which were assumed to be dilated cortical veins. The lesion was on the right side in four patients and on the left side in the other four. The superior sagittal sinus, torcular herophili, and contralateral transverse–sigmoid sinus were demonstrated to be angiographically intact in six patients. The venous drainage route in the ipsilateral cerebral hemisphere in these six patients included the superior sagittal sinus, straight sinus, and/or superficial middle cerebral veins. The dural AVF in the other two patients drained into the torcular herophili and ipsilat-
eral transverse–sigmoid sinus and was associated with thrombosis of the entire superior sagittal and contralateral transverse sinuses, resulting in severe intracranial venous retention in both of these patients, one of whom presented with multiple subcortical hematomas and progressive dementia and the other with cerebellar infarction.

All eight patients were treated with direct sinus packing as soon as possible (Table 1). Five of them were pretreated with transarterial embolization in which glue or platinum coils were used to reduce arterial inflow. At the operation, a landmark for the involved transverse sinus was drawn on the patient’s scalp by using an intraoperative portable DSA device. After anesthesia had been induced in the patients (general anesthesia in seven patients and local anesthesia in one patient who had chronic heart disease and renal failure), the scalp was incised linearly (5 cm) along the landmark and a small craniotomy (4 × 2 cm) was performed. A microcatheter was placed in the involved sinus by direct puncture of the dural sinus wall. Sinography was carefully performed by using a very slow injection of contrast medium so that we could observe sites of occlusion of the isolated sinus and orifices of cortical veins. The sinus was then packed with Interlocking Detachable Coils (IDCs; Target-CMI, Inc., Tokyo, Japan) or free coils with the aid of fluoroscopy and a road-mapping technique. Sinus pressure and sinus blood gas levels were monitored coaxially by means of the microcatheter. Digital subtraction angiography with transforaminal or transbrachial catheterization was performed several times as control angiography during direct sinus packing. After tightly packing the sinus with coils, oxidized cellulose was used to fill in the small dead space that remained beneath the site where the dural wall had been penetrated. The patients’ clinical symptoms were followed postoperatively and angiography was repeated in some patients who consented to it.

**Results**

Five patients underwent nine sessions of transarterial embolization of external carotid branches, which markedly reduced the size of the arteriovenous shunt without any complications. Four patients were not pretreated by transarterial embolization because there were few feeding arteries (usually one or two external carotid branches) and the shunt flow was considered unlikely to impede surgery. Complete obliteration of the dural AVF was verified immediately after completion of direct sinus packing by means of intraoperative DSA in all patients. Sinus pressure and sinus blood levels were monitored in five patients. The initial mean sinus pressure was 29 to 58% of the mean systemic blood pressure in four patients who had been pretreated by transarterial embolization and 53% in one patient who had not. In all five patients, the sinus pressure decreased gradually during packing and finally reached 0 mm Hg when obliteration of the sinus was demonstrated on the control DSA. The initial sinus blood gas levels were equivalent to those of pure arterial blood and approached levels of venous blood at the end of packing.

Angioanatomical results were excellent for all patients. Dural AVFs that emptied into the isolated sinus disappeared completely, and no retrograde cortical venous drainage remained in any of the eight patients. In the two patients in whom thrombosis of the entire sagittal and contralateral transverse sinuses occurred, the dural AVFs were completely obliterated with marked improvement in the clinical symptoms. However, cerebral venous retention remained in both cases. Glasgow Outcome Scale scores for the eight patients at the time of discharge ranged from good recovery in four patients to mild disability in two, severe disability in one, and death in one patient. In the three patients who had a mild or severe disability, the neurological symptoms originated from the initial clinical conditions (one patient with cerebellar infarction, one with hemorrhagic infarction of the right temporal lobe, and a third with subcortical hematoma in the left parietal lobe). Treatment did not aggravate neurological deficits in any of these three patients. The complex dural AVF in one patient (Case 8) was successfully treated with five sessions of combined endovascular and surgical procedures, which resulted in a marked clinical improvement; however, this patient died of acute myocardial infarction 10 days after the last session.

The follow-up period for the other seven patients ranged from 1 to 5 years (mean 2.5 years). No patient has displayed new neurological symptoms or signs. One patient with a mild disability at discharge due to cerebellar ataxia has recovered to live a normal life with minimal symptoms. One patient with a severe disability at dis-

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**TABLE 1**

<table>
<thead>
<tr>
<th>Case No.</th>
<th>Age (yrs)</th>
<th>Sex</th>
<th>Clinical Presentation</th>
<th>No. of TAEs</th>
<th>Type of Anesthesia</th>
<th>Percent Sinus Pressure†</th>
<th>Sinus Blood Gases</th>
<th>AO (%)</th>
<th>GOS Score</th>
<th>Angio Follow Up</th>
<th>Clinical Follow Up</th>
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<td>5 yrs</td>
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<td>3 yrs</td>
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<td>GR</td>
<td>1 yr; cure</td>
<td>3 yrs</td>
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<td>D‡</td>
<td>—</td>
<td>10 days</td>
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* Angio = angiographic; AO = angioanatomical obliteration; D = death; GOS = Glasgow Outcome Scale; GR = good recovery; ICH = intracerebral hemorrhage; MD = mild disability; SD = severe disability; TAE = transarterial embolization; — = test not given.
† Mean sinus pressure/mean systemic blood pressure.
‡ Due to acute myocardial infarction.
Direct sinus packing for dural AVF

Fig. 1. Case 2. Left: Right carotid angiogram obtained before treatment. Note the isolated transverse–sigmoid sinus and retrograde cortical drainage into the vein of Labbé. Center: Cranial radiograph obtained after direct sinus packing demonstrating coils in the affected sinus. Right: Right carotid angiogram obtained 17 days posttreatment revealing obliteration of the dural AVF.

charge has recovered to live an independent life. Repeated angiography was performed in five patients (Cases 1, 3, 4, 6, and 7) 4 months to 1 year after direct sinus packing. Complete angioanatomical cures were verified in four (Cases 1, 3, 6, and 7) of these five patients. A faint dural AVF recurred in one patient (Case 4) in the cortex adjacent to the primary sinus lesion 3 months after treatment. This patient remained asymptomatic and follow-up angiography performed 1 year later revealed spontaneous regression of this lesion.

Illustrative Cases

Case 2

History. This 70-year-old man presented with rapidly progressive dementia and left-sided homonymous hemianopsia. Computerized tomography scanning demonstrated an irregular high-density mass surrounded by a diffuse irregular low-density area in the right temporal white matter. Angiographic studies revealed a dural AVF that was fed by the right occipital artery and drained into the ipsilateral transverse–sigmoid sinus with retrograde drainage into the vein of Labbé (Fig. 1). The involved sinus was isolated by occlusion at both proximal and distal sites. This patient’s physical condition was complicated by both chronic heart and renal failure. Direct sinus packing after induction of local anesthesia was selected as the primary treatment. Linear scalp incision and a small craniotomy were performed over the involved transverse sinus. The patient’s initial mean sinus pressure was 45 mm Hg (53% of the mean systemic blood pressure). The isolated sinus was packed with 29 free platinum microcoils and oxidized cellulose. The feeding occipital artery was compressed manually to avoid bleeding during the procedure. The dural AVF was completely obliterated, and the patient’s neurological condition improved slightly after direct sinus packing.

Case 4

History. This 57-year-old man was admitted to our hospital with the complaint of left pulsatile tinnitus. He displayed no neurological symptoms or signs; however, a vascular bruit was noted in the retromastoid region. Angiography revealed a dural AVF that emptied into the isolated left transverse sinus with prominent retrograde cortical venous drainage. The patient was pretreated by transarterial embolization in which polyvinyl acetate and microcoils were used; this resulted in 90% obliteration of the lesion (Fig. 2). Ten days after the transarterial embolization, general anesthesia was induced in the patient and direct sinus packing was performed. After a small craniotomy was made, a microcatheter was placed in the involved transverse sinus. The patient’s initial mean sinus pressure was 32% of the mean systemic blood pressure and his initial sinus blood gas levels appeared to be purely arterial. With the aid of fluoroscopy and the road-mapping technique, IDCs were used to pack the sinus. Sinus blood gas levels approached those of venous blood gas levels during the packing procedure. Sinus pressure also decreased gradually with packing and was almost 0 mm Hg after placement of 15 IDCs in the sinus, when transbrachial DSA demonstrated complete angioanatomical cure (Fig. 3). The patient’s postoperative course was uneventful, and the tinnitus disappeared completely. Follow-up angiography performed 3 months after treatment revealed a new faint but asymptomatic dural AVF that drained directly into the leptomeningeal vein adjacent to the primary sinus lesion, which remained obliterated. The patient remained asymptomatic; an angiogram obtained 1 year later this new small lesion was found to have regressed spontaneously.

Case 8

History. This 63-year-old man presented with multiple right frontal and left parietal subcortical hematomas and progressive dementia. Angiography demonstrated a dural AVF that involved the right transverse–sigmoid sinus and torcular herophili associated with thrombosis of the entire superior sagittal and contralateral transverse sinuses. The bilateral superficial temporal and occipital arteries formed another dural AVF at the midline over the thrombosed
superior sagittal sinus with pure leptomeningeal drainage into a bridging vein of the right parietal cortex. These complicated lesions not only caused vigorous retrograde filling of both cortical and deep veins but, in addition, severe venous retention throughout the brain (Fig. 4). Three sessions of transarterial embolization were performed to diminish the size of the arteriovenous shunt; after induction of general anesthesia, direct sinus packing was performed. The patient’s initial mean sinus pressure was 58% of the mean systemic blood pressure, despite the several transarterial embolization sessions. His initial sinus blood gas levels were purely arterial. The direct sinus packing successfully occluded the dural AVF that involved the transverse–sigmoid sinus and torcular herophili (Fig. 5), and the patient’s clinical condition recovered dramatically after treatment. The midline dural AVF that drained only into the bridging vein, which had been considered to be at high risk, was treated with surgical interruption of the feeding vessels at the entrance to the skull. Venous drainage routes from the brain included the bilateral sphenoparietal sinuses, emissary veins, and a patent left sigmoid sinus. The patient’s clinical and neurological status was excellent until he died of acute myocardial infarction 10 days after the final treatment. An autopsy was not permitted.

Discussion

Occlusive Sinus Lesions

Dural AVFs account for approximately 12% of intracranial AVFs and are considered to be acquired lesions. Most involve the transverse–sigmoid and cavernous sinuses, and they are sometimes associated with sinus thrombosis. There has been controversy concerning the interpretation of this sinus thrombosis. Since the report by Houser, et al., sinus thrombosis has come to be widely accepted as a cause of dural AVFs, although the precise histopathological evidence has not been well shown. On the other hand, it has been reported that sinus thrombosis results in spontaneous regression of dural AVFs; in this situation, sinus thrombosis has been considered a cause of spontaneous regression. Based on the results of histopathological evaluation of resected specimens, we previously reported that possible mechanisms of secondary sinus thrombosis included intimal thickening, interruption or proliferation of the elastic lamina of the sinus, and repeated regional thrombus formation caused by tur-

![Fig. 2. Case 4. Angiograms. Upper: Early (left) and late (right) phases of left external carotid injection administered at admission demonstrating a dural AVF involving the isolated transverse sinus and prominent retrograde cortical drainage. Lower: Early (left) and late (right) phases of left external carotid injection after transarterial embolization. Note the marked decrease in arterial inflow.](image)

![Fig. 3. Case 4. Left: Cranial radiograph obtained after direct sinus packing showing the region of craniotomy and coils in the affected transverse sinus. Center and Right: Angiograms showing early arterial (center) and late arterial (right) phases of left carotid injection administered 7 days after direct sinus packing. Note the complete obliteration of the dural AVF and retrograde cortical drainage.](image)
bulent arterial influx. We therefore believe that sinus thrombosis may not only cause dural AVFs, but it may also cause their spontaneous regression.

**Angiographic Features**

The natural history and symptoms of intracranial dural AVFs vary significantly depending on the pattern of venous drainage. The most aggressive neurological course is thought to result from intracranial hemorrhage or venous ischemia caused by retrograde cortical drainage. Awad, et al., showed that leptomeningeal venous drainage, variceal or aneurysmal venous dilation, and galenic drainage were significant factors predisposing to this aggressive neurological course. Brown, et al., reported the results of a long-term follow-up study of 54 patients with dural AVFs and concluded that a draining varix was a significant predictor of intracranial hemorrhage. Lesions that drained into the leptomeningeal veins also had an increased incidence of hemorrhage, but this increased risk was not statistically significant in their study. In several reports, pure leptomeningeal drainage without involvement of the dural sinus appeared to increase the risk of bleeding. Sinus thrombosis is another factor that may potentially modify venous drainage. Ishii, et al., identified a subgroup of patients at high risk of hemorrhage and dementia due to severe venous overload resulting from occlusive changes of the transverse–sigmoid sinus.

Several classifications of dural AVFs based on venous restriction and draining patterns have been proposed. In their retrospective study, Lalwani, et al., classified dural AVFs into four grades based on venous restriction: the higher the grade, the higher the risk of central nervous system hemorrhage. Borden, et al., divided dural AVFs into three groups based on their drainage routes; the authors described a rationale for treatment based on their classification. Piton, et al., also classified dural AVFs into three types based on the relationship between the direction of flow in the drainage route and sinus thrombosis. They stated that this classification was significantly related to clinical manifestations and should result in a better therapeutic approach. The eight patients reported here had retrograde leptomeningeal drainage caused by the isolated sinus and were classified as having Lalwani’s Grade 4, Borden’s Type II, and Piton’s Type III disease. They should therefore have been considered high-risk patients. In fact, five of our eight patients presented with intracranial hemorrhage or venous infarction. We believe that therapeutic interventions were appropriate not only for these five patients but for the other three as well, who presented with convulsions or bruit; they exhibited the aggressive angiographic features mentioned above. The remarkably high sinus pressure with pure arterial blood in the sinus, which was measured during the packing procedure, provides strong evidence of the high risk of bleeding that accompanies this type of dural AVF.

**FIG. 4.** Case 8. Angiograms obtained before treatment. Upper: Early arterial (left), late arterial (center), and venous (right) phases of right carotid injection. Lower: Early arterial (left), late arterial (center), and venous (right) phases of left carotid injection. Note the dural AVF involving the right transverse–sigmoid sinus with vigorous retrograde venous drainage into the straight sinus and cortical veins. The right transverse–sigmoid sinus is isolated and the left transverse sinus is thrombosed. The posterior half of the superior sagittal sinus is also thrombosed, resulting in marked intracranial venous congestion. The cerebral venous drainage includes scalp veins, the patent left sigmoid, and the sphenoparietal sinuses.
Treatment of AVFs

Lalwani’s classification has a well-established general treatment algorithm for dural AVFs and appears to be widely accepted. Recent endovascular techniques have enabled effective and less invasive treatment of intracranial dural AVFs. Transarterial embolization appears to be very useful for reducing the arterial inflow to fistulas, although it seldom obliterates such lesions completely and permanently. In the present study, sinus pressure was 29 to 58% of the mean systemic blood pressure even in the four patients who were treated with transarterial embolization before direct sinus packing. This finding strongly suggests that transarterial embolization does not cure dural AVF. Mullan has argued that the principle of treatment for dural AVFs should be venous side occlusion because these lesions are primarily venous based. As Mullan suggested, transvenous embolization is now recognized as one of the most effective and radical treatments of dural AVFs and may be an alternative to standard surgical treatment for some patients.

However, there are some dural AVFs that cannot be accessed transvenously with microcatheters—dural AVFs with an isolated sinus and those with pure leptomeningeal drainage without sinus involvement. These are Lalwani’s Grade 3 and 4 lesions, respectively, and they require surgery with or without transvenous embolization according to Lalwani’s algorithm. There have been several reports of successful treatment of lesions with pure leptomeningeal drainage (Grade 4) by microsurgical techniques, transarterial embolization, radiosurgery, or a combination of these techniques. In most reports, the dural AVFs were located in the tentorium without sinus involvement. On the other hand, the lesions in our patients drained into the isolated sinus with retrograde cortical drainage and were classified as Grade 3. In 1989, Halbach, et al., first reported the technique of transvenous embolization for dural AVFs involving the transverse and sigmoid sinuses. In their study, seven of 11 patients were treated by direct surgical exposure and sinus packing. Although the authors gave no clear description of the sinus occlusion in their patients, no patient with an isolated sinus appears to have been included in the report. The authors used coils and/or liquid adhesive (isobutyl cyanoacrylate) to occlude the sinus. Cortical veins and the involved sinus were surgically ligated to isolate the sinus prior to injection of the liquid adhesive. The lesion was completely obliterated in four of seven patients who were treated by direct surgical exposure. Barnwell, et al., used similar intraoperative techniques including intradural manipulations.

In 1994, we reported on a patient with dural AVFs that drained into the isolated transverse–sigmoid sinus who had been successfully treated with the simple direct sinus packing described here without any intradural surgical manipulation. In 1996, Kasai, et al., reported a similar case in which the same technique was used. Direct sinus packing requires only a small craniotomy and an endovascular coil procedure and no intradural manipulation for treatment of the leptomeningeal veins. It can be performed even when induction of local anesthesia is used. We used only microcoils to occlude the sinus because we consider injection of liquid adhesive into the involved sinus a very dangerous procedure, given the potential for obstruction of cortical veins if there is migration of the adhesive. We believe that it is important that an adequate number of coils be placed precisely at the ostia of the leptomeningeal veins to avoid excessive retrograde inflow into these veins during the packing procedure. Gobin, et al., reported on a successful transjugular approach to the isolated transverse sinus to allow recanalization of the thrombosed sinus. It is unclear whether this approach would be successful in all patients with isolated sinus, but it may be worth trying. However, if this transjugular approach should fail, we believe that direct sinus packing should be performed without delay.

Although the results of radiosurgery combined with transarterial embolization appear to be excellent, months or years are required for complete obliteration of fistulas. It should be recognized that the involved sinus is still subjected to high pressure even after successful transarterial embolization sessions, as indicated in the present study.
Direct sinus packing for dural AVF

Radiosurgery appears to be a good option for treatment of tentorial AVFs with pure leptomeningeal drainage (Grade 4); however, we believe that lesions with an isolated transverse–sigmoid sinus should be promptly occluded by direct sinus packing because patients with this type of fistula have a high risk of bleeding as long as their fistulas remain.

The use of intraoperative DSA and the road-mapping technique enable safe performance of direct sinus packing and are very helpful in monitoring the process of AVF obliteration. Intraoperative monitoring of sinus pressure and blood gas levels was also useful for monitoring the process of obliteration and the terminal point of the procedure and may therefore be useful when intraoperative DSA is not available.

Of the five patients who underwent follow-up angiography after direct sinus packing, one (Case 4) had recurrence of a new faint dural AVF adjacent to the primary sinus lesion. Although the immediate angiographical results of our study appear excellent, long-term angiographic follow up of the patients will be needed.

Conclusions

Direct sinus packing requires only a small craniotomy and an endovascular coil procedure; it can even be performed when local anesthesia has been used. The angiographical result of direct sinus packing was complete obliteration in all eight patients we studied. Compared with other treatment modalities, this procedure appears to be less invasive and the cure it provides is immediate. This technique could become the treatment of first choice for patients with dural AVFs involving the isolated transverse–sigmoid sinus that drain only into leptomeningeal veins. Angiographic follow-up studies will be needed to evaluate the long-term results of this method.

References


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