Transcranial approach for venous embolization of dural arteriovenous fistulas

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Object. Transvenous embolization is effective in the treatment of an intracranial dural arteriovenous fistula (DAVF). Access to the fistula via the internal jugular vein (IJV) may be limited by associated dural sinus thrombosis; a transcranial approach has been developed for venous embolization in such a situation. The authors report their experiences with the use of a transcranial approach for venous embolization of DAVFs.

Methods. Ten patients with DAVFs underwent craniectomy and embolization procedures in which direct sinus puncture was performed. The DAVFs were located inside the dura mater that constituted the walls of the transverse sinus in five cases, the superior sagittal sinus in four cases, and the superior petrosal sinus in one case. All DAVFs drained directly into a sinus with secondary reflux into leptomeningeal veins. In all cases, the fistula could not be accessed from the IJVs. Cranietomy was performed in an operating room and, in seven cases, subsequent enlargement of the craniectomy was required. Sinus catheterization was performed after the patient had been transferred to the angiography room. The DAVFs were embolized using coils only in five patients, glue only in two patients, and both coils and glue in three patients. Angiographic confirmation that embolization of the fistula was successful was obtained in all cases. A transient complication occurred during the first case after sinus catheterization was attempted in the operating room.

Conclusions. The transcranial approach allows straightforward access to DAVFs located on superficial dural sinuses that are inaccessible from the IJVs. The effectiveness of this approach is similar to that of the standard retrograde venous approach. The correct location and adequate extent of the craniectomy are essential for success to be achieved using this technique.

KEY WORDS • dural arteriovenous fistula • dural sinus • embolization • neurosurgical technique

Intracranial DAVFs account for 10 to 15% of all intracranial arteriovenous lesions. Their symptoms are highly variable. It is established that the potential neurological complications of these lesions depend on the pattern of their venous drainage. Those DAVFs with leptomeningeal drainage carry a high risk of intracranial hemorrhage, cerebral ischemia, and intracranial hypertension, and this situation justifies the use of treatment aimed at complete and permanent occlusion. Although both surgical and endovascular treatments have been proposed, the efficacy and safety of these methods vary, according to the angioarchitecture of the individual DAVFs. Surgery has been shown to be effective and safe in the treatment of fistulas that drain directly into pial veins, typically DAVFs located in the anterior fossa and in the region of the tentorium cerebelli. In fistulas that drain directly into a sinus with secondary reflux into pial veins, however, surgery becomes more difficult and carries a higher risk of complications. Endovascular treatment is often proposed in these cases and is the therapy of choice at our institution. Embolization can be attempted either by using a transarterial or transvenous approach. The transarterial approach is usually unsuccessful in the treatment of DAVFs fed by multiple arteries and the transvenous approach has been shown to be more effective in such lesions. The standard operative technique consists of retrograde catheterization along the IJV to the sinus draining the DAVF. This may be not possible when the sinus no longer communicates with the IJVs because of associated dural sinus thrombosis. In such cases, recanalization of the thrombosed sinus may be attempted, but this maneuver is not always successful.

In cases in which the DAVF involves a sinus located close to the skin, our solution is to access the sinus by direct puncture through a craniectomy. This allows simple catheterization of the DAVF and venous embolization. We performed this transcranial approach in 10 patients and, in this article, we report our results and technical recommendations.

Clinical Material and Methods

Patient Population and Imaging Protocol

Between June 1994 and December 2000, 10 patients at Hopital Lariboisière underwent venous embolization of an intracranial DAVF, which was performed using the transcranial approach. The first two patients have been described in a previous article.
All patients underwent thorough preoperative neurological evaluation conducted by a qualified neurologist. When appropriate, cognitive function was assessed using the MMSE. This neurological examination was performed before embolization, a few days after the procedure, and again at 3 months as well as 1 year after treatment. We reviewed these data and noted if the patients had required blood transfusions following craniectomy.

All but one patient underwent cerebral MR imaging before intervention and all patients underwent cerebral CT scanning immediately after the embolization.

Patients were examined with the aid of six-vessel cerebral angiography, performed with selective injections of both ECAs, both internal carotid arteries, and both vertebral arteries before treatment. The location of the DA VF and the type of venous drainage were noted according to the Lariboisière classification. Control angiography was performed at the end of embolization in all cases. Five patients underwent additional cerebral angiography sessions between 3 and 18 months after embolization. Angiographic confirmation of cure was defined as the absence of any early venous opacification.

Craniectomy Technique

Craniectomy was performed in the operating room with the patient in a state of general anesthesia. For DAVFs located in dura mater that formed the walls of the SSS, patients underwent surgery in the prone position. In all cases, an arc-shaped incision was made to avoid extending the incision over the craniectomy site. To access the SSS, the sagittal craniectomy was made on the midline, anterior to the DAVF (Fig. 1 left). Two burr holes were made along the sagittal suture, at the anterior and posterior limits of the craniectomy. Drilling away the bone between these burr holes completed the craniectomy and exposed the dura of the SSS. To remove bone close to the dura, a diamond drill was required. Finally, venipuncture was performed from the SSS to confirm ease of access. Before closing, the dura mater was coated with fibrin glue and a thin layer of Gelfoam. For DAVFs located in the dura that formed the walls of the TS or SPS, patients were placed in the lateral decubitus or prone position with the appropriate site of craniectomy facing uppermost. The craniectomy was made in the retroauricular area (Fig. 1 right), usually making use of a vertical skin incision. The craniectomy was performed in a similar fashion to that described for the SSS. As we gained more experience, we found that correct placement of the craniectomy required fluoroscopic control with a portable C arm in the operating room. In later cases, craniectomy placement was guided by angiography. We also learned that a large bone defect is needed to make catheterization of the sinus straightforward. For catheterization of the SSS, the appropriate craniectomy extends 6 to 8 cm anteroposteriorly and 2 cm across. For catheterization of the TS or SPS, the craniectomy should extend 5 cm across, overlying the upper portion of these sinuses.

After the craniectomy has been performed, the scalp is sutured in two layers and catheterization of the sinus is arranged as a second procedure.

Embolization Technique

In the first case, catheterization of the sinus was attempted surgically in the operating room following craniectomy; this was complicated by a subdural hemorrhage. In all subsequent cases, sinus catheterization was performed in the angiography room 1 week after the craniectomy to allow healing of the subcutaneous fascia. Embolization was performed while the patient was in...
CAROTID ARTERY CATHETERIZATION

After embolization, the patients received low-dose heparin for 5 days followed by aspirin (160 mg/day) for 1 month to prevent thrombosis of pial veins draining the fistula. In the first two cases, cranioplasty was performed 2 months after embolization. In subsequent cases, cranioplasty was not believed to be necessary.

Sources of Supplies and Equipment

The dedicated system (Advantix) for angiography and embolization was purchased from General Electric Medical Systems (Buc, France). The 18-gauge angiocatheter and the 0.035-in Radifocus guidewire were provided by Terumo Inc. (Guayancourt, France). The lead gloves were obtained from Meditech–Boston Scientific (La Garenne-Colombes, France).

Detachable coils were obtained from Cook Inc. (model Detach 18; Charenton, France), Target–Boston Scientific Corp. (model Guglielmi Detachable Coil [GDC] 18), and Balt Inc. (model MDS; Montmorency, France). The Histoacryl glue was supplied by B. Braun Inc. (Boulouge, France). The microcatheters with two distal markers (Tracker 18 GDC or Excel 14) and also the 0.014-in Transend microguidewire were obtained from Target Therapeutics–Boston Scientific (La Garenne-Colombes, France).

Results

Clinical and radiological data are summarized in Table 1.

Characteristics of Patients and DAVFs

All patients were symptomatic. All but one patient had previously undergone unsuccessful surgical attempts in which more conventional approaches were used before they underwent the transcranial approach.

All DAVFs were Type IIb according to the Lariboisière classification; that is, the arteriovenous shunts drained directly into a sinus with secondary reflux into leptomeningeal veins. In all cases, the DAVF did not communicate directly with the IJVs. In eight cases, disconnection from the jugular system had occurred spontaneously during the course of pathogenesis of the DAVF from associated thrombosis of the sinus adjacent to the arteriovenous shunts. In two cases, in which the DAVF was located in the walls of the TS, previous transvenous embolization was considered to be the cause of the disconnection. In one of these cases, therapeutic occlusion of the sinus was incomplete and arteriovenous shunts persisted inside the coils. In the other case,
the patient had received inappropriate treatment at another institution, where an attempted transvenous embolization of the TS had failed to occlude the portion of sinus draining the arteriovenous shunts, but exacerbated the leptomeningeal venous drainage.

Results of Treatment

No major blood loss was reported during craniectomy and no patient required a blood transfusion. Control angiograms obtained at the end of the embolization confirmed angiographic cure in all cases. This occlusion was further shown to be stable on late control angiograms in five patients. A small complication related to surgical puncture was seen in the first case, but otherwise cerebral CT scans obtained after embolization did not show local or parenchymal hemorrhage.

Three months posttreatment, five patients displayed normal reaction during their neurological examinations and five patients showed improvement in their initial symptoms.

Procedure-Related Issues

In seven cases, the craniectomy had to be enlarged by repeated surgery, either because the initial craniectomy was too small or because the site was inappropriate. A transient complication occurred in the first case following a surgical attempt at catheterization of the SSS. No other complication occurred.

Illustrative Cases

Case 1

This 21-year-old woman presented with a 1-year history of headaches and progressive cognitive impairment.

Examination. Neurological examination found a decrease in mental performances, with an MMSE score of 25. Cerebral MR imaging revealed prominent dilated vessels and multiple small areas of hyperintensity in the white matter of both hemispheres. Cerebral angiography demonstrated a DAVF of the posterior SSS, which was fed by multiple arteries arising from both ECAs and both vertebral arteries (Fig. 2). The fistula and its venous drainage were isolated from both IJVs by thrombosis at the medial origin of both transverse sinuses. The fistula drained forward into the anterior portion of the SSS, into the cortical veins of both hemispheres, and, finally, into the deep venous system through transmedullary anastomoses.

Treatment. An attempt at recanalization of the left transverse sinus via the left IJV failed and a transcranial approach was proposed. The craniectomy was performed...
over the anterior SSS and, during the same session, the neurosurgeon attempted to catheterize the sinus, but without success. The patient awoke with a mild right hemiparesis and cerebral CT scans revealed a small parasagittal hematoma. The deficit resolved within 2 weeks and a transcranial approach was proposed to take place with the patient in the angiography room. The craniectomy proved to be too small, however, and it was not possible to puncture the SSS by using an appropriate needle angle to allow introduction of the microcatheter. The patient underwent a second operation to elongate the craniectomy. One week later, during a second radiological procedure, the SSS was punctured directly and a microcatheter was navigated up to the fistula, allowing complete occlusion with coils.

Postoperative Course. The patient’s headaches resolved and her MMSE score improved five points within 1 week following embolization. Control angiography performed 14 months later confirmed a stable occlusion.

Case 7

This 64-year-old woman was hospitalized for an acute right cerebellar syndrome.

Examination. Cerebral MR imaging revealed a right hemispherical cerebellar infarction and a hyperintensity in the medulla oblongata on T₂-weighted images. Cerebral angiography demonstrated a DAVF of the right SPS (Fig. 3). Drainage from the fistula was excluded from both the cavernous and sinus and the TS, with reflux into cerebellar and medullary veins.

Treatment. We initially attempted transarterial embolization of the fistula. A microcatheter was passed distally in the right occipital artery and a mixture of Histoacryl and Lipiodol (20:80 by volume) was injected. Despite the low concentration of Histoacryl, the mixture polymerized before reaching the DAVF and the fistula remained patent due to its blood supply from adjacent arteries. We therefore proposed a transcranial approach. The patient underwent craniectomy; the surgeon tried to excise the DAVF during the same operative session, but without success. One week later the patient underwent transcranial embolization in the angiography room. The patient was placed in the left lateral position and the right SPS was punctured close to its junction with the TS with the aid of an 18-gauge angiocatheter. Because of the small size of the SPS, there was some concern over loss of access, if attempts were made to introduce a mi-
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crocheter. Therefore, we injected more concentrated glue (50:50 by volume) mixed with radiodense Tantalum powder through the angiocatheter sleeve. The control angiogram confirmed complete occlusion of the fistula.

**Discussion**

**Indications for the Treatment of DAVFs**

The neurological risk associated with a DAVF is determined on the basis of its pattern of venous drainage. Fistulas that drain into pial veins carry a risk of neurological complications that include hemorrhage, seizures, or progressive neurological deficit from venous hypertension.4,12 In a patient in whom a DAVF of the SSS drains into the cortical veins of both hemispheres, progressive cognitive impairment may develop. This deficit may be reversed by occlusion of the fistula.11 All DAVFs in this series had leptomeningeal venous drainage and several patients displayed progressive neurological symptoms. Angiographic cure was therefore indicated both to improve neurological status and to prevent hemorrhagic complication.

**Treatment of DAVFs With Leptomeningeal Drainage**

To obtain angiographic cure of a DAVF, the initial segment of the venous compartment draining the arteriovenous shunts must be occluded. Given the numerous arterial anastomoses within the dura mater, occlusion of arteries proximal to the shunt will usually lead to refilling of the shunt by adjacent arteries. Although both surgical and endovascular treatment have been proposed,13 the efficacy and safety of these techniques depend on the venous drainage of the fistula. As described by Collice and colleagues,4 two different patterns of drainage into leptomeningeal veins are seen. The first situation is represented by fistulas that drain directly into pial veins either in the wall of the sinus or simply in the vicinity of a sinus that is not affected by the disease (Type III DAVF in our classification). In such a situation, surgery is straightforward and effective, with coagulation or clipping of the draining vein at its origin.4,7,16 In this instance surgery is similar in principle to that performed for spinal DAVF.3 The second situation is represented by fistulas that drain primarily into a sinus, but with secondary reflux into leptomeningeal veins (Type IIb in our classification). This type of surgery is more complicated and carries a higher risk, requiring surgical excision or packing of the sinus.16 Although it has been performed in some cases, there is a substantial risk from hemorrhagic complications.16 At our institution, Type IIb DAVFs are all treated by means of an endovascular approach.

Endovascular strategies include transarterial and transvenous embolization. Transarterial embolization can be performed with particles or glue.5 It is our opinion that particles are not the best form of treatment for these fistulas, because particles do not occlude the venous compartment and arterial recanalization will often occur during a long-term follow-up period. Glue seldom permits occlusion of the venous compartment if the fistula is fed by multiple arteries or by arteries inaccessible to catheterization. In this series, five patients underwent unsuccessful transarterial embolization.

With the advent of detachable coils over the last decade, transvenous embolization has been shown to be efficient and safe in the treatment of DAVFs that drain into a dural sinus.9,10 However, some criteria must be respected. In general, transvenous embolization should be restricted to DAVFs that drain primarily into a sinus and should be avoided in treating Type III fistulas. In Type III fistulas, the fistula does not drain into the sinus and sinus occlusion would be inappropriate. In cases in which the DAVF involves a dural sinus that participates in cerebral drainage (lateral sinus or SSS), sacrifice is often acceptable if part of the sinus is already occluded. Indeed, these thromboses do not usually recanalize and, therefore, disconnection of the sinus that drains the shunt will not jeopardize cerebral venous drainage. In all cases in our series, the dural sinus drained the fistula alone and no pial vein drained into the sinuses with antegrade flow. Given that these sinuses did not participate in normal parenchymal drainage, it was believed that they could be safely occluded. Finally, coils must be delivered to the segment of sinus that faces the arteriovenous shunts and not to the segment that lies distal to them. Indeed, coils in this situation would worsen the leptomeningeal drainage of the fistula, as seen in one case in this series.

Transvenous access to the fistula via the IJV may be limited by coexistent thrombosis of the dural sinus adjacent to the shunts. Although sinus recanalization has been reported for the lateral sinus,6 this maneuver failed in six cases in our series. In the two fistulas previously treated with coils, the microcatheter could not progress through the mesh of coils. A transcranial approach was developed to provide simple access to the part of the sinus that supports the shunts.

**Transcranial Approach**

The transcranial approach was first reported for embolization of a vein of Galen malformation.15 The technique of catheterization of the vein of Galen following transtorcular puncture and embolization with coils resembles that reported here. The transcranial approach for DAVFs has been previously reported for access to both the TS2,10 and SSS.17 In the published series, there was some variation in technique, with catheterization of the sinuses taking place in the operating room. In several cases reported by Barnwell, et al.,7 the sinus was initially surgically occluded distal to the shunts before the isolated portion was embolized with glue. This technique carries greater risk associated with the surgical ligation of the sinus and with the hazards of glue migration within pial veins. Controllable detachable coils were not available at the time these patients were treated.

**Advantages of the Transcranial Approach**

The transcranial approach succeeded in all 10 cases, despite the fact that previous attempts at embolization or surgery had failed in nine of these cases. The transcranial approach has become our first option when dealing with these types of DAVFs. Apart from the simplicity of fistula access, the combined approach offers advantages over sinus recanalization. For DAVFs of the SSS, it allows dense packing limited to that portion of sinus supporting the shunts. Indeed, as the microcatheter approaches the section of sinus to be occluded from its healthy part, it is directed toward the thrombosed segment, against which the coils are packed. In cases of retrograde recanalization, the microcatheter...
and the coils are directed toward the patent portion of the SSS, and there is less control over the limits of the coil mass. For DAVFs of the TS, craniectomy allows multiple needle punctures if glue injection is required after coil embolization.

In comparison with surgical resection of the dural sinus, this combined approach appears safer. The surgical intervention is limited to a craniectomy that respects the dura mater and carries little risk of neurological damage. In our series, blood loss was minimal even when craniectomy was performed in spite of increased vascularity associated with the dural fistula.

Technical Considerations

Our craniectomy technique has improved with experience. In the first seven patients, the craniectomy was either too small or incorrectly placed. Although the sinus was always visible following craniectomy, puncture did not necessarily allow the angulation needed to access the DAVF. Puncture should be distal to the shunt to permit dense packing with coils and the needle should enter at an angle of 45° to avoid kinking of the microcatheter. A small craniectomy may not allow optimal sinus puncture and we recommend a larger craniectomy to improve access to the fistula. Radiological techniques certainly allow more accurate placement of the craniectomy. We recommend catheterizing the sinus during a second stage, in the angiography room under road map guidance. Delaying embolization 1 week after craniectomy permitted healing of the subcutaneous tissues and avoided subcutaneous hematoma. It was our belief that this facilitated sinus puncture, but such a delay may not be necessary.

The choice of embolization material depends on the location of the fistula and on the caliber of the sinus. For lesions associated with the SSS, we choose to spare the portion of sinus that is unaffected by the arteriovenous shunts as far as possible and to avoid migration of embolization material into the pial veins. Because glue may be carried by flow toward the patent SSS, coils were believed to be a more suitable embolization material.

Glue was used in the treatment of two DAVFs of the TS following initial placement of coils to create a mesh able to trap the glue and prevent migration into cortical veins.

Glue was also injected into an SPS without previous coil embolization because there was concern that access might be lost if attempts were made to introduce a microcatheter.

To conclude, this combined approach is efficient, safe, and simple. It is the first treatment option we choose when dealing with a DAVF that involves a superficial sinus located close to the cranium in which and where drainage is disconnected from both IJVs. A careful craniectomy technique is essential for the success of this method and a careful analysis of the angioarchitecture of the DAVF is crucial to determine the appropriate treatment for the patient.

References


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