True anatomical compartmentalization of the cavernous sinus in a patient with bilateral cavernous dural arteriovenous fistulae

Case report

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An unusual case of complete anatomical compartmentalization of the cavernous sinus in a patient with bilateral Type D cavernous dural arteriovenous fistulae is described. This anatomical anomaly isolated the anterior cavernous sinus and orbital venous system, which was primarily responsible for the patient's clinical presentation. The compartmentalization of the cavernous sinus also limited options for definitive endovascular therapy to a transvenous approach via the superior ophthalmic vein.

KEY WORDS • cavernous sinus • dural arteriovenous fistula • superior ophthalmic vein

The cavernous sinus is often arbitrarily divided into an anterior (anteroinferior) and posterior (posterosuperior) compartment by the course of the internal carotid artery (ICA) for purposes of anatomical description and surgical planning. Although this is a useful description tool, in reality these two compartments usually communicate freely. Interconnection between the two portions of the cavernous sinus can be partially restricted by the presence of septa, although such partitions rarely produce true isolation of the anterior and posterior compartments.

We report a rare case of complete compartmentalization of the cavernous sinus into true anterior and posterior compartments in a patient with bilateral cavernous dural arteriovenous fistulae (AVF's) Type D according to the classification system of Barrow, et al.1 Because of this unique anatomical arrangement and the patient's clinical presentation, definitive endovascular treatment was best accomplished with a transvenous approach via the superior ophthalmic vein.

Case Report

This 40-year-old woman presented with persistent redness of the right eye and double vision which she had suffered for a period of 4 months. Her medical history was notable only for the successful completion of a normal full-term pregnancy 4 months prior to onset of her symptoms.

Examination. Physical examination showed proptosis, chemosis, and conjunctival injection of the right eye. Furthermore, a partial third and sixth cranial nerve palsy was found on the right. The right intraocular pressure was elevated, and visual acuity was normal. A clinical diagnosis of a cavernous dural AVF was suggested.

Cerebral angiography was performed for diagnosis and therapeutic planning. Selective ICA and external carotid artery (ECA) angiography showed bilateral Type D dural AVF's of the cavernous sinus. There was bilateral ICA supply, presumably from branches of the meningohypophyseal and inferolateral trunks (Fig. 1). Each side of the cavernous dural AVF's was also supplied by the ipsilateral ECA through a plexiform network of dural branches arising from the middle meningeal, accessory meningeal, and foramen rotundum arteries (Fig. 2). An unusual pattern of venous drainage was also observed. Left ICA and ECA injections resulted in simultaneous filling of both cavernous sinuses from the dural AVF's, which then drained predominantly through the right inferior petrosal sinus (Fig. 1). Right internal carotid angiography also demonstrated simul-
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![Fig. 1. Left: Right internal carotid angiogram, anteroposterior view, demonstrating bilateral supply to the cavernous dural arteriovenous fistula. There is simultaneous filling of the left posterior cavernous sinus (arrowhead), right anterior cavernous sinus (small arrow), and right superior ophthalmic vein (large arrow). Right: Left internal carotid angiogram, lateral view, also demonstrating bilateral supply to the fistula. There is simultaneous filling of both posterior cavernous sinuses (white arrows) and inferior petrosal sinus veins (black arrows).]

![Fig. 2. Right external carotid angiogram, lateral view, demonstrating unilateral supply to the fistula from dural branches of the middle meningeal (small arrows), accessory meningeal (small arrowheads), and foramen rotundum (open arrow) arteries. Only the anterior cavernous sinus (large arrowhead) and superior ophthalmic vein (large arrow) are seen.]

![Fig. 3. Right superior ophthalmic venogram, lateral view, demonstrating antegrade filling of only the anterior compartment of the cavernous sinus (arrow). The posterior compartment never filled.]

taneous filling of both cavernous sinuses from the dural AVF's with predominant venous outflow from the left inferior petrosal sinus. Some venous outflow was also directed into the right superior ophthalmic vein. Right ECA injection showed exclusive filling of the anterior compartment of the right cavernous sinus with retrograde drainage through the right superior ophthalmic vein (Fig. 2). This finding was initially interpreted as an unusual manifestation of preferential flow phenomenon.

The combined ECA and bilateral ICA supply to these dural AVF's precluded the likelihood of definitive treatment by transarterial embolization alone. Furthermore, since the patient's clinical syndrome was due to orbital venous hypertension produced by diversion of shunt flow into the superior ophthalmic vein, our goal of endovascular therapy was to obliterate only the portion of the dural AVF involving the anterior right cavernous sinus. A combined percutaneous transarterial and transvenous embolization was first attempted.

Operations. A tapered No. 5.5 to 4.0 French guiding catheter was selectively introduced into the right ECA, through which a Tracker-18 microcatheter was coaxially placed for selective catheterization of the middle and accessory meningeal arteries and the pterygopalatine portion of the internal maxillary artery. Superselective angiography showed numerous dangerous anastomoses, including a recurrent meningeal branch of the right ophthalmic artery communicating with the middle meningeal artery, multiple anastomotic branches between the accessory and middle meningeal arteries, and direct communication between the inferolateral trunks and foramen rotundum artery. Thus, transarterial embolization was abandoned.

The right internal jugular bulb was then cannulated with the same guiding catheter. A Tracker-18 microcatheter with various microguidewires was used to gain access to the right cavernous sinus through the inferior petrosal sinus. Although the posterior compartment of the right cavernous sinus was easily reached via that route, it was not possible to enter the anterior compartment. Cavernous sinography showed no filling of the anterior compartment, consistent with complete compartmentalization of the cavernous sinus. Thus, this particular transvenous approach was also abandoned.

Six days later, the patient returned for transvenous embolization of the right cavernous sinus via the superior ophthalmic vein. Under general anesthesia, the superficial portion of the right superior ophthalmic vein was surgically exposed and then punctured with a No. 4 French micropuncture introducer set. Under fluoroscopy, a thin-walled No. 4 French sheath was easily navigated through the length of the right superior ophthalmic vein. Venography confirmed complete isolation of the anterior compartment of the cavernous sinus (Fig. 3). A 70-cm Tracker-18 microcatheter was then
positioned into the anterior compartment of the cavernous sinus, through which 27 3- and 4-mm platinum microcoils were deposited.

Postoperative Course. Postembolization venography through the superior ophthalmic vein showed no filling of the right cavernous sinus. Right external and internal carotid angiography showed complete obliteration of arteriovenous shunt flow into the anterior cavernous sinus (Fig. 4).

Discussion

The cavernous sinus is the second most commonly affected system by dural AVF's. Although there is no clearly defined etiology of these lesions, it has been suggested that prior thrombosis of a dural sinus may be a predisposing event initiating their development. Other predisposing factors have also been identified, including prior surgery, pregnancy, sinusitis, and trauma.

Development of a carotid-cavernous fistula (direct or dural type) causes increased flow and pressure within the venous drainage pathways, which in turn produces reflux of flow within the tributaries of the cavernous sinus. If diversion of shunt flow into the superior and inferior ophthalmic veins occurs, then the resultant orbital venous hypertension will often produce the classic signs and symptoms of a carotid-cavernous fistula such as a pulsating exophthalmos, chemosis, or conjunctival injection.

Treatment of cavernous dural AVF's is largely determined by the severity of symptoms. These anomalies are usually characterized by slow shunt flow and low morbidity, and a variable, but significant percentage (18% to 50%) may undergo spontaneous resolution. Therefore, patients with mild symptoms are usually managed conservatively. Aggressive treatment is indicated, however, in patients with deterioration of vision, recruitment of corneal venous drainage, glaucoma, severe exophthalmos, or persistent ophthalmoplegia.

Endovascular treatment of cavernous dural AVF’s is often divided broadly into transarterial and transvenous approaches. Transarterial embolization of the ECA supply to such lesions is usually preferred as a first-line treatment due to lower risks of complication. This approach has been most successful for treatment of cavernous dural AVF’s without ICA supply (Type C). In our experience, however, transarterial ECA embolization alone is often inadequate for the following reasons: 1) frequently, there is associated ICA supply which cannot be embolized safely; 2) the ECA supply to the dural AVF commonly consists of innumerable plexiform branches which cannot be satisfactorily reached; and 3) dangerous ECA-ICA anastomoses often exist. Thus, in many cases definitive treatment of cavernous dural AVF’s requires attempting a transvenous approach. Most commonly this is first approached by a femoral venipuncture to gain access to the internal jugular vein and eventually the inferior petrosal sinus. Some authors have reported that the number of patients who can be successfully treated using this transvenous approach is limited, either due to inability to reach the inferior petrosal sinus or inability to enter the anterior compartment of the cavernous sinus because of the presence of intracavernous partitions/trabeculae. This latter problem is usually associated with attempts to navigate a detachable balloon catheter through the cavernous sinus. Since steerable microcatheters and microguidewires have become available, it has been our experience that, if the ipsilateral inferior petrosal sinus is patent, we are then usually successful in reaching the site of the dural AVF, even when it is in the anterior compartment.

A variety of alternative transvenous approaches are also possible, including direct puncture of the internal jugular vein, direct and indirect cannulation of the angular vein, surgical exposure and cannulation of the superior ophthalmic vein, and direct surgical exposure of the cavernous sinus. Transvenous embolization of cavernous dural AVF’s using the superior ophthalmic venous approach (either by surgical exposure or transcutaneous puncture) has been previously used safely and successfully in a limited number of selected cases. We favor surgical exposure of the superior ophthalmic vein by an experienced neuro-ophthalmologist, because we have found that this technique provides superior access to the vein, is better tolerated by the patient, and is associated with less potential complications associated with alternative routes of access.

The existence of complete anatomical compartmentalization of the cavernous sinus presented a unique problem in the endovascular therapeutic management of this patient’s cavernous dural AVF. We were unable to perform transarterial ECA embolization due to the presence of dangerous anastomoses and were unable to reach the anterior compartment of the cavernous sinus via the inferior petrosal sinus. Consequently, the best approach was to enter the anterior compartment of the cavernous sinus through the superior ophthalmic vein in order to precisely embolize the site of the dural AVF responsible for the patient’s clinical syndrome.
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If this unusual anatomical anomaly of the cavernous sinus had been recognized earlier, we would have altered our therapeutic strategy. Definitive transvenous embolization of the anterior cavernous sinus component of the dural AVF using a superior ophthalmic venous approach would have been chosen as the first-line method of treatment.

References

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