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Tools and techniques

Direct transcranial coil and Onyx embolization of a dural arteriovenous fistula: Technical note and brief literature review

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ABSTRACT

Intracranial high-grade dural arteriovenous fistulas (DAVFs) have higher bleeding rates compared to other intracranial vascular malformations. Endovascular treatment is usually recommended for high-grade lesions, aiming at a complete fistula obliteration. However, some patients have vascular abnormalities that limit endovascular access to the precise location of the shunt. Alternative techniques may be considered in this scenario. A middle-aged man presented with intracranial hypertension secondary to a high-grade DAVF. Because of vascular abnormalities precluding transvenous access to the intracranial venous circulation, the patient required treatment by a direct transcranial coil and Onyx embolization of the shunt. Direct transcranial cannulation of a dural sinus is an alternative and effective route for transvenous embolization of DAVFs, especially if abnormal venous anatomy precluding venous access to the required cranial venous system is identified.

1. Introduction

Dural arteriovenous fistulas (DAVFs) are ten percent of the intracranial arteriovenous malformations, commonly diagnosed in the sixth decade of life. [1–3] Annual bleed rates and rebleed rates have been reported between 1.7 and 3.7% and 3.7 to 8.4%, respectively. [3,4] The presence of venous reflux increases 10 to 40% the probability of having hemorrhage and a high mortality rate, particularly if the fistula has a tentorial location. [2,4–6]

Several grading systems allow estimating the risk of hemorrhage and intracranial hypertension of these lesions and, hence, guiding management. For asymptomatic low-grade DAVFs, the treatment of choice is imaging follow-up. [7,8] Symptomatic low-grade and high-grade lesions can be treated by endovascular embolization, stereotactic radiosurgery, open microvascular surgery, or a combination of these approaches. [9,10]

Some patients with high-grade DAVFs have vascular abnormalities that limit endovascular access to the precise location of the shunt. Alternative techniques may be considered for the treatment of these patients, including a transcranial embolization of the shunt. [9] We report a case of a middle-aged man who presented with intracranial hypertension secondary to a high-grade DAVF and required treatment by a direct transcranial embolization of the shunt. Institutional Review Board approval and patient consent were obtained before the commencement of this report.

2. Case description

2.1. Patient history and physical examination

A 44-year-old man was admitted to the emergency department. He complained of frontotemporal oppressive intense headaches and visual abnormalities during the last 10 days, which were worse after Valsalva maneuvers. These symptoms did not improve with analgesic therapy. No remarkable past medical history was found. On examination, he was isochoric, the visual acuity for his right eye was 20/40 and 20/20 for his left eye. Bilateral papilledema was identified.

2.2. Imaging

A diagnosis of intracranial hypertension was suspected, and a non-contrast computed tomography (CT) scan was obtained, showing generalized vascular prominence and small lateral ventricles. A brain magnetic resonance imaging (MRI) without contrast

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revealed supra and infratentorial venous engorgement attributable to reflux, suggesting the presence of a DAVF involving the right transverse sinus, and cortico-subcortical edema of posterior dominance in both cerebral hemispheres compatible with central venous hypertension (Fig. 1).

The patient was taken to the Neuroangiography suite, and cerebral arteriography was performed. It confirmed the presence of a DAVF fed by dural arterial branches from the right external carotid artery and draining to the right sigmoid-transverse sinus junction, associated with venous reflux (Fig. 2). It was graded as a Borden II, Cognard IIa + b DAVF. Endovascular treatment was indicated because of the high risk of hemorrhage and the presence of visual deterioration and intracranial hypertension.

2.3. Treatment

The patient initially underwent liquid Onyx (eV3, Medtronic, Irvine, CA, USA) embolization of the right middle meningeal, right occipital, and right posterior auricular arteries, through a transarterial femoral approach. Post- embolization cerebral angiography showed occlusion of 80% of the shunt (Fig. 3 Panel A). The left femoral vein was then cannulated to intent a transvenous coil embolization of the right sigmoid-transverse sinus junction. However, it was not possible because the right transverse sinus and the first portion of the right sigmoid sinus were anatomically disconnected from the left transverse sinus (through torcular Herophili) and the remaining caudal two-thirds of the right sigmoid sinus, respectively. Also, access through the superior petrosal sinus was not anatomically possible. A decision was made to offer expectant management and imaging follow-up for the residual fistula.

A follow-up cerebral angiography was performed one month after the initial embolization, showing recanalization of 30% of the lesion (Fig. 3 Panel B). Furthermore, the patient complained of progressive deterioration of his visual acuity, possibly attributed to a steal phenomenon. Considering these findings, and the inability to perform other embolization techniques, a second intervention was proposed aiming at a direct transcranial coil embolization of the right sigmoid-transverse sinus junction.

Fig. 2. Cerebral digital subtraction angiography, lateral view, confirming the presence of a Borden II and Cognard IIa + b DAVF with arterial feeders from the external carotid artery (arrow), draining to the sigmoid-transverse sinus junction (black arrowhead) and with the presence of retrograde venous flow (white arrowhead).

2.4. Direct transcranial coil and Onyx embolization technique

The patient was taken to the hybrid operating room. General anesthesia was administered. The patient was placed supine with his head rotated 60° to the left. The right groin and the right retroauricular region were prepped and draped. A right trans-femoral arterial access was obtained. The right internal carotid artery was selected with a Simmons-II catheter, and a lateral angiogram was obtained. Using fluoroscopic guidance, road-mapping, and a syringe needle, the right transverse sinus was

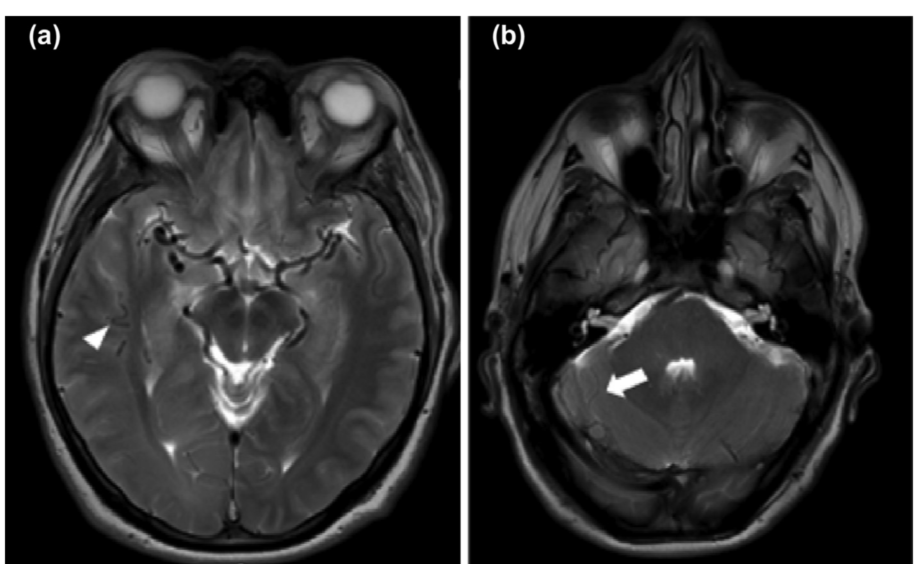

Fig. 1. Panel A and B. Axial view of a T2 cerebral MRI showing supra (arrowhead) and infratentorial (arrow) engorged veins, attributable to venous reflux and arterialization secondary to a DAVF.

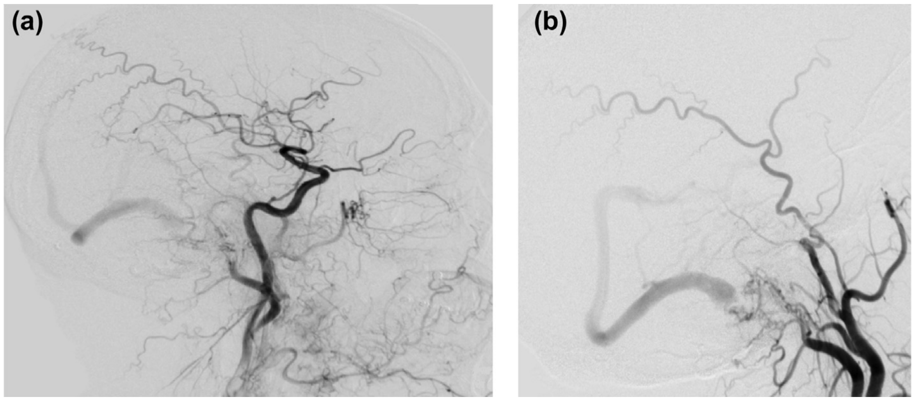

Fig. 3. Cerebral digital subtraction angiography, lateral views. **Panel A.** Immediate angiographic control after transarterial Onyx embolization of the right middle meningeal, right occipital, and right posterior auricular arteries. 80% of the shunt was occluded. **Panel B**. One-month follow-up angiography after transarterial embolization showing recanalization of 30% of the fistula.

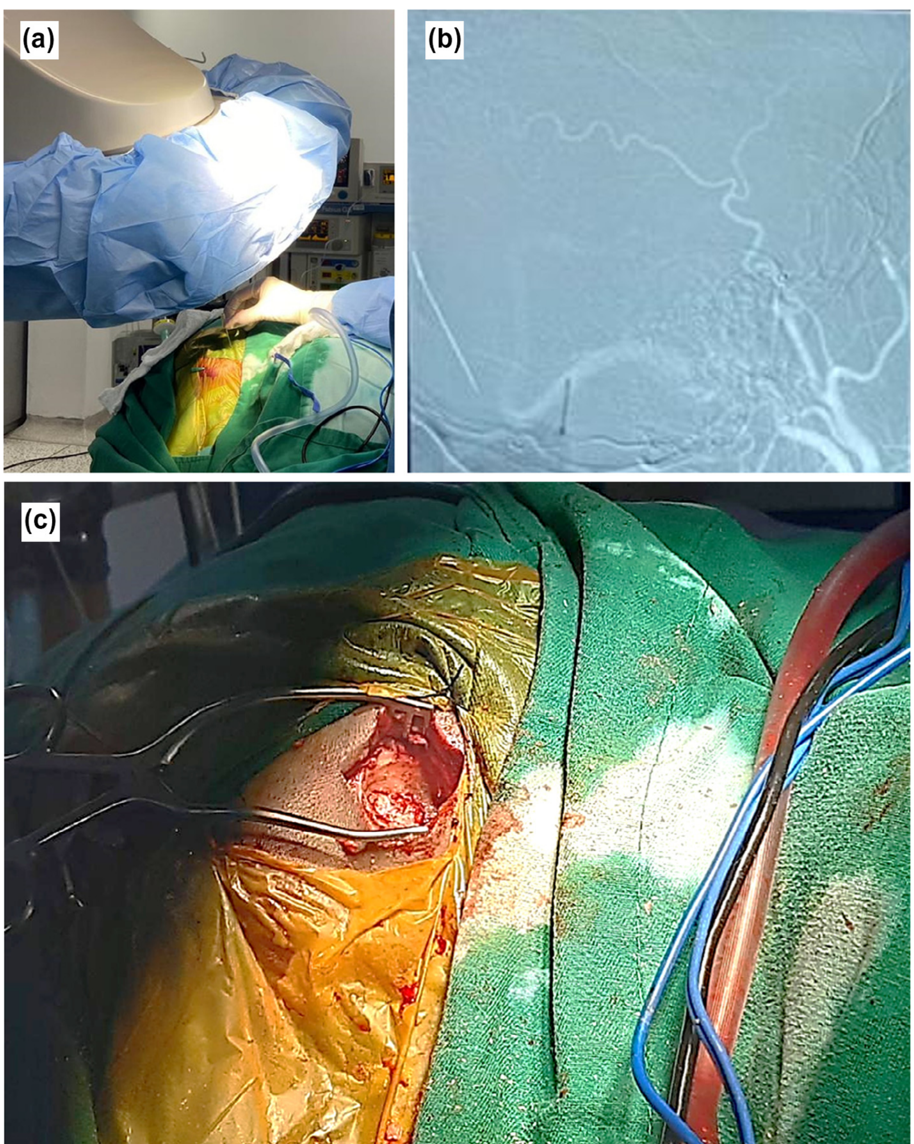

Fig. 4. Panels A and B. The patient was placed supine with his head rotated 60° to the left. The right transverse sinus was located and marked under fluoroscopic guidance using road-mapping and a syringe needle. **Panel C.** A right sub-occipital *retro*-mastoid burr-hole craniostomy was performed.

located and marked on the retroauricular skin (Fig. 4 Panels A and B). A cephalocaudal linear incision on the retroauricular region and a right sub-occipital *retro*-mastoid burr-hole craniostomy were performed, exposing the external dural fold of the right transverse sinus (Fig. 4 Panel C). A 4–0 Vycril was used to pierce the external dural fold of the right transverse sinus in the center of the burr-hole, with a 4 mm distance between the entry and exit points of the suture. The suture was not knotted.

At the middle point of the 4 mm distance between the entry and exit point of the suture, direct cannulation of the transverse sinus with a 22-gauge angiocatheter was made. A 0.017 in. Echelon microcatheter (Medtronic, Irvine, CA, USA) was advanced over a 0.014 in. Avigo microwire (Medtronic, Irvine, CA, USA) (Fig. 5 Panel A). Proper placement of the microcatheter into the sigmoid-transverse sinus junction was confirmed through iodinated contrast injection (Fig. 5 Panel B). A coil basket was formed inside the transverse-sinus junction. Three Axium (Medtronic, Irvine, CA, USA) detachable coils were employed (Fig. 5 Panel C). Repetitive arterial contrast injections were performed to evaluate the progress of the shunt obliteration. Finally, Onyx (eV3 Endovascular, Medtronic, Irvine, CA, USA) was injected into the transverse sinus (Fig. 5 Panel D). Total occlusion of the fistula was obtained (Fig. 6). The microcatheter and the microwire were removed. The 4–0 Vycril suture was knotted to prevent blood leakage, and the wound was closed.

One month after the second embolization, the patient reported complete resolution of his visual symptoms, and a cerebral angiography revealed no residual fistula.

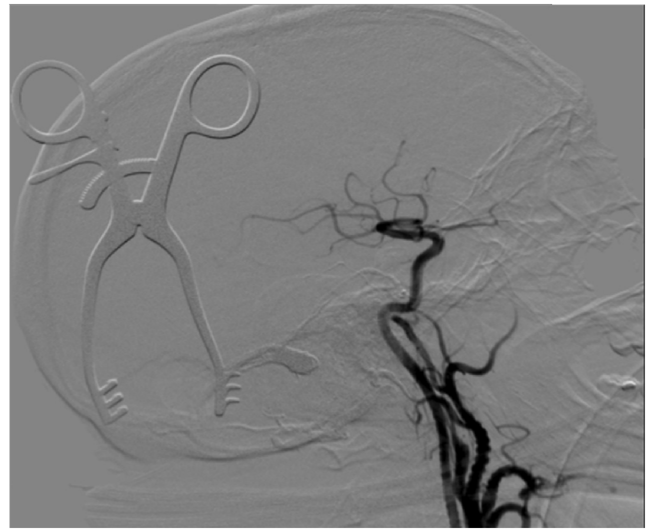

Fig. 6. Intraoperative cerebral digital subtraction angiography, lateral view, after direct coil and Onyx embolization of the right sigmoid-transverse sinus junction. Total occlusion of DAVF is observed.

3. Discussion

Intracranial DAVFs are vascular abnormalities in which dural arteries from the carotid or vertebral arteries drain directly into a dural venous sinus or cortical veins. [1,2] They are usually located

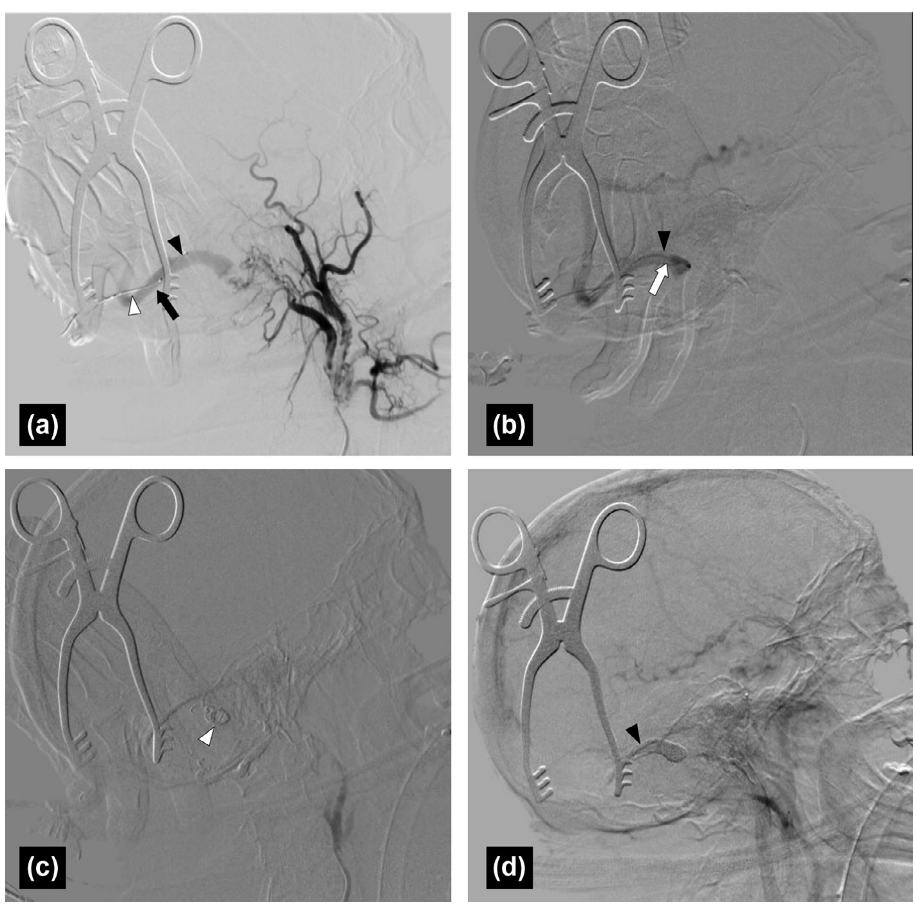

Fig. 5. Cerebral digital subtraction angiography, Lateral views. **Panel A.** With a 22-gauge angiocatheter (white arrowhead) the right transverse sinus (black arrow) was cannulated, and a 0.017 in. Echelon microcatheter (black arrowhead) was advanced over a 0.014 in. Avigo microwire. **Panel B.** Proper placement of the microcatheter (black arrowhead) into the transverse-sigmoid sinus junction (white arrow) was confirmed through iodinated contrast injection. **Panel C.** A coil basket (white arrowhead) was formed inside the transverse-sinus junction. **Panel D.** The embolization was completed after injection of Onyx (black arrowhead) into the transverse sinus.

in the supratentorial region, commonly involving the transverse-sigmoid sinus junction. [1,2] Accounting for 10–15% of all intracranial malformations, the detection rate for these lesions is 0.15 per 100.0000 persons per year in the USA, and 0.29 per 100.000 persons per year in Japan. [2] Diagnosis is frequently made in the sixth decade of life, and there is no clear gender predilection. [3,5]

The most common presenting symptoms are headaches, tinnitus, and focal neurological deficit secondary to intracerebral hemorrhage or steal phenomenon. [1,5] Hemorrhage is a frequent complication associated with DAVFs. Annual bleed rates and rebleed rates have been reported between 1.7 and 3.7% and 3.7 to 8.4%, respectively. [3,4] Some features increase the risk of bleeding. For instance, the presence of venous reflux increases 10 to 40% the probability of having hemorrhage and it is linked to a higher mortality rate, particularly if the fistula has a tentorial location. [2,4–6,11]

Diagnosis is habitually suspected with the presence of vascular prominence on CT and MRI scans, but it is confirmed through a cerebral angiography, which also allows grading the DAVF. [3,9] Grading enables the prediction of the expected clinical behavior in terms of risk of intracranial hypertension and hemorrhage. [2,3,8,9,12]

The Borden grading system describes the venous flow direction and the presence of cortical venous drainage. [2,7] A Borden Type I DAVF has anterograde flow into a dural sinus or meningeal vein, type II has anterograde flow into a dural sinus and retrograde cortical venous reflux, and type III has direct reflux from the fistula into cortical veins with venous hypertension. [2,7]

The Cognard grading system divides the DAVFs into five categories: Type I, dural sinus drainage and anterograde flow; type IIa, dural sinus drainage and retrograde flow; type IIb, dural sinus drainage, anterograde flow, and cortical vein reflux; type IIa + b, dural sinus drainage, retrograde flow, and cortical vein reflux; type III, direct cortical vein drainage; type IV, direct cortical vein drainage and venous ectasia; and type V direct spinal perimedullary veins drainage. [8,12] Cognard type I and IIa (Borden I) have 0% annual risk of hemorrhage, Cognard Type IIb and IIa + b (Borden II) have 6% annual risk of hemorrhage and Cognard Type III, IV, and V (Borden III) have 10% annual risk of hemorrhage. [8,12]

Management of DAVFs depends on symptoms, comorbidities, and risk of intracranial hypertension and/or hemorrhage. The main goal is to obliterate the arteriovenous shunt to reduce the risk of hemorrhage and secondary intracranial hypertension. [9,10] Some authors recommend asymptomatic low-grade DAVFs (Borden type I/Cognard type I-IIa) should be treated conservatively with neuroimaging follow-up, while symptomatic low-grade DAVFs and high-grade DAVFs (Borden type II-III/Cognard type IIb-V) should be intervened. [9,12]

Open microvascular surgery, endovascular embolization, and stereotactic radiosurgery are the interventional treatment options. [3] Nowadays, endovascular treatment is qualified as the mainstay therapy for high-grade DAVFs, and it gives excellent obliteration rates. [9,13] Stereotactic radiosurgery is usually reserved for symptomatic low-grade DAVFs, demonstrating fair obliteration rates. Chen et al. described some benefits of stereotactic radiosurgery for the treatment of high-grade DAVFs, but there is a lack of strong evidence for generalizing such recommendation. [14]

The role of open surgical interventions for the complete excision of a DAVF has progressively narrowed because of the higher morbidity and mortality rates associated with it [9] However, it must be considered in patients with complex shunt anatomy limiting endovascular interventions. [9]

Endovascular routes for treatment of DAVFs include transarterial and/or transvenous embolization of the shunt, usually through a femoral or radial route. [12,15] Transarterial embolization is a well-known technique that can be performed through a transfemoral or transradial approach. It has some limitations due to the intrinsic properties of the embolic agents and the presence of small diameter feeding arteries and/or multiple arterial microscopic feeders that may result in partial occlusion of the shunt. The major risk with this intervention is an alteration of the flow dynamics that could cause an elevation of the risk of hemorrhage and intracranial hypertension. [9,12]

Transvenous obliteration techniques, typically through a transfemoral approach, are also used for curative treatment purposes. They are well-tolerated and highly effective techniques requiring a thorough knowledge of the functional anatomy of the venous circulation and location of the arteriovenous shunt. The neurointerventionalists need to make sure that sacrificing the involved sinus(es) will not cause further complications. [9,12] Transvenous coiling is the most used technique and it could be complemented with transvenous Onyx embolization. A combination of coils and Onyx can improve the obliteration rates of a venous sinus because Onyx has better penetration into the fistula, and the cohesive liquid form is modeled by blood flow. [6,10]

Direct transcranial puncture of a dural sinus also allows access to the venous cranial circulation. [5,9,12] This embolization approach may be used for the treatment of DAVFs if the required cranial venous circulation cannot be accessed through a regular transvenous approach because of underlying venous anatomic limitations. [9] In our patient, we first made a transarterial Onyx embolization of the DAVF obtaining 80% occlusion of the shunt. Then, we decided to make a second embolization through transvenous access. However, the right transverse-sigmoid junction could not be accessed through the right jugular vein, the left transverse sinus, or the superior petrosal sinus, because it was anatomically disconnected from those structures. Therefore, successful direct transcranial cannulation of the right sigmoid-transverse sinus junction was performed, the fistula was completely obliterated, and the patient symptoms completely resolved.

The craniostomy and direct canalization technique for the transvenous embolization of intracranial vascular malformations was first reported by Mickle and Quisling in 1986. [16] They described a small craniostomy over the torcular region for performing a direct transtorcular coil embolization of a vein of Galen aneurysmal malformation. [16]

One of the biggest challenges of this type of procedure is the precise location of the burr-hole craniostomy. [7] In the case series of Houdart et al. they recommended fluoroscopic guidance for localization of the transverse sinus before performing a *retro*-auricular craniostomy. [8] Correct recognition of the superior border of the transverse sinus and avoiding a small craniostomy are key points to facilitate the sinus cannulation. A small or uncentered craniostomy limits the angulation of the catheter and makes the cannulation harder. [8,15,17] In our case, we used fluoroscopic guidance for the location of the transverse sinus, which facilitated a centered craniostomy and correct cannulation of the sigmoid-transverse sinus junction.

4. Conclusion

Direct transcranial cannulation of a dural sinus is an alternative and effective route for transvenous embolization of DAVFs, especially if abnormal venous anatomy precluding venous access to the required cranial venous system is identified.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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