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HOW I DO IT

Direct superior sagittal sinus puncture via a surgical burr hole for curative embolization of the complex transverse-sigmoid sinus dural arteriovenous fistula: How I do it

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Abstract

Background Transvenous embolization of high-grade dural arteriovenous fistulas (dAVFs) is challenging particularly when the direct sinus access is favorable due to the complex venous anatomy which prohibits endovascular access via the transfemoral approach.

Method The procedure was conducted in the hybrid operating suite, where a burr hole was performed, followed by direct catheterization of the superior sagittal sinus. Coil embolization was then executed to achieve complete obliteration of the fistula.

Conclusion The direct puncture of the superior sagittal sinus is a safe and effective method for treating complex dAVFs. This approach grants access to the fistula channel which facilitates curative embolization.

Keywords Superior sagittal sinus · Dural arteriovenous fistula · Burr hole · Embolization · Coil · Transvenous embolization

Abbreviations

CT	Computed tomography
DSA	Digital subtraction angiography
ECA	External carotid artery
ICA	Internal carotid artery
dAVF	Dural arteriovenous fistula
SSS	Superior sagittal sinus
TSS	Transverse-sigmoid sinus
TVE	Transvenous embolization

Relevant surgical anatomy

Endovascular transvenous embolization (TVE) is a fundamental therapeutic approach in the management of dural arteriovenous fistulas (dAVFs). Nevertheless, the transcranial approach of gaining direct access to the sinus might be advantageous in cases when the venous architecture does not permit a traditional transfemoral approach [4].

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In this case, a 69-year-old female patient presented with seizure and dementia. The brain computed tomography (CT) showed a small intracerebral hemorrhage at the right periventricular area (Fig. 1a). The CT angiography showed bilateral cortical and deep medullary venous dilatation (Fig. 1b and c). Brain magnetic resonance imaging showed white matter changes secondary to venous hypertension (Fig. 1d). Time of flight angiography showed diffuse enlarged of the deep medullary veins and cortical venous reflux, and also venous thrombosis of the proximal left transverse-sigmoid sinus (TSS) (Fig. 1e). Schematic illustration of the left TSS dAVF is shown in Fig. 1f. Digital subtraction angiography (DSA) revealed multiple arterial feeders from the left external carotid artery (ECA) including the middle meningeal artery, ascending pharyngeal artery, posterior auricular artery, and transosseous feeders from the superficial temporal artery and occipital artery to the left transverse-sigmoid sinus (TSS) (Fig. 1g and h). The dAVF venous drainages were retrograde filling to straight sinus, superior sagittal sinus (SSS), and cortical veins. The brain parenchyma venous drainage was drained to the SSS and cortical veins (Fig. 2a and b). The left internal carotid artery (ICA), right ECA, and vertebral artery branches also fed the fistula (Fig. 2c–f). The diagnosis was left TSS dAVF (Borden II/Cognard IIa + b). The decision to utilize TVE was made based on the understanding that the transarterial technique alone would not result in a complete obliteration of the fistula. Unfortunately, the proximal left TSS was already thrombosed, and the distal right TSS was considerably absent, thus prohibiting access via the internal jugular vein. Furthermore, the feasibility of performing direct access and embolization of the left TSS might be hindered by the compartmentalization of the sinus and the acute angle required for catheterization. As a result, we opted to conduct cannulation of the SSS as it would provide direct access to the fistula.

Description of the technique

The procedure was conducted in the hybrid operating room where the operative setup is shown in Fig. 3a. The patient was placed in a supine position under general anesthesia. Initially, the right common femoral artery was approached for the control angiogram and to create the roadmap for transvenous access.

Direct superior sagittal sinus puncture

The SSS puncture site was set as anteriorly as possible to avoid venous complications and within the hairline. The linear incision was created in the midline under fluoroscope guidance. Then, the surgical burr hole was carried out (Operative Video). First, we punctured the SSS with a micropuncture system (Prelude, Merit Medical, USA), using the Seldinger technique, by introducing a 21-gauge needle at approximately 45° angle to the sinus, cannulated with a 0.018″ guidewire, and catheterized by placing a 4-Fr introducer sheath. The procedure was done under a microscope to ensure precise cannulation and in situations where indocyanine green angiography was necessary to localize the SSS. After the advance of the 4-Fr sheath, a contrast injection through the SSS sheath was performed to confirm the proper sheath position (Fig. 3b). The sheath was then fixed to the skin using a 2–0 silk thread for stabilization and connected to heparinized saline for continuous irrigation.

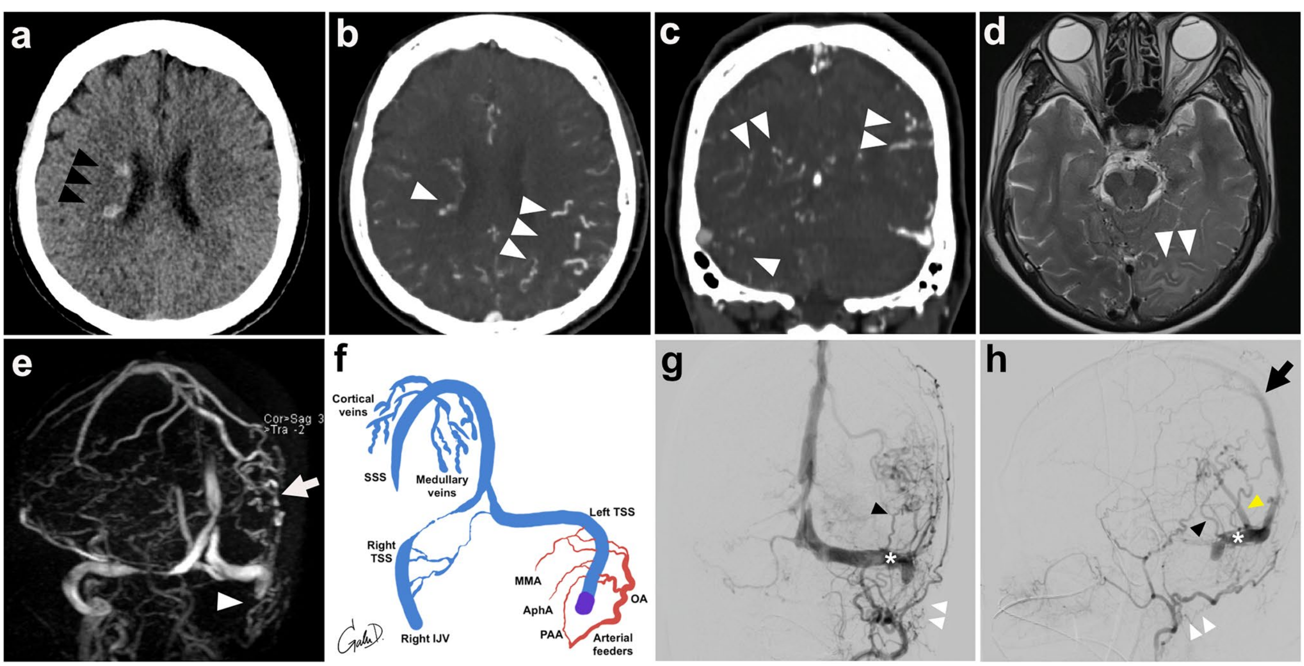

Fig. 1 **a** Non-contrast CT showing a small intracerebral hemorrhage at the right periventricular area (black arrowheads). **b** and **c** Axial and coronal view of CT angiography showing abnormal dilatation of the bilateral cortical and deep medullary veins (white arrowheads). Preoperative magnetic resonance imaging. **d** T2 weighted image showing multiple abnormal flow voids with white matter change at the left posterior temporal area (white arrowheads). **e** Time of flight angiography showing the cortical venous reflux (white arrow) and thrombosed of the proximal left TSS (white arrowhead). **f** Schematic illustration of the left TSS dAVF. Preoperative digital subtraction angiography (DSA). **g** and **h** Anteroposterior and lateral view of left ECA injection showing multiple arterial feeders (white arrowheads) that supply to the left TSS (white asterisk) which drained to the straight sinus (yellow arrowhead), SSS (black arrow), and cortical venous reflux (black arrowhead). SSS, superior sagittal sinus; TSS, transverse-sigmoid sinus; IJV, internal jugular vein; MMA, middle meningeal artery; AphA, ascending pharyngeal artery; PAA, posterior auricular artery; OA, occipital artery

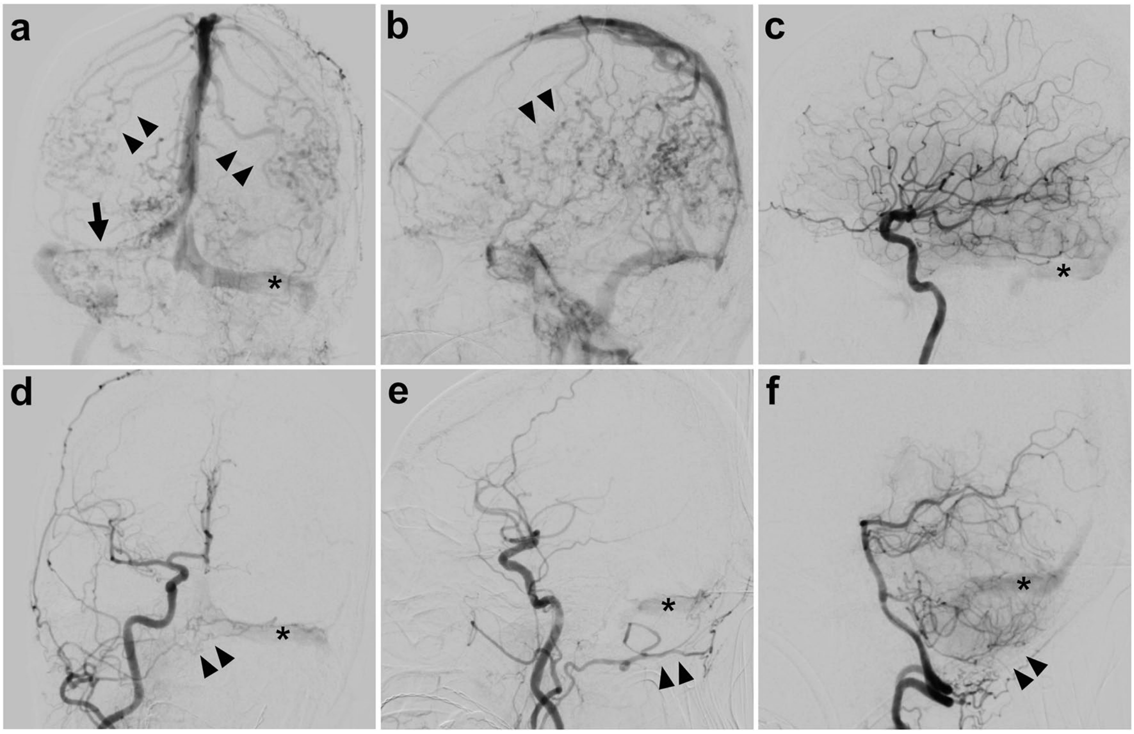

Fig. 2 Preoperative digital subtraction angiography (DSA). **a** and **b** Anteroposterior (AP) and lateral view of the late venous phase showing the fistula drained from the left TSS (black asterisk) to the cortical and medullary veins (black arrowheads) via the superior sagittal sinus and also drained to the right transverse sinus which the connection to the Torcular Herophili was nearly absent (black arrow). **c** Lateral view of the left ICA injection showing left TSS (black asterisk) was fed from the tentorial artery. **d** and **e** AP and lateral view of the right common carotid artery injection showing multiple arterial feeders (black arrowheads) from the contralateral ECA supplying the left TSS (black asterisk). **f** Lateral view of the vertebral artery injection showing arterial feeders from the posterior meningeal artery (black arrowheads) and intradural branches supplying the fistula (black asterisk). TSS, transverse-sigmoid sinus; ICA, internal carotid artery; ECA, external carotid artery

Endovascular procedure

We used a microcatheter (Echelon, Medtronic, USA) along with a 0.014″ microguidewire (Avigo, Medtronic, USA) for navigation into the fistula pocket at the left TSS under roadmap guidance. When the venous channels are compartmentalized, posing challenges for microcatheter navigation, the 0.035″ guidewire was occasionally employed to establish a tunnel. However, extreme caution was taken to avoid perforation of the sinus wall.

After the microcatheter was in place, the polyglycolic-polylactic acid (PGLA) coils (Axium, Medtronic, USA) were then deployed until complete fistula obliteration was achieved (Fig. 3c). The area of arterial feeders entering the sinus was entirely occluded without violating the normal venous drainage. The ECAs and ICAs injection showed no remaining arteriovenous shunting and sparing of normal venous drainage of the brain through the SSS and the right transverse sinus (Fig. 3d, e, and f). The sheath was removed from the SSS; the bleeding was stopped using an absorbable gelatin sponge (Spongostan, Ethicon, Johnson and Johnson, USA) and fibrin sealant (Tisseel, Baxter, USA). The burr hole was covered with a titanium plate and the scalp was closed in a standard manner. The patient was transferred to the intensive care unit for 24 h and subsequently discharged home without complications after 5-day post-operation. At the 3-month follow-up, the patient's cognitive function had improved; the modified Rankin scale was evaluated at 2.

Indications

A transcranial approach for entering the affected sinus is required in cases where the venous anatomy prohibits venous access via the conventional transfemoral approach or the internal jugular vein [4, 10]. The surgical treatment for dAVFs was traditionally performed by direct sinus packing [3]. After the emergence of endovascular treatment, several authors reported the hybrid approach using a small craniotomy or burr hole to access the sinus directly to facilitate endovascular embolization [1, 6, 8]. The transcranial approach is therefore suitable for dAVFs with isolated sinuses or the conventional venous accesses are not feasible. Many authors directly access the TSS dAVFs by catheterization of the TSS itself [1, 4]; nevertheless, the data on the

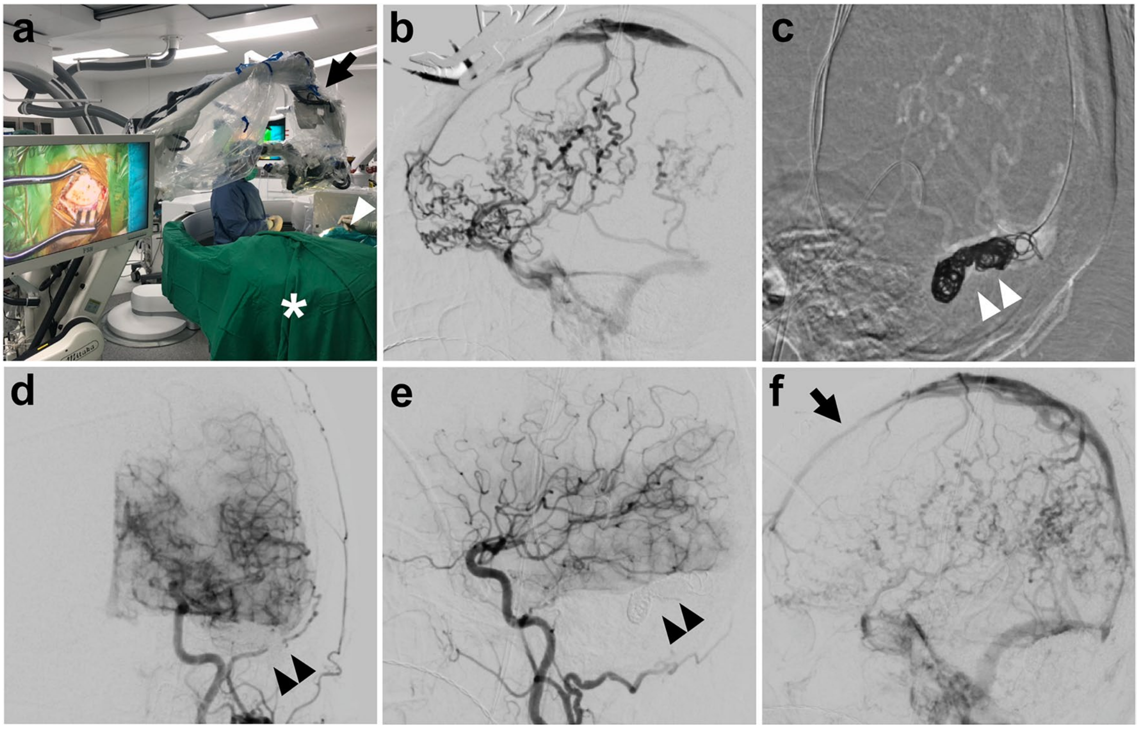

Fig. 3 **a** The operative setup in a hybrid operating suite where the patient (white arrowhead) was set in the supine position. The microscope (black arrow) was used to meticulously cannulate the sinus and a C-arm (white asterisk) was prepared for the sinus catheterization under fluoroscope guidance. **b** Contrast injection via the sheath confirming the proper position of the sinus cannulation. **c** Coils (white arrowheads) were deployed in the left TSS to occlude the fistula. **d** and **e** Anteroposterior and lateral view of the left common carotid artery injection showing complete fistula obliteration without remaining arteriovenous shunting. The coil mass (black arrowheads) was noted in the left TSS. **f** Lateral view of the late venous phase showing patency of normal venous drainage of the brain including the SSS (black arrow). TSS, transverse-sigmoid sinus; SSS, superior sagittal sinus

SSS approach via a surgical burr hole for embolization of TSS dAVFs is limited [7]. In our opinion, the pathologic sinus is often compartmentalized which might cause difficulty in navigating the microcatheter to the primary venous drainage of the fistula, as a result, direct puncture of the SSS in this case would grant direct access to the fistula channel and provide curative embolization.

Limitations

To achieve direct sinus access for TVE, a venous system with viable anatomy is mandatory. Additionally, a hybrid operating suite may be required for precise sinus cannulation and secure closure, especially to prevent bleeding complications.

How to avoid complications and specific perioperative considerations

The transvenous approach carries a risk of major complications including sinus/venous perforation during navigation of the wire/catheter which could result in cerebral hemorrhage or venous infarction [5]. Reducing the risk of sinus injury and minimizing the necessity for a large craniotomy can be achieved by more accurately localizing the sinus using the neuronavigation system, Doppler ultrasonography, or Indocyanine green under the microscope [1, 7, 8]. Since high-grade dAVFS particularly with cortical venous reflux increases the risk for intracranial hemorrhage, complete obliteration of the fistula is necessary. For postoperative concerns, the patient has to be observed in an intensive care unit for potential complications, e.g., intracranial hemorrhage.

Specific information to give to the patient about surgery and potential risks

The annual mortality rate for malignant type dAVFs, as the patient in our case, is 10.4%, while the annual risk of hemorrhagic events is 8.1% [9]. In the first 2 weeks, the rebleeding rate can reach 35% if left untreated [2]. As a result, the patient presented with dAVFs accompanied by intracranial hemorrhage and cortical venous reflux, both of which required prompt treatment in order to eradicate the fistula. Intracerebral hemorrhage (caused by sinus perforation or venous infarction) and incomplete fistula occlusion are among the perioperative risks.

Consent to participate

Informed consent was obtained. The patient has consented to the submission of this How I Do It to the *Acta Neurochirurgica*.

Conflict of interest

The authors declare no competing interests.

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Author contribution Gahn Duangprasert: conceptualization, investigation, data curation, writing an original draft, revise the manuscript. Dilok Tantongtip: supervision. All authors reviewed and approved the final version of the manuscript.

Data availability Not applicable.

Code availability Not applicable.

Declarations

Ethics approval The research project was conducted following the principles outlined in the Declaration of Helsinki. The ethics approval was waived by the local university hospital review board according to an anonymized presentation of a single case.

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Key points

1. Malignant dAVFs carry a high risk of intracranial bleeding secondary to the cortical venous reflux; therefore, complete fistula obliteration is mandatory despite the complexity of the venous access.

2. To determine the most suitable venous access for transvenous embolization, the anatomy of venous drainage must be comprehensively assessed prior to the procedure.

3. Transcranial approach should be considered for direct sinus puncture when the transfemoral approach is not feasible due to the complex venous anatomy.

4. The hybrid operating room facilitates the combined approach of surgical and endovascular procedures.

5. A variety of techniques can be employed to precisely localize the sinus, such as indocyanine green videography, neuronavigation, and fluoroscopy.

6. In order to prevent complications such as sinus perforation, which may result in intracranial bleeding, cautious cannulation is required when performing direct sinus access.

7. Since the affected sinus typically divides into several compartments, complete embolization would be achieved if the venous drainage route is directly accessed.

8. Superior sagittal sinus puncture should be performed as anteriorly as possible to avoid venous complications in cases where sinus sacrification is required.

9. While coils are widely used due to their durability and controllability, liquid embolic materials may also be utilized in conjunction with coils to ensure that the fistulas are completely occluded.

10. Particular cases of dAVFs might benefit from a combined endovascular and surgical approach, making this a crucial skill for hybrid neurovascular surgeons.