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Dural arteriovenous fistula involving superior petrosal sinus with petrosal venous drainage in association with cerebral venous thrombosis: Literature review and illustrative case

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A R T I C L E I N F O

Keywords:
Dural arteriovenous fistula
Superior petrosal sinus
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A B S T R A C T

Background: Dural arteriovenous fistulas (DAVFs) involving superior petrosal sinus (SPS) and superior petrosal vein (SPV) are extremely rare. The pathogenesis of these fistulas remains unclear. We are illustrating 2 cases of DAVFs involving the superior petrosal sinus and veins associated with venous sinus thrombosis with a literature review.

Methods: We reviewed the literature using the PRISMA (preferred reporting items for systematic reviews and meta-analyses) guidelines focusing on DAVFs involving the SPS and/or SPV. Additionally, we searched for additional articles through the reference lists of the included studies.

Results: Our review yielded 20 articles from 1997 until 2022 involving 33 patients with 34 fistulas, including our 2 patients. The mean age was 55.1 ± 12.9 years (range 25–85), 54.5% were males (n = 18). The patients presented with hemorrhage in 36.4% (n = 12), and progressive myelopathy in 30.3% (n = 10). Most fistulas often had arterial supply from MMA, MHT, and/or OA. The fistulas had infratentorial drainage in 64.71% (n = 22), supratentorial drainage in 23.53% (n = 8), and both supra and infratentorial drainage in 11.76% (n = 4). In 27.3% (n = 9), cerebral venous thrombosis was mentioned or identified. Endovascular treatment was performed in 47.1% of cases (n = 16), surgery in 29.4% (n = 10), and combination of treatments in 23.5% (n = 8). A total of 30.3% (n = 10) of cases had incomplete recovery or poor result.

Conclusion: DAVFs involving the SPS and/or SPV are associated with aggressive natural history, requiring early diagnosis and prompt treatment, leading to good prognosis. These fistulas may be acquired in origin, probably secondary to cerebral venous thrombosis.

1. Introduction

Lawton et al.[1] categorized tentorial dural arteriovenous fistulas (DAVFs) into six types based on anatomic location, dural base, associated venous sinus, and direction of venous drainage. According to their classification, tentorial DAVFs were divided into galenic, straight sinus, torcular, tentorial sinus, superior petrosal sinus (SPS), and incisural DAVFs. DAVFs of SPS are located laterally where the tentorium joins the dura of the middle cranial fossa and drain into the superior petrosal vein (SPV) and its tributaries.

DAVFs involving the SPS and SPV are distinctly rare and account for approximately 1–5% of all intracranial DAVFs.[2–5] The pathogenesis of these fistulas remains unclear. We are illustrating 2 cases of DAVFs involving the superior petrosal sinus and veins associated with venous

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sinus thrombosis. We also review the literature of previously reported cases of DAVFs involving the SPS and/or SPV.

2. Methods

Using the PRISMA (preferred reporting items for systematic reviews and meta-analyses) guidelines, we reviewed the previously reported case and series which have enough clinical description and clearly demonstrated figures of DAVFs involving the SPS and/or SPV. A literature search was performed using the Ovid MEDLINE, Pubmed, Cochrane Database of Systemic Reviews, and Google Scholar (1997–2022) with following key words of "dural arteriovenous fistulas", "superior petrosal sinus", and "superior petrosal vein". Exclusion criteria included non-English-language articles, commentaries, and information from expert opinions. Additional articles were searched through the reference lists of included articles. The collected data in this review included the demographic data (i.e., patient gender and age), presentation, imaging findings, side of the fistula, arterial feeders and venous drainage of the fistula, presence of cerebral venous thrombosis or venous sinus occlusion, treatment, and neurological outcome after treatment.

3. Case illustration 1

A 36-year-old woman was admitted to local hospital because of progressive quadriparesis with bowel and bladder dysfunction for 2 weeks. Magnetic resonance (MRI) of the cervical spine was obtained and showed abnormal hypersignal intensity extending from the medulla oblongata to level of C7 (Fig. 1A). Provisional diagnosis was transverse myelitis, and she was treated with high dose intravenous corticosteroid for 3 days. Due to worsening symptoms, she was transferred to our institution for further investigation and proper management. Two years ago, she suffered from ectopic pregnancy following tubal sterilization failure. Subsequently, she had taken oral contraceptive pills for 2 years. The neurological examination revealed evidence of weakness of upper extremities (muscle strength 3/5) and lower extremities (muscle strength 0/5). Repeat MRI, obtained 1 week after initial MRI, was done on a 3 T MR scanner, and clearly demonstrated intradural flow voids along both ventral and dorsal surfaces of the spinal cord (Fig. 1B). In addition, contrast-enhanced MR angiography (MRA) disclosed dilatation of left SPV and spinal veins, leading to suspicion of intracranial DAVFs (Fig. 1C). Digital subtraction angiography (DSA) with angiographic computerized tomography in maximum intensity projection-reformatted images revealed DAVF involving the left superior petrosal sinus and vein, Cognard type V, supplied by branches of the posterior meningeal artery of vertebral artery, middle meningeal artery (MMA), and occipital artery (OA) with caudal drainage into spinal veins through perimedullary venous system (Fig. 2A–F). Transarterial embolization with Onyx 34 (Medtronic, Irvine, California) was successfully performed through the branch of left MMA (Fig. 2G and H). Control DSA confirmed complete obliteration of the fistula (Fig. 3A and B). Her postoperative course was uneventful. Contrast-enhanced MR venography (MRV), obtained 1 week after embolization, illustrated irregular and shaggy wall enhancement at the distal half of left transverse sinus with absent flow into the left sigmoid sinus, representing venous sinus thrombosis (Fig. 3C). Therefore, she was given standard anticoagulation therapy. Follow up MRI and MRA, obtained 2 months after embolization, showed resolution of venous congestion of the medulla oblongata and cervical cord and no recurrent of the fistula (Fig. 3D). The patient gradually improved until being able to walk with walking aid at 4 months. However, the problem of urinary incontinence remained, and she was sent to urologist for proper management.

4. Case illustration 2

A 55-year-old woman, with medical history of hypertension, type 2 diabetes mellitus, and dyslipidemia, was hospitalized to local hospital due to sudden loss of conscious and right hemiparesis. Cranial computed tomography (CT) scan revealed acute intraparenchymal hematoma at

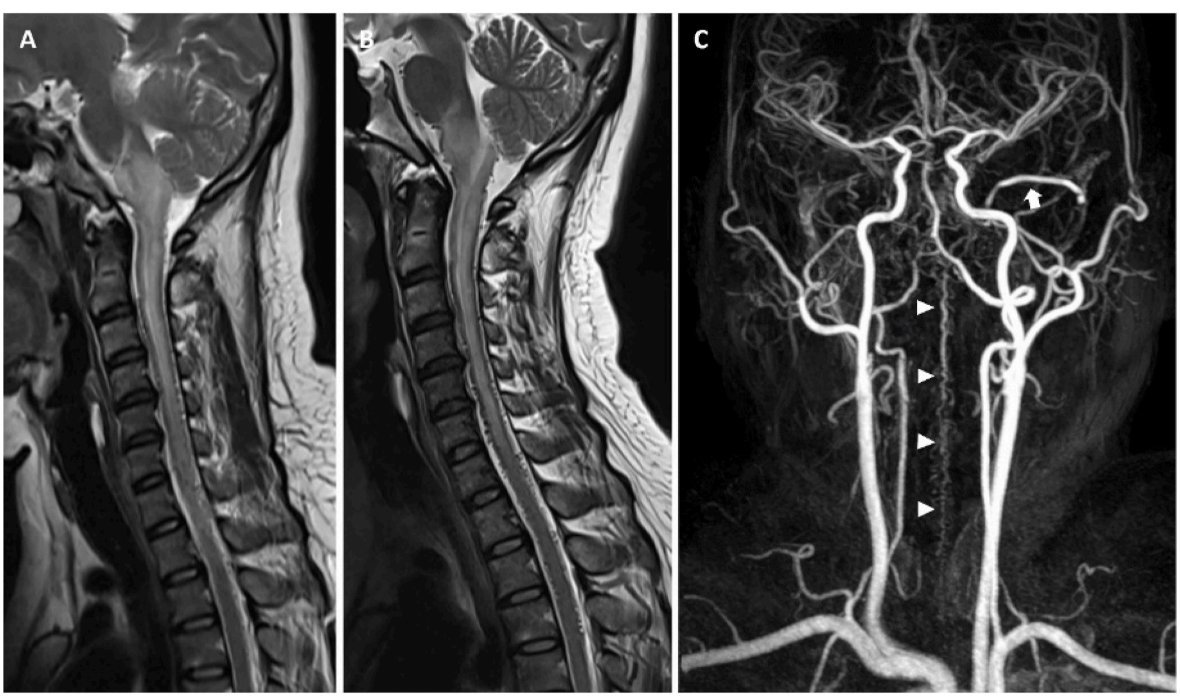

Fig. 1. Case illustration 1. (A) Sagittal T2-weighted image of the cervical spine on 1.5T magnetic resonance imaging (MRI) shows abnormal hypersignal intensity extending from the medulla oblongata to the level of C7, incorrectly interpreting as transverse myelitis from the local hospital. (B) Sagittal T2-weighted image of the cervical spine on 3T MRI, obtained 1 week after initial MRI, clearly reveals intradural flow voids along both ventral and dorsal surfaces of the spinal cord (C) Anteroposterior view of maximum intensity projection from contrast-enhanced MR angiography demonstrates the dilatation of the left superior petrosal vein (arrow) and spinal veins (arrowheads).

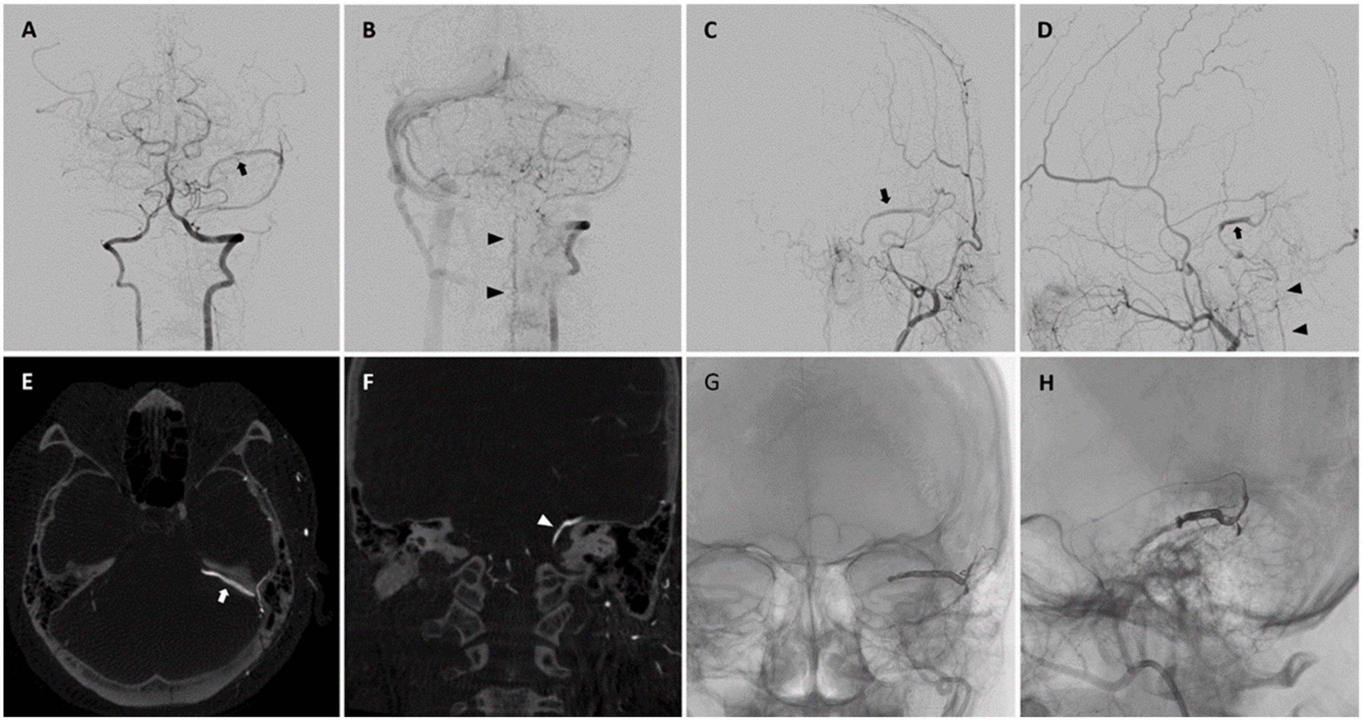

Fig. 2. Case illustration 1. Anteroposterior (AP) views of the left vertebral artery injection in (A) arterial and (B) venous phases and (C) AP and (D) lateral views of the left internal maxillary artery injection reveal a dural arteriovenous fistula involving the left superior petrosal sinus (black arrows) and vein. This fistula is supplied by posterior meningeal and middle meningeal arteries with caudal drainage into spinal veins (black arrowheads) through perimedullary venous system. (E) Axial and (F) coronal maximum intensity projection reformatted images of angiographic computerized tomography demonstrate the dilated superior petrosal sinus (white arrow) and vein (white arrowhead). (G) AP and (H) lateral views of unsubtracted image illustrate dense cast of Onyx.

the left lateral thalamus with intraventricular hemorrhage (Fig. 4A). She was treated conservatively and had nearly fully recovered. One week later, the patient developed drowsiness and CT scan showed obvious hydrocephalus (Fig. 4B). Emergency shunting was performed, and she regained fully conscious. Follow-up CT scan, obtained 1 week later, demonstrated markedly resolved thalamic hematoma and hydrocephalus (Fig. 4C). The following day, she developed generalized seizure and subsequent loss of consciousness. Cranial CT scan showed rebleeding of the left thalamic hemorrhage with large volume of blood in ventricles (Fig. 4D). The patient was transferred to our institution for further investigation and proper management. The neurological examination revealed evidence of quadriparesis (muscle strength 2/5) with a GCS score of 5T (E1VTM4). Emergency external ventricular drainage was performed to decrease intracranial pressure. Subsequently, a time-of-flight MRA disclosed dilatation of the left SPS, petrosal vein, and basal vein of Rosenthal (BVR). Intracerebral hemorrhage occurs in the vicinity of dilated left BVR with suspicion of venous aneurysm, probably being the cause of bleeding (Fig. 5). In addition, three-dimensional contrast-enhanced MRV revealed narrowing and irregularity of the left transverse sinus with absent flow in the left sigmoid sinus, representing venous sinus thrombosis (Fig. 6). DSA revealed a DAVF involving the remnant junction of the left transverse-sigmoid sinus and SPS, Cognard type IV, supplied by the branches of the left MMA and OA with upward drainage into the left BVR through the dilated lateral mesencephalic vein (LMV) (Fig. 7A–C). 3D rotational angiography clearly demonstrated a small venous aneurysm on the left BVR (Fig. 7D). Transarterial embolization with Onyx 34 was successfully done via the branch of left MMA (Fig. 7E and F). DSA following the embolization confirmed complete obliteration of the fistula (Fig. 7G and H). The patient gradually improved to GCS score of 7T (E2VTM5). Two weeks later, she was transferred back to the local hospital for rehabilitation program.

5. Results

Our search yielded 55 results with 1 duplicate record found. All studies were screened based on their titles and abstracts, and non-relevant studies (n = 30) were excluded. The remaining articles (n = 24) were then fully read for eligibility. Overall, 20 studies met the eligibility criteria for final review (Fig. 8).

From the literature review, there were 33 patients, including our 2 patients, with 34 DAVFs involving SPS and/or SPV due to bilateral lesions in 1 case (Table 1).[1–20] Eighteen (54.5%) males and 15 (45.5%) females with mean age was 55.1 $\pm$ 12.9 years, range 25–85 years, were included in this review. The patients presented with hemorrhage in 12 (36.4%) cases, progressive myelopathy due to edema of brainstem and/or spinal cord in 10 (30.3%), headache, tinnitus, and/or vertigo due to engorged veins and/or edema in cerebellum in 7 (21.2%), venous varix compressing the brainstem in 2 (6.1%), hemifacial spasm in 1 (3%), and incidental finding in 1(3%). The fistula was located on the right in 20 (58.8%), and on the left in 14 (41.2%). Most fistulas often had arterial supply from the meningohypophyseal trunk (MHT), MMA, and/or OA. Meningeal branches of the ophthalmic, internal maxillary, ascending pharyngeal, posterior auricular, vertebral, superior cerebellar, and anterior inferior cerebellar arteries were relatively infrequent. Most fistulas drained into the perimedullary venous system. The venous reflux drained into infratentorial veins (cerebellar and/or spinal veins) in 22 (64.71%) fistulas, supratentorial veins (BVR) in 8 (23.53%), and both supra and infratentorial veins in 4 (11.76%). Cerebral venous thrombosis was mentioned or identified in 9 (27.3%) cases. Sixteen (47.1%) fistulas were treated with endovascular treatment, ten (29.4%) with surgery, and eight (23.5%) with combination of endovascular and surgical treatments. Following treatment, twenty-one (63.6%) cases had good recovery, seven (21.2%) incomplete recovery, three (9.1%) poor result, and two (6.1%) no available data. One patient developed permanent hearing loss after combination of endovascular and surgical

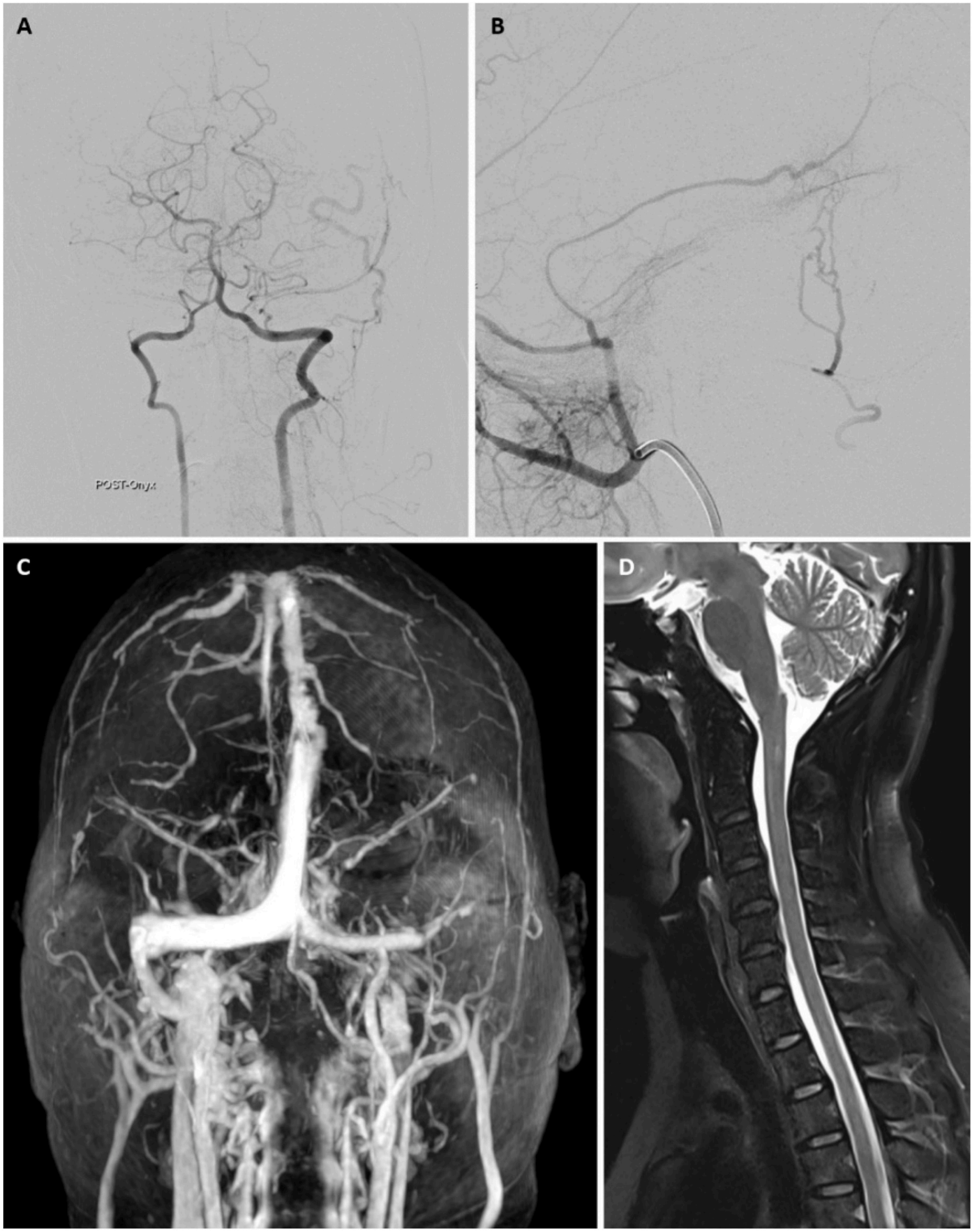

Fig. 3. Case illustration 1. (A) Anteroposterior view of the left vertebral artery and (B) lateral view of the left internal maxillary artery injections following the embolization confirm complete obliteration of the fistula. (C) Posterior view of three-dimensional contrast-enhanced magnetic resonance venography, obtained 1 week after embolization, reveals the disappearance of the dilated spinal veins and narrowing of the left transverse sinus with absent flow in the left sigmoid sinus, representing venous sinus thrombosis. (D) Sagittal T2-weighted image of the cervical spine, obtained 2 months after embolization, shows the resolution of venous congestion of the medulla oblongata and cervical cord.

treatments.

6. Discussion

6.1. Venous drainage patterns of DAVFs involving SPS and SPV

The most common tributaries of the superior petrosal venous system

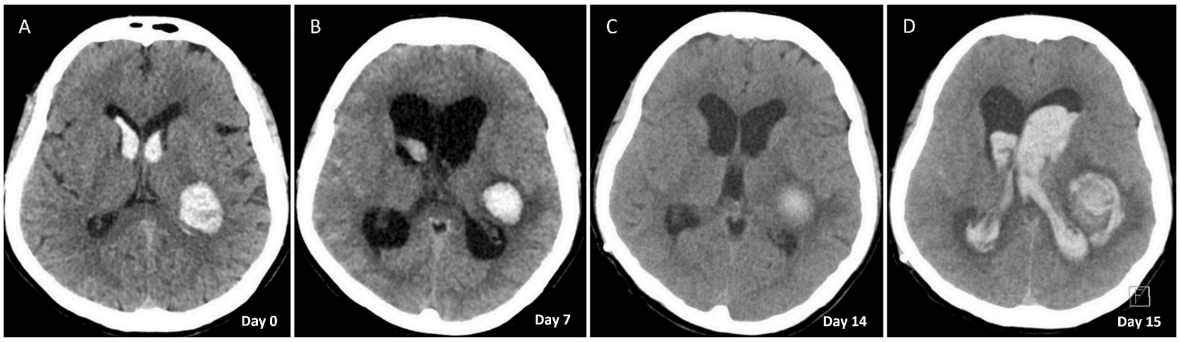

Fig. 4. Case illustration 2. (A) After initial presentation, axial cranial computed tomography (CT) scan shows the acute intraparenchymal hematoma at the left lateral thalamus with intraventricular hemorrhage. (B) At seventh day, axial CT scan reveals the resolved thalamic hematoma and hydrocephalus (C) At fourteenth day after shunting procedure, axial CT scan demonstrates markedly resolved hematoma and reduction of the ventricular dilatation (D) At fifteenth day, axial CT scan discloses rebleeding of the left thalamic hemorrhage with large volume of blood in the ventricles.

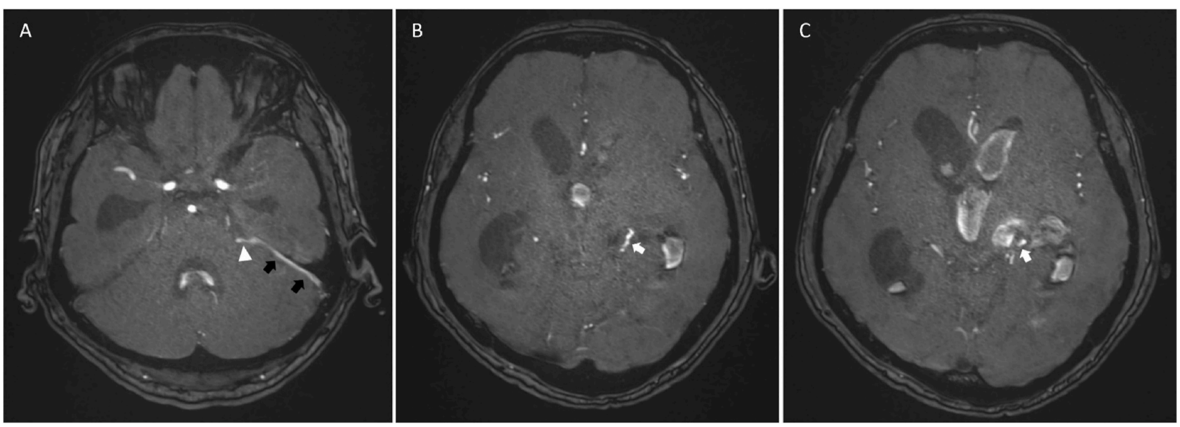

Fig. 5. Case illustration 2. (A–C) Sequential axial time-of-flight magnetic resonance angiography discloses the dilatation of the left superior petrosal sinus (black arrows), petrosal vein (arrowhead), and basal vein of Rosenthal (white arrows). Intracerebral hemorrhage occurs in the vicinity of the dilated left basal vein of Rosenthal with suspicion of venous aneurysm, probably being the cause of bleeding.

include the transverse pontine veins, pontotrigeminal veins, superior hemispheric veins, and veins of the cerebellopontine fissure and middle cerebellar peduncle. These 2 or 3 tributaries join and form a common trunk of the SPV which runs anterolaterally to join the SPS at a variable site along the petrous ridge.[24]

The patterns of drainage of the SPV drainage into the SPS are classified into 3 subtypes, including type I (19%), draining into the SPS above and lateral to boundaries of the internal acoustic meatus (IAM); type II (72%), draining into the SPS between lateral limit of the trigeminal nerve at Meckel cave and medial limit of the facial nerve at IAM; and type III (9%), draining into the SPS above or medial to boundaries of the Meckel cave.[22]

LMV, running in proximity of the mesencephalic sulcus, represents an important anastomosis pathway between the supratentorial and infratentorial compartments by connection of the third segment of BVR and petrosal system. The direction of venous drainage via the LMV is more frequently from the infratentorial to supratentorial area.[13,23]

From our literature review, DAVFs involving the SPS and SPV have 3 main different drainage patterns through the perimedullary venous system, including supratentorial drainage into the BVR, infratentorial drainage into cerebellar cortical veins, and infratentorial drainage into spinal medullary veins.

6.2. Clinical manifestations of SPS and/or SPV DAVFs

The determinant clinical manifestation of DAVFs involving the SPS and/or SPV is related primarily to the venous drainage pattern of fistulas.[12,25] Intracranial hemorrhage, including intracerebral hemorrhage, intraventricular hemorrhage or SAH, is the major manifestation of these fistulas and occurs either from dilated cortical, subarachnoid veins or venous aneurysm.[4,7,8,13,14] Retrograde venous reflux into the BVR may result in intracerebral hemorrhage near the thalamus that may be misinterpreted as hypertensive hemorrhage, as shown in our illustrative case. Retrograde leptomeningeal venous drainage to the cerebellar veins is responsible for cerebellar congestion and/or hemorrhage.[5,9,19]

Intracranial DAVFs, Cognard type V, can cause spinal myelopathy due to spinal perimedullary drainage from the fistulas through perimedullary venous system.[26,27] Progressive myelopathy due to the edema of spinal cord from venous hypertension is another major symptom of DAVFs involving the SPS and/or SPV.[9,11,14,18,20] However, patients harboring SPS and/or SPV DAVFs with myelopathy without dilated vascularity around the spinal cord on MRI were often unrecognized or misdiagnosed as transverse myelitis, Guillain-Barré syndrome, or neoplasm, leading to devastating morbidity or irreversible symptoms.[11,12,20] As shown in our illustrative case, the high-resolution MRI at 3.0 T may be helpful for demonstrating abnormal perimedullary flow voids around the brainstem and spinal cord. In addition, MRA is useful for localizing fistula location.

Furthermore, patients harboring DAVFs involving the SPS and/or SPV may present with trigeminal neuralgia or hemifacial spasm, caused by compression of cranial nerve V or VII, respectively, from the ectasia of SPV.[10,14]

Fig. 6. Case illustration 2. Posterior view of three-dimensional contrast-enhanced magnetic resonance venography reveals narrowing and irregularity of the left transverse sinus with absent flow in the left sigmoid sinus, representing venous sinus thrombosis.

6.3. *Intracranial DAVFs in association with venous sinus thrombosis*

The pathogenesis of cerebral DAVFs remains uncertain. It is generally accepted that these fistulas in adults are acquired. Intracranial DAVFs may be caused by venous thrombosis, which initiate and promote angiogenesis ingrowth into the thrombus of an occluded venous lumen, creating arteriovenous shunts from the meningeal arteries to neighboring venous lumen in or adjacent to dural sinus.[25] Recently, Kuiper et al.[21] studied association between DAVFs and cerebral venous thrombosis in 178 patients and found that one-third of patients harboring DAVFs were diagnosed with cerebral venous thrombosis. In almost two-third of patients, cerebral venous thrombosis was diagnosed prior to or concurrent with DAVFs. In 97% of patients with DAVFs and cerebral venous thrombosis, the thrombosis was located in the same or adjacent venous sinus as the DAVF. There was a female predominance in the DAVF with sinus thrombosis. Thrombosis was most frequently seen in the sigmoid (51%) and transverse (47%) sinuses.

Additionally, inherited or acquired thrombophilia and the use of oral contraceptives are critical related causes of venous sinus thrombosis and consequent DAVFs.[28–30] Furthermore, infectious diseases such as otitis media and mastoiditis can lead to thrombophlebitis and dural fistulas.[31–33]

From our review, cerebral venous thrombosis in association of DAVFs involving the SPS was identified in only 27.3% because concomitant sinus thrombosis was not be mentioned in many previously reported cases. However, Ng et al.[4] reported 18 cases of SPS DAVFs. The SPS was occluded in 15 (83%) cases. In this series, antegrade drainage of the SPS into the sigmoid sinus was occluded in 16 (60%) cases and stenotic in 2 (11%).

6.4. *Treatment strategy*

DAVFs involving the SPS and/or SPV require urgent treatment due to their potential risk of serious deterioration of neurological deficits.[12,14] Transvenous approach for these fistulas is difficult due to occlusion of the downstream SPS or significant stenosis proximal to its junction with the sigmoid sinus.[19] However, it was possible to treat these fistulas with transvenous coil embolization in limited cases.[4,7,16]

Because of multiple tiny feeding arteries from the MHT or MMA, it is

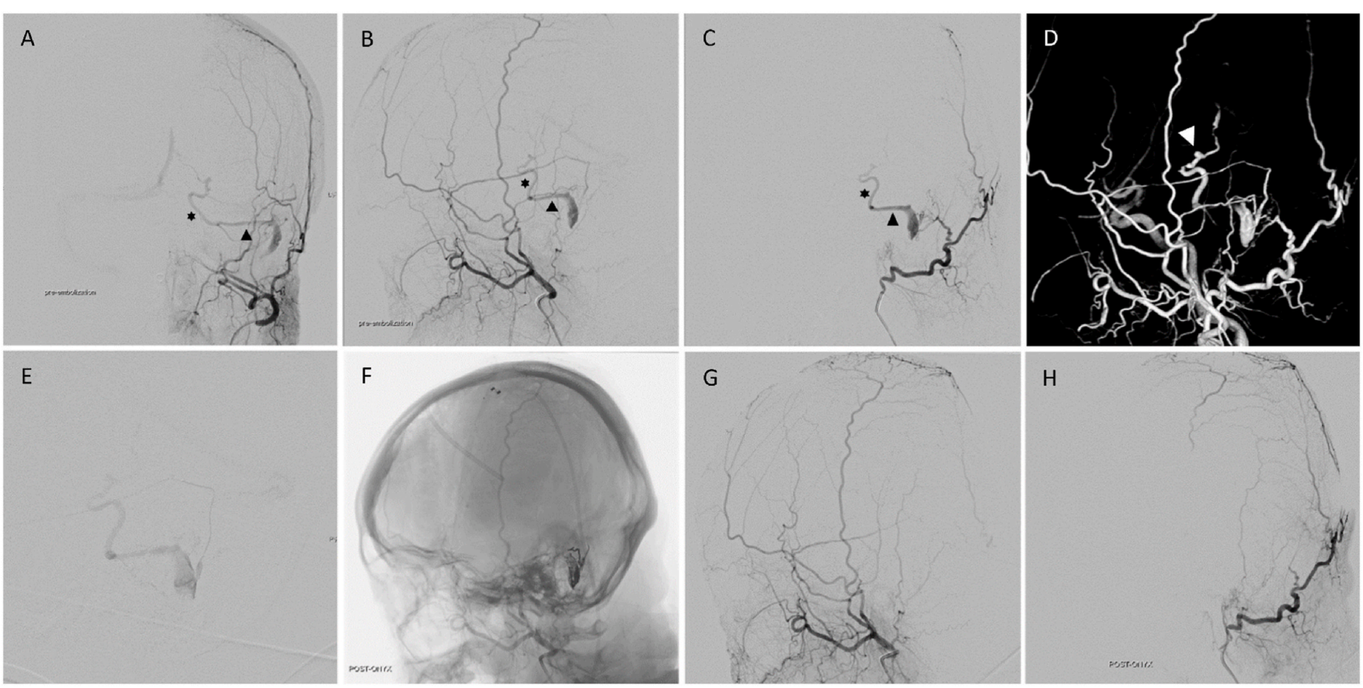

Fig. 7. Case illustration 2. (A) Anteroposterior and (B) lateral views of the left internal maxillary artery and (C) lateral view of the left occipital artery injections reveal the dural arteriovenous fistula involving the remnant junction of the left transverse-sigmoid sinus and superior petrosal sinus (arrowheads). This fistula is supplied by the branches of the left middle meningeal and occipital arteries with upward drainage into the left basal vein of Rosenthal (BVR) through the dilated lateral mesenteric vein (asterisks). (D) 3D rotational angiography clearly demonstrates a small venous aneurysm on the left BVR (E) lateral view of the superselective injection via the left middle meningeal artery before embolization. (F) Lateral view of unsubtracted image illustrates the cast of Onyx. Lateral views of the left (G) middle meningeal and (H) occipital arteries injections following the embolization confirm complete obliteration of the fistula.

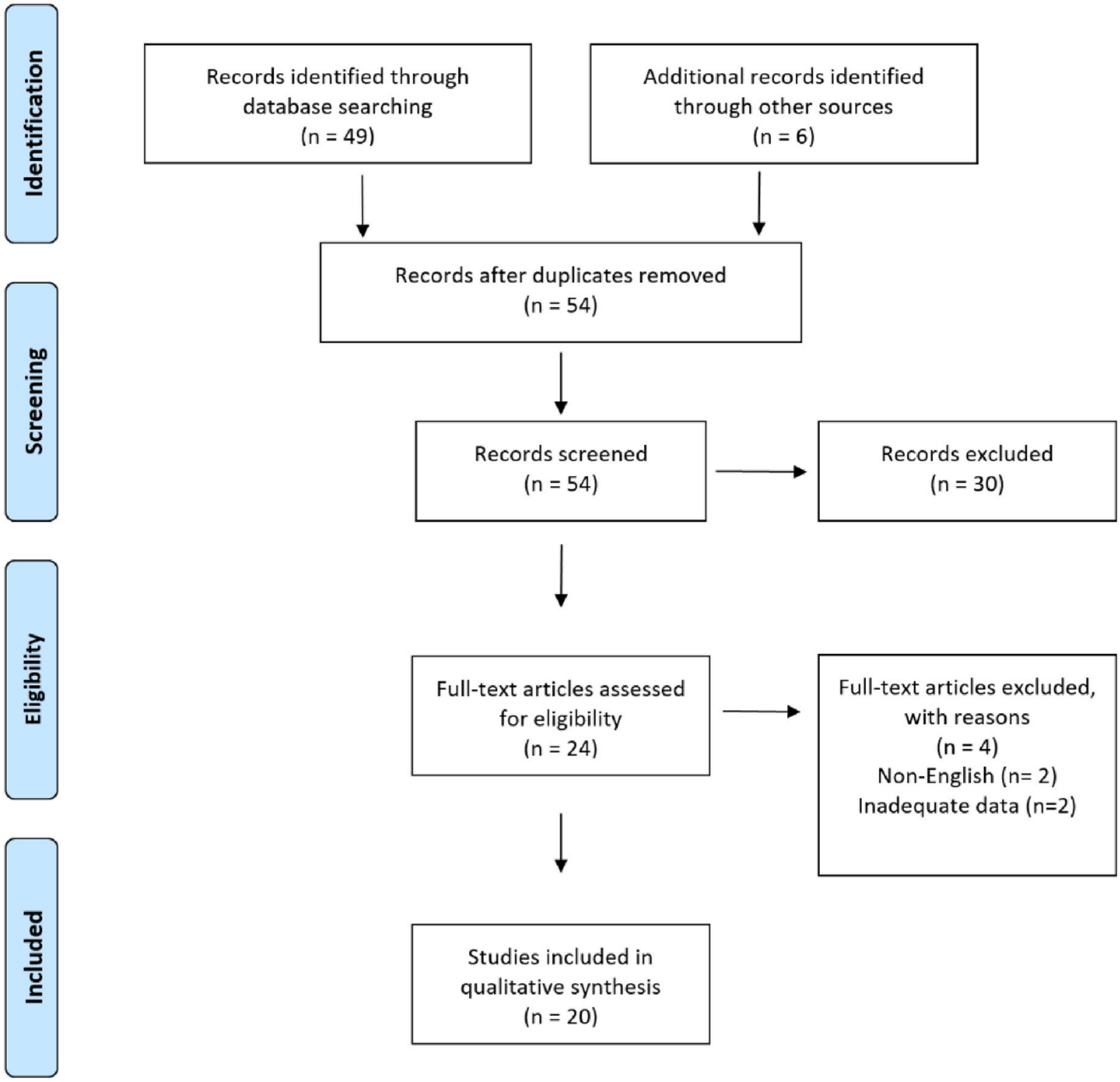

Fig. 8. Flow diagram showing a summary of our search strategy using the PRISMA (preferred reporting items for systematic reviews and meta-analyses) guidelines for relevant studies on dural arteriovenous fistulas involving superior petrosal sinus and/or superior petrosal vein.

also difficult to treat SPS and/or SPV DAVFs with transarterial embolization.[7,18] The introduction of an ethylene-vinyl alcohol (EVOH) copolymer-based liquid embolic agent, such as Onyx, has changed the treatment of intracranial DAVFs due to slow polymerization and non-adhesive properties providing reduced risk of microcatheter entrapment than N-butyl cyanoacrylate (NBCA) and prolonged embolization time resulting in more controlled injection.[34,35] Therefore, EVOH copolymer based liquid embolic agent may be the first choice for transarterial embolization via of these fistulas through the MMA, as shown in our illustrative cases. However, the risk of infarction in cranial nerves and recurrent or recanalization of the fistulas may occur following transarterial embolization with any liquid embolic materials.[4,7,15]

Surgery may be an effective treatment for DAVFs involving the SPS and/or SPV in many studies.[1,3,7–9,14,15,19,20] These fistulas can be treated by microsurgical interruption of the pathological dilated arterialized petrosal vein with preservation of other normal functional tributaries veins using indocyanine green video angiography.[1,14,18,19]

Due to the rarity of these fistulas, the preferable approach between microsurgical and endovascular treatment remains unclear. It is difficult to conduct a prospective study with the large numbers of patients. To create guideline to treat this rare disease, a further collaborative multicenter clinical study may be required for recruitment the large number of patients with DAVFs involving the SPS and/or SPV.

Importantly, early recognition of DAVFs involving the SPS and/or SPV and prompt treatment are the key to successfully managing these fistulas, leading to good prognosis.[19,20]

7. Conclusion

Dural arteriovenous fistulas (DAVFs) involving the SPS and/or SPV are extremely rare and associated with an aggressive natural history, requiring early diagnosis and prompt treatment, leading to good prognosis. Our illustrative cases may provide additional evidence supporting an acquired etiology of these fistulas, probably secondary to cerebral venous thrombosis.

CRediT authorship contribution statement

Prasert Iampreechakul: Conceptualization, Methodology, Writing – original draft, Writing – review & editing. **Korrapakc Wangtanaphat:** Resources, Software. **Songpol Chuntaroj:** Data curation, Validation.

Table 1
Literature review of patients with dural arteriovenous fistulas involving superior petrosal sinus and/or superior petrosal vein.

Authors	Gender/ Age	Symptoms and signs/Imaging findings on CT or MRI.	Side	Arterial feeders	Venous drainage/ CVT	Treatment	Neurological outcome
Branco et al (1997) [10]	M/72	A sudden onset of dull occipital headache and vertigo. Right parietal hemorrhagic infarction.	Lt.	MHT, MMA	LMV, BVR, SS, JV/-	•TVE with coils •TAE with liquid material	GR
Alleyne et al (2000) [2]	F/62	A 3-month history of difficulty focusing her eyes, tinnitus, and vertigo with any head movement. Engorged cerebellar hemispheric veins.	Lt.	MMA, OA	CV/+	•TAE with NBCA	GR
Satoh et al (2001) [21]	F/63	Coma. Acute hydrocephalus, a small hemorrhage in the cerebellum, and IVH.	Lt.	MMA, OA	LMV, CV/+	•TAE with NBCA	IR
	M/74	Coma. Massive cerebellar hemorrhage.	RT.	N/A	LMV, CV/N/A	•Surgery	PR
Ng et al (2003) [8]	M/39	Headache. Prominent flow voids in Meckel's cave and superior cerebellar recess.	RT.	MMA, MHT, APA, AMA, IMA, PAA, OphA, PMA	LMV, BVR/+	•TAE with PVA •Surgery	GR
	M/41	Left hemiparesis. Thalamic hemorrhage and IVH.	Rt.	MHT, MMA, OphA, AICA, SCA	LMV, BVR, CV/+	•TVE with coils	GR
Seong et al (2006) [16]	M/55	Progressive right-sided numbness for 6 months. Venous aneurysm in the CPA.	Rt.	MHT, MMA, IMA, APA, OA, AICA, PMA	PMV, CV/N/A	•TAE with NBCA and PVA •Surgery	GR HL (Rt.)
		Venous aneurysm in the perimesencephalic cistern, indenting the midbrain and extending into thalamus.	Lt.	MMA, MHT, OA, APA	LMV, BVR/N/A	•TAE with NBCA •TVE with coils	
Lawton et al (2008) [22]	M/59	Hematoma in the cerebellar peduncle, surrounding edema, and dilated veins in the CPA.	Lt.	MMA, MHT	CV/N/A	•TAE •Surgery	IR
Mitsuhashi et al (2009) [11]	M/45	Progressive motor and sensory disturbance in left extremities over the course of 4 months. Large, partially thrombosed varix compressing the right midbrain and thalamus with perifocal edema.	Rt.	MMA, MHT, ILT, OA, SCA	LMV, BVR/N/A	•TAE with NBCA	IR
	F/45	SAH	Rt.	MMA, AMA, MHT, OphA	PMV/N/A	•TAE with NBCA	GR
Kimura et al (2009) [4]	F/85	Head heaviness, nausea, and vomiting persisting for 3 weeks. Venous infarction of the cerebellum.	Rt.	MMA, OA, PAA	LMV, CV/+	•Failed TVE •Incomplete TAE •Surgery	GR
Hwang et al (2011) [17]	M/35	Progressive quadriparesis. Five months after first embolization, he developed sudden quadriplegia and severe respiratory difficulty.	Rt.	MMA, MHT, AMA, APA, OphA	PMV, SV/N/A	•TAE with NBCA •Surgery	IR
	F/68	Worsening headache, dizziness, and left-sided weakness. Venous congestion at midbrain, pons, and cerebellar hemisphere.	Rt.	MMA, MHT	PMV, CV/N/A	•Failed TAE •Surgery	IR
Li et al (2012) [18]	M/56	Severe chronic hemifacial spasm. A dilated petrosal vein.	Rt.	MHT, MMA, PICA	BVR, CV/N/A	•TAE with Onyx	GR
Gross et al (2014) [14]	F/34	Progressive worsening bilateral upper and lower extremity weakness over 1 week. Edema at medulla oblongata, cervical, and thoracic cord.	Lt.	OA	PMV, SV/+	•TAE with Onyx	GR
Kim et al (2015) [7]	M/61	Progressive cervical myelopathy, BBD. Swelling with diffuse enhancement of cervical cord and no dilated vascularity.	Lt.	MMA	PMV, SV/N/A	•TAE with NBCA	PR
Cannizzaro et al (2016) [23]	F/67	Incidental finding. A venous varix at the pontomesencephalic junction.	Rt.	MMA	LMV, BVR/N/A	•Failed TAE with Onyx •Surgery	GR
Li et al (2018) [19]	F/54	A 20-day history of limb weakness and sphincter dysfunction. Edema of brainstem and cervical cord.	Rt.	MHT	PMV, SV/N/A	•Surgery	GR
	M/53	Headache, nausea, and vomiting. SAH.	Rt.	MHT, MMA	CV/N/A	•TAE with Onyx	GR
	F/47	A 10-day history of occipital pain. Hemorrhage from venous ectasia.	Rt.	MHT, MMA, OphA	CV/N/A	•TAE with NBCA •Surgery	GR
Stapleton et al (2018) [6]	F/59	Acute onset headache and emesis. SAH.	Lt.	MMA, MHT, SCA	BVR, CV/N/A	•TAE with Onyx •Surgery	GR
	M/57	Acute onset headache. Extensive SAH and IVH.	Lt.	MMA, MHT	LMV, BVR/N/A	•TAE with Embospheres •Surgery	IR
	M/67	Chronic intermittent tinnitus. Congested cerebellar veins.	Lt.	MMA, MHT, OphA	CV/N/A	•TAE with Onyx	GR
Okuma et al (2019) [24]	F/67	A headache, vertigo, and nausea, followed by a disturbance of consciousness. SAH, ICH in cerebellum, and venous ectasia at CPA and extensive edema in the cerebellum.	Lt.	APA, MMA, OA	LMV, BVR, CV/+	•TVE with coils	GR
Ros de San Pedro et al (2019) [3]	M/49	A sudden episode of headache, photophobia, and dizziness.	Lt.	MMA	BVR/N/A	•Surgery	GR

(continued on next page)

Table 1 (*continued*)

Authors	Gender/ Age	Symptoms and signs/Imaging findings on CT or MRI.	Side	Arterial feeders	Venous drainage/ CVT	Treatment	Neurological outcome
		Hyperdense lesion in CPA (CT). Engorged SPV and BVR (MRI).					
Sun et al (2020) [20]	F/65	A 6-month history of progressive quadriplegia. Severe edema at medulla oblongata and cervical cord.	Rt.	MHT	PMV, SV/N/A	•Failed TAE •Surgery	GR
	F/54	A 3-month history of progressive bilateral weakness and BBD.	Rt.	MHT	PMV, SV/N/A	•Surgery	GR
	M/54	SAH 3 years ago. Progressive quadriplegia, dysphagia, and dyspnea. Edema at medulla oblongata and cervical cord.	Rt.	MHT	PMV, SV/N/A	•Surgery	GR
Su et al (2022) [5]	M/25	Weakness and numbness in his lower and upper limbs for 12 days. Edema at the medulla oblongata and cervical cord.	Rt.	MMA, MHT	SV/N/A	•Surgery	N/A
	M/54	Headache and right-sided tinnitus for 10 years. Flow void signs and edema in the cerebellum.	Rt.	MMA, OA, APA, OphA	LMV, BVR, CV	•TAE with Glubran and Onyx	N/A
Ohnishi et al (2022) [12]	M/62	A 2-year history of progressive lower limb weakness and numbness, urinary disturbance. Venous congestive cervical edema.	Rt.	MHT, MMA	PMV, SV/N/A	•Surgery	IR
Present study, 2023	F/36	Progressive quadriparesis with bowel and bladder dysfunction for 2 weeks. Edema at medulla oblongata and cervical cord.	Lt.	MMA, OA, PMA	PMV, SV/+	•TAE with Onyx	GR
	F/55	sudden loss of conscious and right hemiparesis. ICH at the left lateral thalamus with IVH. Rebleeding occurred 2 weeks later.	Lt.	MMA, OA	LMV, BVR/+	• TAE with Onyx	PR

AICA: anterior inferior cerebellar artery; AMA: accessory meningeal artery; APA: ascending pharyngeal artery; BBD: bowel and bladder dysfunction; BVR: the basal vein of Rosenthal; CPA: cerebellopontine angle CT: computed tomography; CV: cerebellar vein; CVT: cerebral venous thrombosis; F: female; GR: good recovery; HL: hearing loss; ICH: intracerebral hemorrhage; ILT: inferolateral trunk; IMA: internal maxillary artery; IR: incomplete recovery; IVH: intraventricular hemorrhage; JV: jugular vein; Lt: left; LMV: The lateral mesencephalic vein; M: male; MHT: meningohypophyseal trunk; MMA: middle meningeal artery; MRI: magnetic resonance imaging; N/A: not appliable; NBCA: N-butyl cyanoacrylate; OA: occipital artery; OphA: recurrent meningeal branch of ophthalmic artery; PAA: posterior auricular artery; PICA: posterior inferior cerebellar artery; PMA: posterior meningeal artery of the vertebral artery; PMV: perimedullary vein; PR: poor result; PVA: polyvinyl alcohol; Rt: right; SAH: subarachnoid hemorrhage; SCA: superior cerebellar artery; SS: sigmoid sinus, SV: spinal vein; TAE: transarterial embolization; TVE: transvenous embolization.

Sirirat Khunvutthidee: Investigation. **Yodkhwan Wattanasen:** Project administration. **Sunisa Hangsapruek:** Investigation. **Punjama Lertbutsayanukul:** Data curation, Visualization. **Somkiet Siriwimonmas:** Supervision, Writing – review & editing.

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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Abbreviation

BVR: Basal vein of Rosenthal
DAVFs: Dural arteriovenous fistulas
GCS: Glasgow Coma Scale
IAM: Internal acoustic meatus
LMV: Lateral mesencephalic vein
MMA: Middle meningeal artery
MHT: Meningohypophyseal trunk
OA: Occipital artery
SPS: Superior petrosal sinus
SPV: superior petrosal vein