Dural Arteriovenous Fistulas in the Parasellar Region Other Than the Cavernous Sinus

Masafumi Hiramatsu, Kenji Sugiu, Jun Haruma, Tomohito Hishikawa, Yu Takahashi, Satoshi Murai, Kazuhiko Nishi, Yoko Yamaoka, and Isao Date

Besides cavernous sinus (CS) dural arteriovenous fistulas (AVFs), AVF may develop around the parasellar region. They can cause various symptoms, and some of them may show similar symptoms to those of CS dural AVF. Therefore, these AVFs may be misdiagnosed as CS dural AVFs. In this review, we divided parasellar AVFs into four groups based on their locations related to the CS: anterior group (orbit), anterolateral group (sphenoid wing), posteroinferior group (inferior petrosal sinus and clivus), and posterior group (superior petrosal sinus and petrosal vein). Although parasellar AVFs share common points, there are many differences between the four groups. We herein discuss commonalities and differences in parasellar AVFs based on a review of the literature and our experience.

Introduction

The parasellar venous structures that connect to the cavernous sinus (CS) are the superior ophthalmic vein (SOV), sphenoparietal sinus, superficial middle cerebral vein (SMCV), uncal vein, venous plexus of the foramen ovale (pterygoid venous plexus), inferior petrosal sinus (IPS), basilar venous plexus, and superior petrosal sinus (SPS) (**Fig. 1A**). Arteriovenous fistulas (AVFs) may develop around these venous structures. AVFs in the parasellar region share common points, and their symptoms may mimic CS dural AVF. Furthermore, their angioarchitecture and treatment strategies differ depending on their locations. Therefore, it is important to consider the possibility of AVF in each location and make accurate diagnoses.

Department of Neurological Surgery, Okayama University Graduate School of Medicine, Dentistry and Pharmaceutical Sciences, Okayama, Okayama, Japan

Corresponding author: Masafumi Hiramatsu. Department of Neurological Surgery, Okayama University Graduate School of Medicine, Dentistry and Pharmaceutical Sciences, 2-5-1, Shikata-cho, Kita-ku, Okayama, Okayama 700-8558, Japan
Email: mhiramatsu@okayama-u.ac.jp

Based on their spatial relationship to the CS, we categorized parasellar AVFs into the following four groups: anterior group (orbit), anterolateral group (sphenoid wing), posteroinferior group (IPS and clivus), and posterior group (SPS and petrosal vein) (**Fig. 1B**). We reviewed the literature and discussed angioarchitecture, clinical presentations, and treatment strategies based on these groups (**Table 1**). We also described representative cases in these groups.

Angioarchitecture of the Anterior Group

A fistula of the anterior group is located within the orbit (**Fig. 2**). Its incidence has not been reported due to its rarity. This location does not include anterior cranial fossa dural AVF. Lv et al.[1] reviewed 26 intraorbital AVFs from their three cases and the literature. Intraorbital AVFs are mainly supplied by branches of the ophthalmic artery, followed by branches of the external carotid artery (ECA), such as the distal branches of the internal maxillary artery and middle meningeal artery (MMA). These features of feeders differ from CS dural AVF, which are mainly supplied by branches of the ECA, followed by meningeal branches of the internal carotid artery (ICA). Intraorbital AVFs drain into the SOV, inferior ophthalmic vein, or their tributaries. Their draining veins sometimes form a varix. These draining veins rarely connect to the CS and transvenous embolization (TVE) of the AVF via the IPS, and the CS can be applied in such cases.
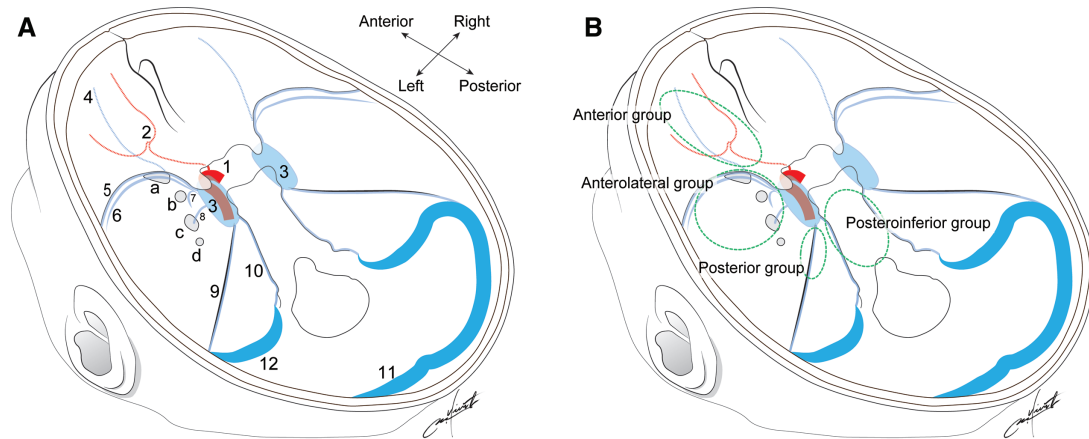
Fig. 1 (A) Schematic illustration of vessels and foramina in the skull base. 1 = ICA; 2 = ophthalmic artery; 3 = CS; 4 = SOV; 5 = sphenoparietal sinus; 6 = SMCV; 7 = uncal vein; 8 = venous plexus of the foramen ovale; 9 = SPS; 10 = IPS; 11 = transverse sinus; 12 = sigmoid sinus; a = superior orbital fissure; b = foramen rotundum; c = foramen ovale; d = foramen spinosum. (B) Each location of AVFs is divided into four groups. The anterior group consists of orbital AVF. The anterolateral group includes lesser and greater sphenoid wing dural AVF. The posteroinferior group includes IPS and clival AVF. The posterior group comprises SPS dural AVF. AVF: arteriovenous fistula; CS: cavernous sinus; ICA: internal carotid artery; IPS: inferior petrosal sinus; SMCV: superficial middle cerebral vein; SOV: superior ophthalmic vein; SPS: superior petrosal sinus

Table 1 Characteristics and symptoms of CS and parasellar AVF

Group	Location	Main feeder	Main drainer	Symptom	Sex ratio
CS	CS	ECA, ILT, MHT	CS– SOV/IPS	Benign	M < F
Anterior	Orbit	Ophthalmic artery	Ophthalmic veins	Aggressive	M > F
Anterolateral	Lesser sphenoid wing	ECA, ILT	Sphenoparietal sinus	Benign	M = F
	Greater sphenoid wing	ECA, ILT	SMCV	Aggressive	M = F
Posteroinferior	IPS	ECA	IPS	Benign	n.d.
	Clivus (osseous/dura)	APhA, MHT	Basilar venous plexus	Benign	M < F
Posterior	SPS	MMA, MHT	Petrosal vein	Aggressive	M > F

APhA: ascending pharyngeal artery; AVF: arteriovenous fistula; CS: cavernous sinus; ECA: external carotid artery; F: female; ILT: inferolateral trunk; IPS: inferior petrosal sinus; M: male; MHT: meningohypophyseal trunk; MMA: middle meningeal artery; n.d.: not described; SMCV: superficial middle cerebral vein; SOV: superior ophthalmic vein; SPS: superior petrosal sinus

An arteriovenous malformation (AVM) may also occur within the orbit.[2,3] It is difficult to distinguish intraorbital AVF from intraorbital AVM. Though it is arguable that we should distinguish AVM from AVF within the orbit, it is important to analyze whether the shunt involves the optic nerve and ocular bulb, and current imaging modalities using high-resolution cone-beam computed tomography (CBCT) and/or selective angiography are useful to display the accurate location of a shunt.[4–6] Intraorbital AVM may occur as a phenotype of genetic disease, such as Wyburn-Mason syndrome or hereditary hemorrhagic telangiectasia.[2,3] Luo et al.[2] reported that 13 out of 14 patients with Wyburn-Mason syndrome had orbital AVM. On the other hand, orbital trauma generally leads to the formation of intraorbital AVF.[1]

The anterior–posterior location of intraorbital AVF or the relationship between feeders and the central retinal artery is also important. It affects to the potential for and safety of transarterial embolization (TAE). TAE for the posterior location of intraorbital AVF supplied by branches of the first or second segment of the ophthalmic artery is associated with a greater risk of occlusion of the central retinal artery.[1]

Angioarchitecture of the Anterolateral Group

A fistula of the anterolateral group is located around the lesser (**Fig. 3**) and greater (**Fig. 4**) sphenoid wing. Shi et al.[7] reported 11 case series (3.4% of their cases of intracranial dural AVFs) of middle cranial fossa sphenoidal region dural AVF divided into five cases of lesser sphenoid wing dural AVF and six cases of greater sphenoid wing dural AVF. They concluded that lesser sphenoid wing dural AVFs were less likely to directly recruit cortical venous drainage but more likely to drain into the CS, whereas the majority of greater sphenoid wing dural AVFs connected to the SMCV and all greater sphenoid wing dural AVFs had
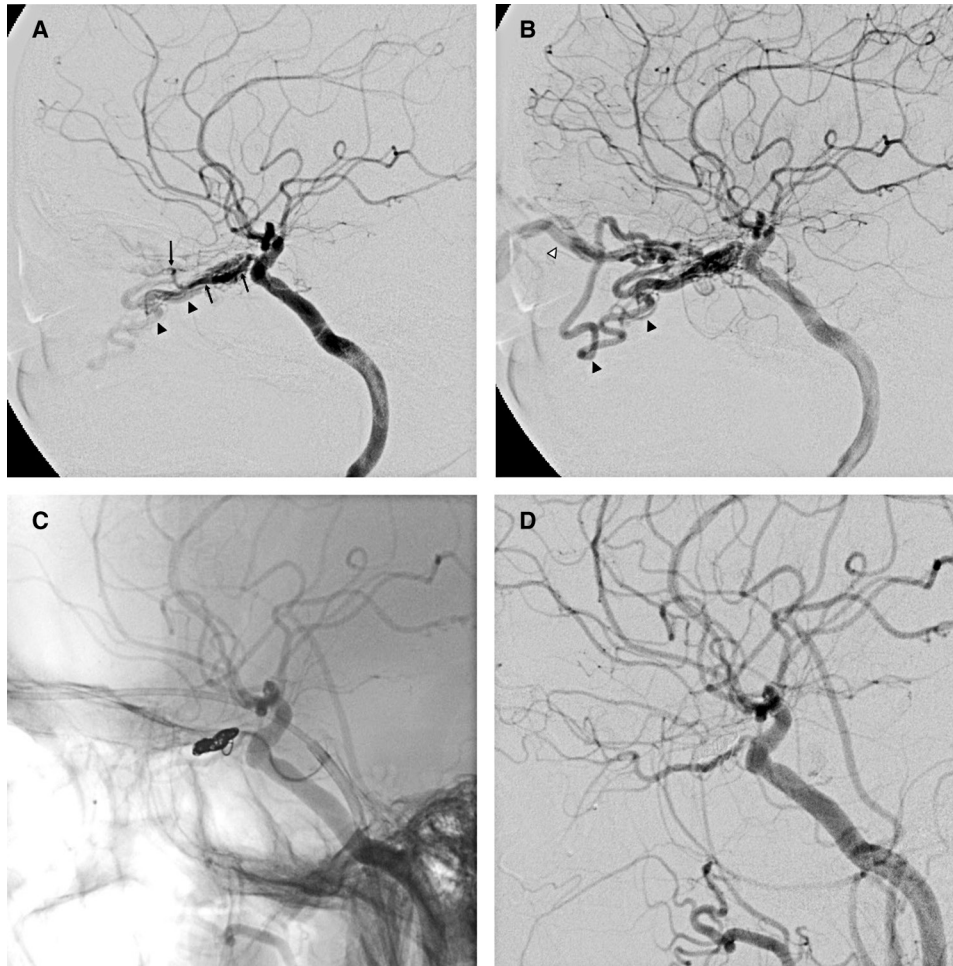
Fig. 2 An orbital AVF (the anterior group). (**A** and **B**) A 43-year-old male presented with right exophthalmos and chemosis. Early phase (**A**) and delayed phase (**B**) angiography from the right internal carotid artery revealed an AVF in the right orbit fed by the branch of the right ophthalmic artery (black arrow), draining to the right superficial temporal vein (not shown) through the right inferior (black arrowheads) and superior (white arrowheads) orbital veins. (**C**) Transvenous coil embolization of the drainer was performed via the right superficial temporal vein, SOV, and inferior ophthalmic vein using a transfemoral approach. The coil mass was located in the orbital apex and optic canal. (**D**) An angiogram of the right internal carotid artery revealed occlusion of the AVF. AVF: arteriovenous fistula; SOV: superior ophthalmic vein

varices. Kandyba et al.[8] explained these differences using illustrations.

Sphenoid wing dural AVFs are fed by branches of the ECA (the sphenoid branch from the anterior cranial branch of the MMA, the accessory meningeal artery [AMA], and the artery of the foramen rotundum [AFR]) and the ICA (the inferolateral trunk and recurrent meningeal artery from the ophthalmic artery). The arterial supply of both regions was previously shown to be similar.[7,9] Lesser sphenoid wing dural AVF typically drain into the sphenoparietal sinus connecting to the CS. This AVF occasionally exhibits venous reflux to the SMCV or basal vein of Rosenthal. Greater sphenoid wing dural AVFs typically drain into the SMCV. The SMCV may connect to the sphenobasal vein, sphenopetrosal vein, laterocavernous sinus, CS, deep middle cerebral vein, and other cortical veins.[7,9]

The greater sphenoid wing has some foramina, such as the foramen rotundum, ovale, lacerum, and spinosum. These foramina are covered by a periosteum, which is the outer layer of the dura mater. Dural AVF may occur in these foramina and may be regarded as greater sphenoid wing dural AVF. We present a case of dural AVF of the foramen rotundum in **Fig. 5**. Especially, the vein of the foramen ovale is an emissary vein from the CS to the pterygoid venous plexus; therefore, AVF around the foramen ovale may mimic to the CS dural AVF. Nomura et al.[10] reported a case of dural AVF of the sphenobasal sinus. According to their figure, the shunt can be located around the foramen ovale.
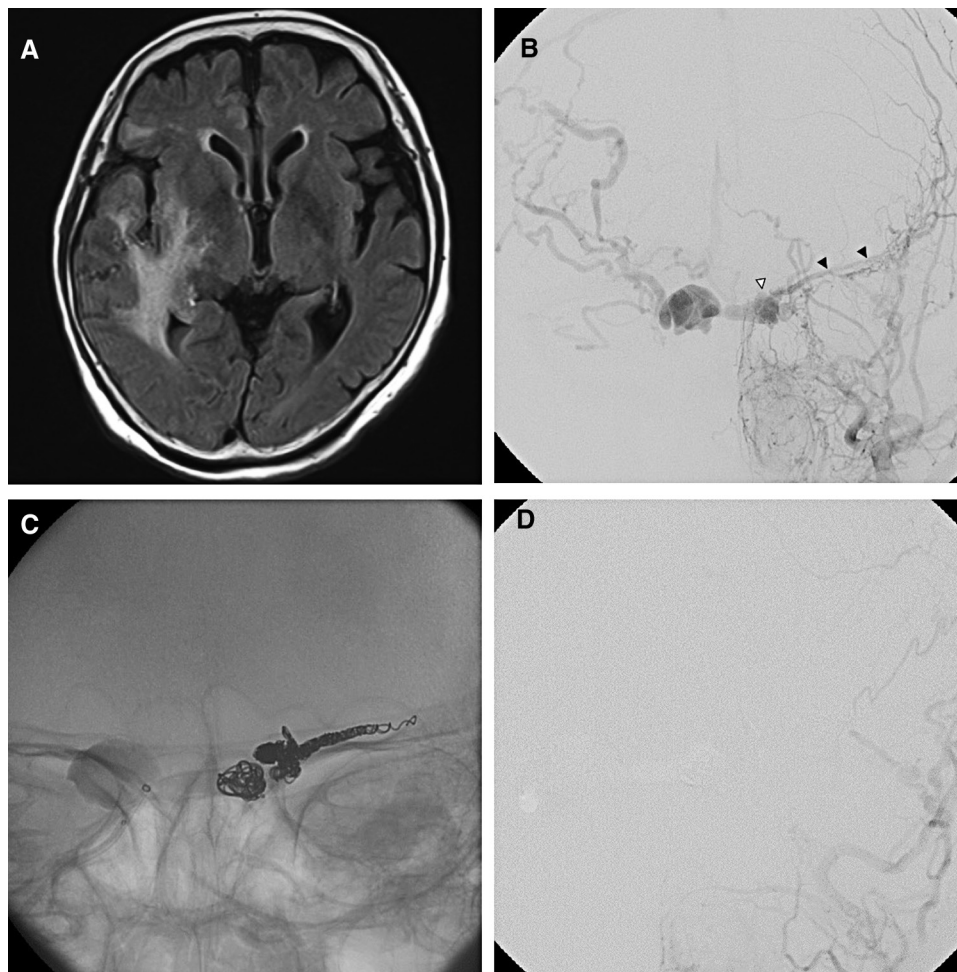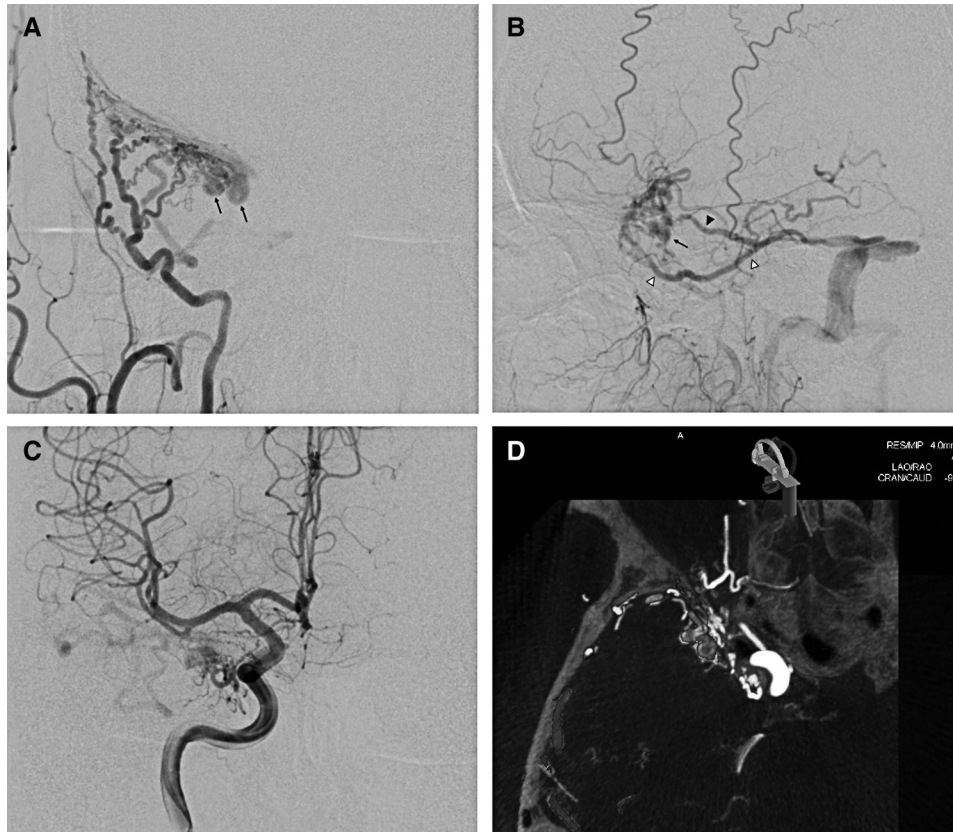
Fig. 3 A lesser sphenoid wing dural AVF (the anterolateral group). (**A**) A 78-year-old female presented with left hemiparesis and dysarthria. A fluid-attenuated inversion-recovery image revealed high-intensity signals in the right temporal lobe, basal ganglia, internal capsule, and thalamus. (**B**) An A–P view of the left external carotid angiogram revealed AVFs in the left lesser sphenoid wing (black arrowheads) and left CS (white arrowhead), draining to the right SMCV via the right CS and left basal vein of Rosenthal via the left CS. Note that there was no direct cortical venous reflux from the left sphenoparietal sinus. (**C**) Transvenous coil embolization of the left sphenoparietal sinus and left CS was performed via the right IPS and right CS using a transfemoral approach. (**D**) An angiogram of the left ECA revealed complete obliteration of the AVF. A–P: anterior–posterior; AVF: arteriovenous fistula; CS: cavernous sinus; ECA: external carotid artery; IPS: inferior petrosal sinus; SMCV: superficial middle cerebral vein

Angioarchitecture of the Posteroinferior Group

There is some confusion regarding the AVF belonging to this group. We included IPS dural AVF (**Fig. 6**) and clival AVF (**Fig. 7**) in this category. Many cases of IPS dural AVF reported in the literature were identified as AVF around the anterior condylar confluence (ACC) or hypoglossal canal.[11–14] In these cases, the IPS was only the drainage route, not the shunt point, and the shunt point was located below the level of the lower end of the IPS, which may be the ACC or hypoglossal canal. In our case of IPS

dural AVF (**Fig. 6**), the shunted pouch was located on the sinus wall of the IPS, and the shunt directly drained into the IPS. Since the IPS is one of the dural sinuses, dural AVF may develop in the IPS.

As a similar lesion in the IPS, there have been two case reports of AVF in the inferior petroclival vein (IPCV).[15,16] The IPCV communicates with the ACC or jugular bulb and CS, courses along the extracranial surface of the petroclival fissure, and is separated from the overlying IPS by a thin plate of bone.[17,18] The shunt points of these cases were confirmed by post-embolization CT images, which revealed a coil mass in the extracranial surface of the petroclival

Fig. 4 A greater sphenoid wing dural AVF (the anterolateral group). (**A**) A 54-year-old male presented with convulsions. An A–P view of the right external carotid angiogram revealed an AVF with varices (arrow) around the right sphenoid wing. (**B**) A lateral view of the right external carotid angiogram revealed that the AVF drained into the transverse/sigmoid sinus via the sphenopetrosal vein (white arrowheads) and the anterior temporal vein (black arrowhead) from the SMCV. (**C**) An A–P view of the right internal carotid angiogram revealed an AVF on the medial side of the right sphenoid wing. (**D**) A fusion slab maximum intensity projection image of the right internal and external carotid angiograms revealed an AVF on the greater sphenoid wing near the superior orbital fissure. A–P: anterior–posterior; AVF: arteriovenous fistula; SMCV: superficial middle cerebral vein

fissure. These AVFs drained caudally into the ACC or lower lesion of the IPS, draining to the IPS and CS. Therefore, these cases mimicked ACC dural AVF or CS dural AVF.

Reported cases of clival AVF may be divided into "dural" AVF[19–21] and "osseous" AVF.[22] Clival "dural" AVFs occur on the dura mater just above the dorsum of the clivus.[19–21] Clival "osseous" AVFs may occur in the venous channel within the bone of the clivus (**Fig. 7**).[22] Mizutani et al.[23] reported the detailed anatomy of venous channels within the clivus using multidetector CT digital subtraction venography.

Clival AVFs are mainly supplied by medial and lateral clival branches from the ascending pharyngeal artery and meningohypophyseal trunk (MHT) of the ICA.[20] Other feeders appear from the MMA, AMA, and anterior meningeal artery of the vertebral artery. Clival "dural" AVFs drain into the basilar venous plexus connecting to the CS or ACC via the IPS.[19,20] The basilar venous plexus is an epidural venous plexus that connects inferiorly with the anterior spinal epidural venous plexus; therefore, this lesion may be regarded as a possible homolog of spinal "epidural" AVF. The posterior aspect of the CS adjacent to the basilar venous plexus may connect to the anterior pontomesencephalic or transverse pontine veins via bridging veins.[24] Therefore, clival "dural" AVFs may drain into the bridging veins.[19,20] Clival "osseous" AVFs usually drain into the CS, IPS, and ACC.[23]

Angioarchitecture of the Posterior Group

SPS dural AVF (**Fig. 8**) is one of the subtypes of tentorial dural AVFs. Lawton et al.[25] reported operative strategies for and the microsurgical outcomes of tentorial dural AVFs based on six types and defined SPS dural AVFs as follows: SPS dural AVFs are located laterally where the tentorium
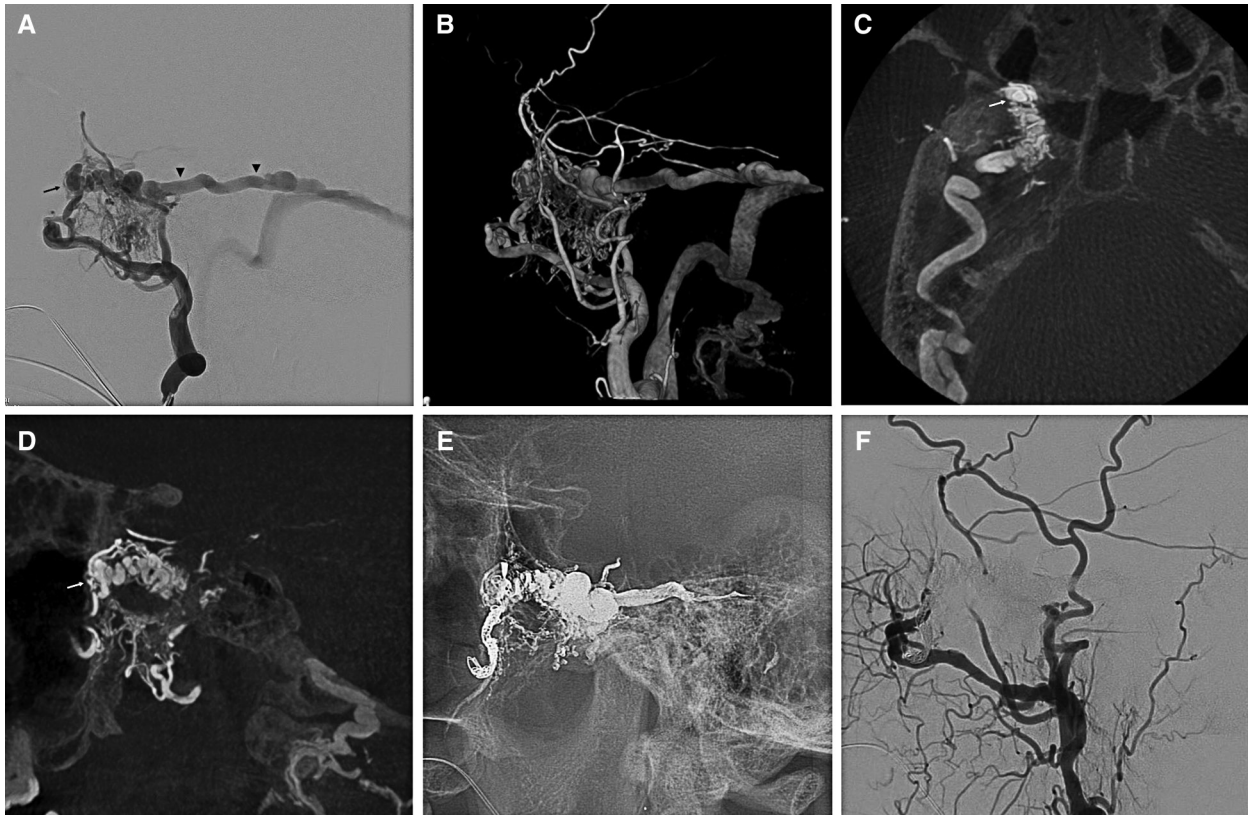
Fig. 5 A greater sphenoid wing dural AVF at the foramen rotundum (the anterolateral group). (**A**) A 60-year-old male presented with intracerebral hemorrhage in the left parietal lobe due to an AVF of the superior sagittal sinus (not shown). A lateral view of the right external carotid angiogram revealed another AVF around the right sphenoid wing that had no symptoms. The arrow shows the shunt point, and the arrowheads show the drainer (sphenopetrosal vein). (**B**) A 3D image (lateral view) of the right external carotid angiogram revealed an AVF fed by the AFR, vidian artery, MMA, and AMA. (**C** and **D**) Slab maximum intensity projection images (axial [**C**] and sagittal [**D**] views) of the right external carotid angiogram revealed that the AVF was at the foramen rotundum. White arrows show the shunt point. (**E**) TAE using Onyx was performed from the AFR. (**F**) A lateral view of the right external carotid angiogram revealed that the AVF was completely obliterated. AFR: artery of the foramen rotundum; AMA: accessory meningeal artery; AVF: arteriovenous fistula; MMA: middle meningeal artery; TAE: transarterial embolization

joins the dura of the middle cranial fossa, associated with the SPS, with infratentorial drainage to the petrosal vein and its tributaries. These AVFs have also been described as dural AVFs at the petrous apex in the literature.[26,27] The most distinctive characteristics of SPS dural AVFs are a predominant ICA supply from the tentorial artery of the MHT and venous drainage into the petrosal vein.[25,26,28,29]

Li et al.[26] reported the largest series (64 patients) of this location. Their analyses revealed that the dural branches (tentorial artery) of the MHT (98.4%) and MMA (84.4%) were the two most common feeders, whereas the dural branches of the internal maxillary artery (26.6%), ophthalmic artery (26.6%), occipital artery (20.3%), and ascending pharyngeal artery (10.9%) were relatively infrequent. They also identified pial feeding arteries from the cerebellar arteries in 40% of cases. Venous ectasia was detected in 50% of cases. They did not describe the patency of the SPS.

Ng et al.[28] reported 18 case series of SPS dural AVF, which was approximately 5% of 395 patients with dural AVF. The most common feeders were from cavernous ICA branches (83%), namely, the tentorial artery of the MHT. Moreover, feeders from cerebellar arteries were identified in 22% of cases. Venous ectasia or a varix was found in all but one case. The SPS was occluded in 15 cases (83%), and drainage to the CS was detected in one case.

In contrast to other groups of parasellar AVF, SPS dural AVFs rarely drain into the CS.[28,30] Although Toki et al.[30] reported tentorial dural AVF in this location with drainage to the CS, the drainage route to the CS was not the direct venous route of the medial part of the SPS, it was the petrosal vein, the transverse pontine vein (TPV), and the bridging vein between the TPV and CS. One reason for the rarity of drainage to the CS is the anatomical variety of the SPS. The complete type of the SPS, which has both medial and
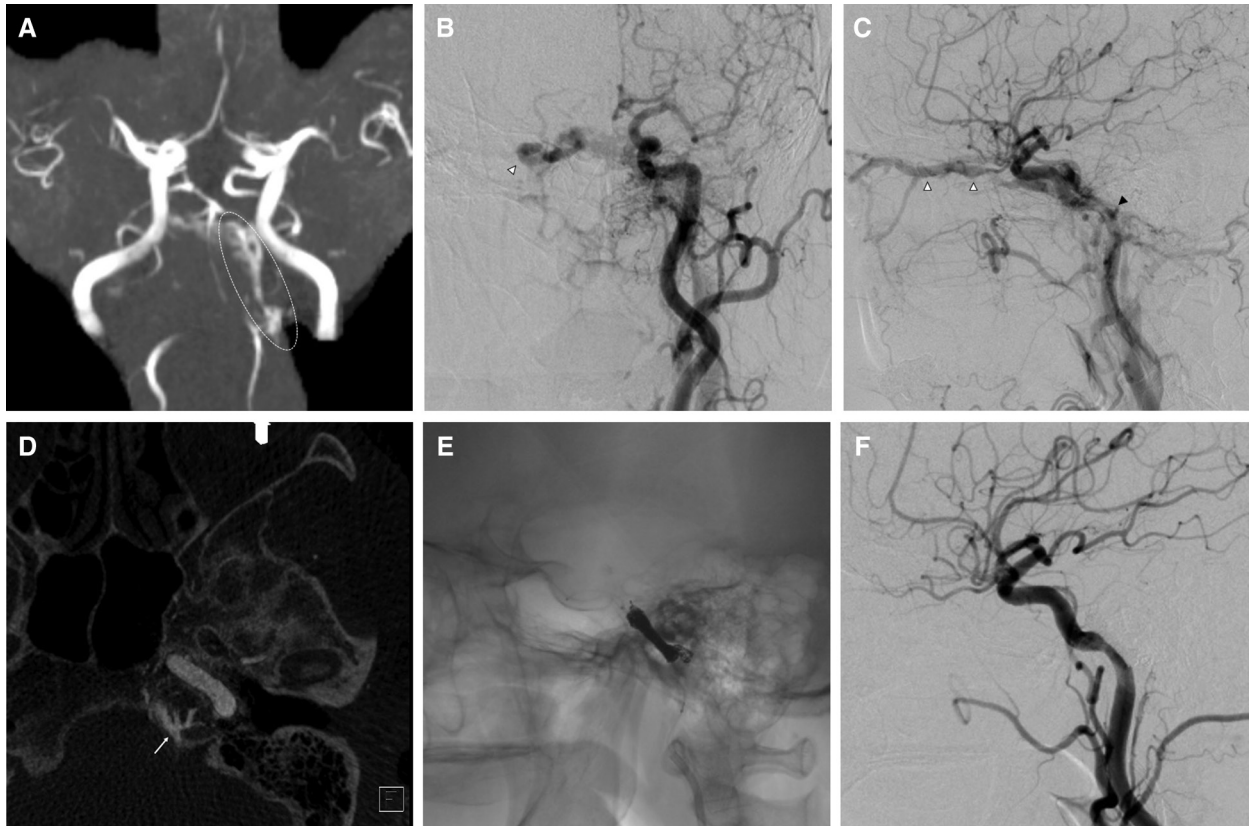
Fig. 6 An IPS dural AVF (the posteroinferior group). (**A**) A 64-year-old female presented with right exophthalmos, chemosis, double vision, and pulsatile tinnitus. An MRA image revealed abnormal vessels (white dotted circle) around the left IPS. (**B** and **C**): An A–P view (**B**) and lateral view (**C**) of the left common carotid angiogram revealed an AVF around the clivus that drained into the left internal jugular vein and right SOV (white arrowheads) via the left IPS (black arrowhead) and bilateral CSs. (**D**) Slab maximum intensity projection images (axial view) of the left common carotid angiogram revealed that the AVF (white arrow) was on the wall of the IPS fed by transosseous feeders and directly drained into the IPS. (**E**) Transvenous coil embolization of the left IPS was performed via the left internal jugular vein with a transfemoral approach. (**F**) A lateral view of the left common carotid angiogram revealed that the AVF was completely obliterated. A–P: anterior–posterior; AVF: arteriovenous fistula; CS: cavernous sinus; IPS: inferior petrosal sinus; SOV: superior ophthalmic vein

lateral segments of the SPS, accounts for 60% of the normal SPS, whereas the medial or lateral segment of the SPS was absent in residual cases.[31] On the other hand, superior petrosal veins, which connect to the SPS, are among the largest and most frequent veins in the posterior fossa.[32] Therefore, if part of the SPS is occluded, SPS dural AVF may easily develop venous reflux to the petrosal vein.

Clinical Presentation

The anterior group manifests with ocular symptoms of chemosis, exophthalmos, bruit, extraocular motor palsy, and loss of visual acuity due to the elevated venous pressure of the ophthalmic veins mimicking direct carotid-cavernous fistula or CS dural AVF. Hamada et al.[33] reported that orbital symptoms were frequently associated with not only the degree of the shunt but also the adequacy of external

drainage of the SOV; therefore, very slow flow shunts may result in severe symptoms because of poor or nonexistent external drainage. Lv et al.[1] found that intraorbital AVFs result in up to 30% visual deterioration because they involve a direct connection from the ophthalmic artery to the ophthalmic vein. This is more frequent in intraorbital AVFs than in CS dural AVFs, in which the frequency of diminished visual acuity was reported to be 11%.[34] In rare cases, intraorbital hematoma may occur due to rupture of the feeder aneurysm.[35] Lv et al.[1] reported that the mean patient age of spontaneous orbital AVFs was 61 years with a significant male predominance (male:female = 2:1) based on a review of 26 cases of this lesion.

The symptoms of the anterolateral group differ between greater and lesser sphenoid wing dural AVFs due to differences in their angioarchitecture. Ghali[9] reported that greater sphenoid wing dural AVFs were more likely to
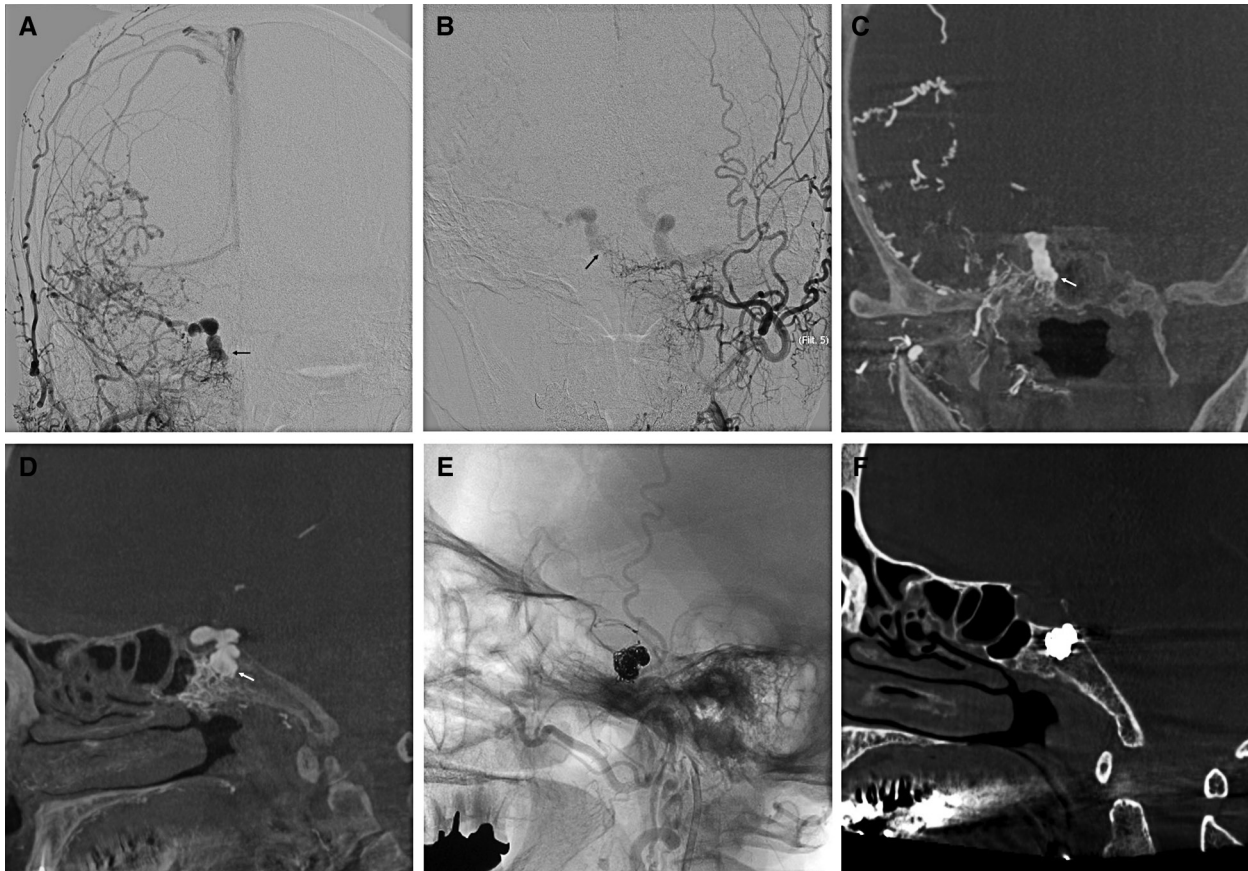
Fig. 7 A clival osseous AVF with CS drainage (the posteroinferior group). (**A**) A 77-year-old female presented with double vision due to right oculomotor nerve palsy. An A–P view of the right external carotid angiogram revealed an AVF (black arrow) around the right CS that drained into the right CS and right SMCV. (B) An A–P view of the left external carotid angiogram revealed the same shunted pouch (black arrow). (**C** and **D**) Slab MIP images (coronal [**C**] and sagittal [**D**] views) of the right external carotid angiogram revealed that the AVF (white arrows) was in the clival bone and drained into the right CS. (**E**) Transvenous coil embolization of the intraosseous shunted pouch was performed via the right IPS with a transfemoral approach. The AVF was completely obliterated after coil embolization (not shown). (**F**) A slab MIP image (sagittal view) of the bone and coil mass after embolization revealed that the coil mass was located within the clival bone. A–P: anterior–posterior; AVF: arteriovenous fistula; CS: cavernous sinus; IPS: inferior petrosal sinus; MIP: maximum intensity projection; SMCV: superficial middle cerebral vein

develop an aggressive clinical course, with a higher probability of cortical venous reflux and consequent intracranial venous hypertension, intracranial hemorrhage, and symptomatic presentation. In contrast, lesser sphenoid wing dural AVFs have a more benign clinical course because of prominent epidural venous drainage into the CS, thereby reducing the risk of cortical venous reflux and aggressive symptoms, similar to the nature of CS dural AVFs.[9] These descriptions are the general rule, with some exceptional cases being reported, such as lesser sphenoid wing dural AVF with aggressive symptoms.[36] Some case reports described sphenoid wing dural AVF with unique venous drainage solely into the SOV without CS drainage that caused ocular symptoms.[37,38] Shi et al.[7] showed that the mean patient age of sphenoid wing AVFs was 56 years, and there was no sex difference based on their 11 cases.

The majority of cases in the posteroinferior group present with ocular symptoms due to retrograde drainage to the CS and SOV.[20,22] This phenomenon is similar to anterior condylar AVF. Spittau et al.[39] conducted a systematic literature review of hypoglossal canal AVFs and divided them into three types: Type 1, with antegrade drainage (62.5%); Type 2, with retrograde drainage to the CS and/or orbital veins (23.3%); and Type 3, with cortical and/or perimedullary drainage (14.2%). Type 2 is associated with ocular symptoms and may mimic CS dural AVF. Other symptoms of the posteroinferior group are headache or bruit. Hemorrhage or venous congestion may occur in rare cases with cortical venous reflux.[19] Shi et al.[20] reported that mean patient age was 63 years with a significant female predominance (male:female = 1:4) based on their 10 cases of clival "dural" AVF.
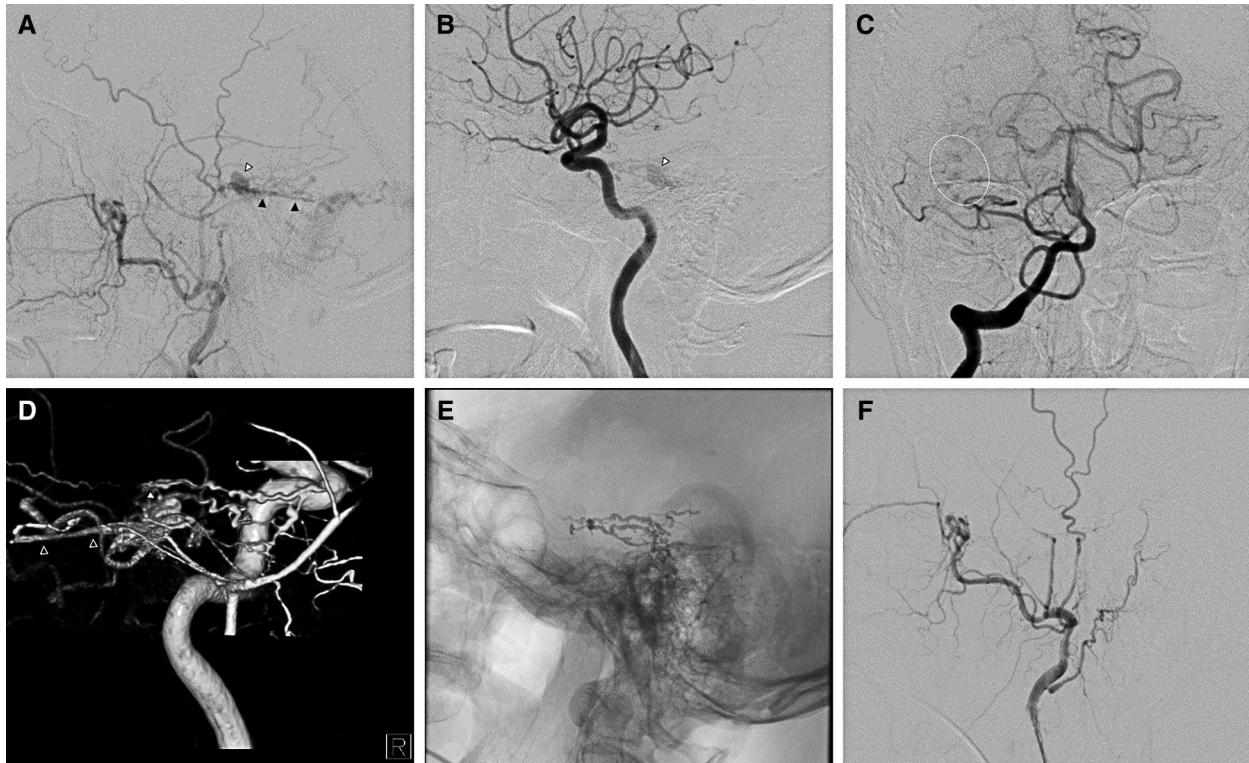
Fig. 8 An SPS dural AVF (the posterior group). (**A** and **B**) A 78-year-old male presented with syncope and an AVF was revealed by MRI. Lateral views of the right external (**A**) and internal (**B**) carotid angiogram revealed an AVF around the SPS (black arrowheads) that drained into the petrosal vein with a varix (white arrowhead). (**C**) An A–P view of the right vertebral angiogram revealed the same shunt (white dotted circle) fed by the subarcute artery of the right anterior inferior cerebellar artery. (**D**) A fusion image (lateral view) of the right internal and the external carotid arteries revealed the AVF around the petrosal vein (white arrowhead) with the SPS (black arrowheads). (**E**) A skull plain film after TAE using *n*-butyl-cyanoacrylate via the right MMA. (**F**) Lateral view of the right external carotid angiogram revealed that the AVF was completely obliterated. A–P: anterior–posterior; AVF: arteriovenous fistula; MMA: middle meningeal artery; SPS: superior petrosal sinus; TAE: transarterial embolization

Owing to the complex nature of the angioarchitecture, most cases in the posterior group manifest with aggressive symptoms, such as intracranial hemorrhage and venous infarction of the brain stem or cerebellum. Li et al.[26] reported eight cases (13%) with hemorrhage and 53 (83%) with non-hemorrhagic neurological defects, including 37 with brainstem edema, out of 64 cases. The reported rate of intracranial hemorrhage ranged between 13% and 63%.[25,26,28] A unique symptom of this location is trigeminal neuralgia, of which the reported rate ranged between 6% and 11%.[26,28] Trigeminal neuralgia may occur due to compression of the trigeminal nerve or trigeminal ganglion by tortuous feeding arteries or dilated arterialized draining veins in the cerebellopontine cistern. Other reported symptoms are headache and pulsatile tinnitus. Ocular symptoms may occur in cases with CS and SOV drainage.[28,30] Ng et al.[28] reported that 11% of their cases presented with ocular symptoms. Asymptomatic cases are rare. Li et al.[26] found that mean patient age was 49 years with a significant male predominance (male:female = 4:1) based on their 64 cases of dural AVF at the petrous apex.

Treatment

Treatment options for the anterior group are as follows: surgical interruption, TAE, and TVE. Lv et al.[1] reported that TVE was associated with a higher cure rate and better visual outcomes than other treatment options. There are some transvenous approach routes, most of which are the anterior approach of the SOV via the facial vein,[4,6] direct puncture,[40] or surgical exposure.[41] Surgical exposure may be difficult due to extensive hemorrhage.[5] Direct puncture and surgical exposure are specific treatment options in this shunt location, which is near the body surface. Rare cases may approach the ophthalmic veins via the IPS and CS from the femoral vein.[42] If the shunt has the possibility of intraorbital AVM, TVE needs to be avoided. In limited cases, TAE may be performed for orbital AVF[43] but is

associated with a risk of visual loss due to occlusion of the central retinal artery.[1] Therefore, for safe TAE of the ophthalmic artery, appropriate knowledge of anatomy, distal catheterization beyond the second part of the ophthalmic artery, and the injection of embolic material without reflux is necessary.[44] Direct surgical interruption needs to be selected in cases of treatment failure by embolization.

Various treatment strategies are available for the anterolateral group, and the surgical interruption of dural AVF at this location is easier than that of other parasellar AVFs.[7,10,45] The drainer may be approached using usual frontotemporal craniotomy. An extradural approach is sometimes required.[10] Lesser sphenoid wing AVFs may be treated using TVE via the IPS and CS approaches.[8] Regarding greater sphenoid wing AVFs, TVE may be difficult due to its drainage route. Shi et al.[7] reported six cases of greater sphenoid wing AVF, and one was treated by TVE from the vein of Galen, a procedure that is associated with a number of risks. TVE via the SOV may be a treatment option for limited cases with SOV drainage.[37,38]

Treatment strategies for the posteroinferior group differ between "dural" AVFs and "osseous" AVFs of the clivus. Most cases of clival "dural" AVFs are small and do not have a shunted pouch; therefore, TAE is the main treatment option.[20] However, since TAE may be difficult and dangerous because the target vessels are generally small and dangerous feeders, we need to consider other treatment options, such as direct surgery or stereotactic radiosurgery. Similar to CS dural AVF and anterior condylar AVF, clival "osseous" AVFs may be treated by TVE.[22] IPS dural AVFs may also be treated by TVE (**Fig. 6**).

In the posterior group, conservation is not recommended due to its aggressive features. The combination of TAE and subsequent direct surgery has been the main treatment strategy.[25,28] Lawton et al.[25] reported that most cases in this location were obliterated with an extended retrosigmoid approach. On the other hand, the development of embolic materials and strategies using liquid embolic agents has resulted in a high obliteration rate for TAE.[26] However, caution is needed when performing radical TAE because MHT from the ICA or pial feeders from cerebellar arteries are often involved in this location. Liquid material may migrate to the pial artery via these arteries. TVE has been reported in limited cases.[28,46] In contrast to the invisible IPS approach for CS dural AVF, TVE via invisible SPS is dangerous because conventional examination can not distinguish whether invisible SPS is occlusion or agenesis.[31] When we attempt to approach via the invisible SPS,

visualization methods of the occluded sinus are required for a safe procedure.[46]

Parasellar AVF may be misdiagnosed as CS dural AVF. Some previous cases of parasellar AVF were misdiagnosed as CS dural AVF before angiography.[5,6,15] Discrimination from CS dural AVF and precise shunt localization are essential for the selection of appropriate treatment strategies for parasellar AVFs. Maximum intensity projection or multi-planar reconstruction images of rotational angiography or CBCT facilitate more accurate diagnoses.[6,22] Moreover, parasellar and CS dural AVFs may co-exist.[47] We also encountered the co-existence of lesser sphenoid wing dural AVF and CS dural AVF (**Fig. 3**). When TVE is planned for a co-existence case, the embolization step is important. If the proximal lesion is treated by sinus packing, the distal lesion may become more dangerous due to flow conversion of the draining route.[34]

Conclusion

Although parasellar AVFs share some common points, there are many differences between the four groups. Precise diagnoses based on the latest and detailed imaging modalities and the development of treatment strategies based on angioarchitecture are needed.

Acknowledgment

Disclosure Statement

The authors declare that they have no conflicts of interest.

References

1) Lv X, Li W, Liu A, et al: Endovascular treatment evolution for pure intraorbital arteriovenous fistula: three case reports and literature review. *Neuroradiol J* 2017; 30: 151–159.

2) Luo CB, Lasjaunias P, Bhattacharya J: Craniofacial vascular malformations in Wyburn-Mason syndrome. *J Chin Med Assoc* 2006; 69: 575–580.

3) Van Went C, Ozanne A, Saliou G, et al: Spontaneous thrombosis of an orbital arteriovenous malformation revealing hereditary haemorrhagic telangiectasia (Rendu-Osler-Weber disease). A case report. *Interv Neuroradiol* 2011; 17: 466–471.

4) Deguchi J, Yamada M, Ogawa R, et al: Transvenous embolization for a purely intraorbital arteriovenous fistula. Case report. *J Neurosurg* 2005; 103: 756–759.

5) Huna-Baron R, Setton A, Kupersmith MJ, et al: Orbital arteriovenous malformation mimicking cavernous sinus dural arteriovenous malformation. *Br J Ophthalmol* 2000; 84: 771–774.

6) Sato M, Matsumaru Y, Amano T, et al: Orbital arteriovenous fistula around the optic nerve treated by transvenous embolization. *Turk Neurosurg* 2019; 29: 303–305.

7) Shi ZS, Ziegler J, Feng L, et al: Middle cranial fossa sphenoidal region dural arteriovenous fistulas: anatomic and treatment considerations. *AJNR Am J Neuroradiol* 2013; 34: 373–380.

8) Kandyba DV, Babichev KN, Stanishevskiy AV, et al: Dural arteriovenous fistula in the sphenoid bone lesser wing region: endovascular adjuvant techniques of treatment and literature review. *Interv Neuroradiol* 2018; 24: 559–566.

9) Ghali MGZ: Sphenoid dural arteriovenous fistulas. *Neurosurg Rev* Dec 7, 2019. [Epub ahead of print]

10) Nomura S, Anegawa S, Nakagawa S, et al: Subarachnoid hemorrhage caused by dural arteriovenous fistula of the sphenobasal sinus–case report. *Neurol Med Chir (Tokyo)* 2002; 42: 255–258.

11) Barnwell SL, Halbach VV, Dowd CF, et al: Dural arteriovenous fistulas involving the inferior petrosal sinus: angiographic findings in six patients. *AJNR Am J Neuroradiol* 1990; 11: 511–516.

12) Gentric JC, Ferré JC, Raoult H, et al: Endovascular treatment of inferior petrosal sinus dural arteriovenous fistula via percutaneous puncture of the superior ophthalmic vein. *J Neuroradiol* 2013; 40: 144–146.

13) Mironov A: Dural arteriovenous fistula of the inferior petrosal sinus producing contralateral exophthalmus. *Neuroradiology* 1994; 36: 619–621.

14) Yamada M, Miyasaka Y, Kitahara Y, et al: Dural arteriovenous malformation involving the inferior petrosal sinus–case report. *Neurol Med Chir (Tokyo)* 1994; 34: 300–303.

15) Hayashi N, Kawanishi M, Okubo S, et al: A case of dural arteriovenous fistula involving the inferior petroclival vein. *JNET J Neuroendovasc Ther* 2019; 13: 136–142.

16) Sugiura Y, Nishizawa S: Arteriovenous fistula involving the inferior petroclival vein--case report. *Neurol Med Chir (Tokyo)* 2011; 51: 45–47.

17) Tanoue S, Kiyosue H, Sagara Y, et al: Venous structures at the craniocervical junction: anatomical variations evaluated by multidetector row CT. *Br J Radiol* 2010; 83: 831–840.

18) Tubbs RS, Watanabe K, Loukas M, et al: Anatomy of the inferior petro-occipital vein and its relation to the base of the skull: application to surgical and endovascular procedures of the skull base. *Clin Anat* 2014; 27: 698–701.

19) Pouw AE, Rabin RL, Karanjia R, et al: Angioarchitectural evolution of clival dural arteriovenous fistulas in two patients. *Case Rep Ophthalmol* 2015; 6: 93–100.

20) Shi ZS, Ziegler J, Gonzalez NR, et al: Transarterial embolization of clival dural arteriovenous fistulae using liquid embolic agents. *Neurosurgery* 2008; 62: 408–415; discussion 415.

21) Urdaneta-Moncada A, Feng L, Chen J: Occlusion of a clival dural arteriovenous fistula using a novel approach through the foramen ovale. *J Neurointerv Surg* 2013; 5: e46.

22) Jung C, Kwon BJ, Kwon OK, et al: Intraosseous cranial dural arteriovenous fistula treated with transvenous embolization. *AJNR Am J Neuroradiol* 2009; 30: 1173–1177.

23) Mizutani K, Toda M, Kurasawa J, et al: Analysis of the venous channel within the clivus using multidetector computed tomography digital subtraction venography. *Neuroradiology* 2017; 59: 213–219.

24) Kiyosue H, Tanoue S, Sagara Y, et al: The anterior medullary-anterior pontomesencephalic venous system and its bridging veins communicating to the dural sinuses: normal anatomy and drainage routes from dural arteriovenous fistulas. *Neuroradiology* 2008; 50: 1013–1023.

25) Lawton MT, Sanchez-Mejia RO, Pham D, et al: Tentorial dural arteriovenous fistulae: operative strategies and microsurgical results for six types. *Neurosurgery* 2008; 62: 110–124; discussion 124–125.

26) Li J, Ren J, Du S, et al: Dural arteriovenous fistulas at the petrous apex. *World Neurosurg* 2018; 119: e968–e976.

27) Westermaier T, Bendszus M, Solymosi L, et al: Surgical treatment of dural arteriovenous fistulas of the petrous apex. *World Neurosurg* 2012; 77: 591.e7–591.e13

28) Ng PP, Halbach VV, Quinn R, et al: Endovascular treatment for dural arteriovenous fistulae of the superior petrosal sinus. *Neurosurgery* 2003; 53: 25–32; discussion 32–33.

29) Stapleton CJ, Patel AP, Walcott BP, et al: Surgical management of superior petrosal sinus dural arteriovenous fistulae with dominant internal carotid artery supply. *Interv Neuroradiol* 2018; 24: 331–338.

30) Toki N, Masuo O, Nishibayashi H, et al. Tentorial dural arteriovenous fistula presenting with ocular symptoms: a case report. *No Shinkei Geka* 2018; 46: 219–225. (in Japanese)

31) Matsushima K, Matsushima T, Kuga Y, et al: Classification of the superior petrosal veins and sinus based on drainage pattern. *Neurosurgery* 2014; 10 Suppl 2: 357–367; discussion 367.

32) Rhoton AL: The posterior fossa veins. *Neurosurgery* 2000; 47: S69–S92.

33) Hamada J, Morioka M, Kai Y, et al: Spontaneous arteriovenous fistula of the orbit: case report. *Surg Neurol* 2006; 65: 55–57; discussion 57.

34) Yoshida K, Melake M, Oishi H, et al: Transvenous embolization of dural carotid cavernous fistulas: a series of 44 consecutive patients. *AJNR Am J Neuroradiol* 2010; 31: 651–655.

35) Kirsch M, Henkes H: A ruptured intraorbital ophthalmic artery aneurysm, associated with a dural arteriovenous fistula: combined transarterial and transvenous endovascular treatment. *Minim Invasive Neurosurg* 2011; 54: 128–131.

36) Nakajima H, Ishiguro T, Terada A, et al: Dural arteriovenous fistula of the sinus of the lesser sphenoid wing presenting with pontine hemorrhage. *World Neurosurg* 2017; 98: 871.e17–871.e21.

37) Cohen JE, Gomori JM, Grigoriadis S, et al: Dural arteriovenous fistula of the greater sphenoid wing region in neurofibromatosis type 1. *Pediatr Neurosurg* 2008; 44: 172–175.

38) Misaki K, Uchiyama N, Mohri M, et al: Unique venous drainage of a sphenoid wing dural arteriovenous fistula with ocular symptoms. *World Neurosurg* 2017; 97: 753.e1–753.e5.

39) Spittau B, Millán DS, El-Sherifi S, et al: Dural arteriovenous fistulas of the hypoglossal canal: systematic review on imaging anatomy, clinical findings, and endovascular management. *J Neurosurg* 2015; 122: 883–903.

40) Lv M, Jiang C, Liu D, et al: Direct percutaneous transorbital puncture under fluoroscopic guidance with a 3D skull reconstruction overlay for embolisation of intraorbital and cavernous sinus dural arteriovenous fistulas. *Interv Neuroradiol* 2015; 21: 357–3611.

41) Naqvi J, Laitt R, Leatherbarrow B, et al: A case of a spontaneous intraorbital arteriovenous fistula: clinico-radiological findings and treatment by transvenous embolisation via the superior ophthalmic vein. *Orbit* 2013; 32: 124–126.

42) Williamson RW, Ducruet AF, Crowley RW, et al: Transvenous coil embolization of an intraorbital arteriovenous fistula: case report and review of the literature. *Neurosurgery* 2013; 72: E130–E134; discussion E134.

43) Konstas AA, Rootman DB, Quiros PA, et al: Transarterial embolization of a spontaneous intraorbital arteriovenous fistula with n-BCA glue. *Ophthalmic Plast Reconstr Surg* 2017; 33: e63–e64.

44) Matsumaru Y, Alvarez H, Rodesch G, et al: Embolisation of branches of the ophthalmic artery. *Interv Neuroradiol* 1997; 3: 239–245.

45) Kakarla UK, Deshmukh VR, Zabramski JM, et al: Surgical treatment of high-risk intracranial dural arteriovenous fistulae: clinical outcomes and avoidance of complications. *Neurosurgery* 2007; 61: 447–457; discussion 457–459.

46) Hosoo H, Tsuruta W, Nakai Y, et al: The visualization methods of occluded dural sinus for safe transvenous embolization of dural AVFs. *World Neurosurg* 2019; 127: e337–e345.

47) Watanabe T, Matsumaru Y, Sonobe M, et al: Multiple dural arteriovenous fistulae involving the cavernous and sphenoparietal sinuses. *Neuroradiology* 2000; 42: 771–774.