9 Dural Carotid-Cavernous Fistula Treatment

Anchalee Churojana, Ekawut Chankaew, and Ittichai Sakarunchai

Abstract

The aggressive characteristic of dural carotid-cavernous fistula (dCCF) is characterized by elevated intraocular pressure or the presentation of leptomeningeal venous drainage. It is necessary to treat an aggressive dCCF to prevent permanent secondary glaucoma and intracerebral sequelae. The endovascular approach is the treatment modality for dramatic improvement after fistula obliteration. Transvenous catheterizations are performed through the inferior petrosal sinus (IPS) and selection of coil packing within each of the venous drainage channel, such as cavernous sinus (CS)-superior orbital vein (SOV) junction, the connection between the CS and the leptomeningeal vein if there is presence of leptomeningeal drainage. An alternative to the CS and SOV approach can be performed using the transfemoral transvenous or percutaneous approach if cannulation of the IPS fails. Coils are mainly used as the embolic material rather than liquid embolic materials to prevent intracerebral complications and cranial nerve dysfunction. The angiographic endpoint of the endovascular procedure is either subtotal or complete occlusion of the fistula. Any small residual non-aggressive angiographic characteristic can be completely obliterated in a future surgery after routine clinical and radiological follow-up. The results are excellent with a low rate of complications. However, dCCF treatment requires experienced operators with a good understanding of the angiographic architecture and the appropriate skills in endovascular techniques.

Keywords

Dural carotid-cavernous fistula · Endovascular treatment · Transvenous catheterization · Coil embolization · IPS cannulation

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9.1 Introduction

Dural carotid-cavernous fistulas (dCCFs) or indirect carotid-cavernous fistulas are defined as an abnormal connection between the dural branches of either the external or internal carotid artery and the cavernous sinus (CS) [1]. Bilateral dCCFs are not uncommon [2].

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A dCCF is the most frequent dural arteriovenous shunt, and the incidence is more common in Asian populations than in Western countries [3]. Although the exact etiology is unknown, dCCFs are considered to be an acquired disease following different triggers such as venous thrombosis, trauma, or infection [4].

Clinical presentations depend on the pattern of venous drainage of the shunts. Most dCCFs have orbital venous congestion symptoms such as chemosis, exophthalmos, bruit, or visual acuity impairment [5–7]. However, dCCFs with cortical venous reflux are associated with the potential risk of neurological deficits or even intracranial hemorrhage (Fig. 9.1) [4–7].

Nevertheless, arteriovenous fistulas or dural arteriovenous shunts in other locations may drain toward the CS and ophthalmic vein (Figs. 9.2 and 9.3) [8]. Furthermore, cerebral venous drainage may convert into the cavernous sinuses as a rerouting pathway in the presence of venous hyperpressure from an intracranial dural venous thrombosis or venous obstruction (Fig. 9.4) [7]. These conditions may have clinical presentations mimicking a dCCF.

The current classifications for dural arteriovenous fistulas are from Borden, Cognard, and the Bicetre group. They are helpful in understanding the morphology and predicting the natural history or prognosis leading to proper options and timing for treatment (Table 9.1) [7, 9, 10]. However, in the case of dCCFs, these existing classifications are not applicable for practical use in planning treatment. They do not incorporate the special characteristics of dCCFs, such as unilateral or bilateral shunt location, ipsilateral, contralateral or bilateral venous drainage, and the relevant antegrade drainage of the inferior petrosal sinus (IPS). Even the modified Cognard classification, which attempted to describe the morphology and characteristics of shunts and venous drainage [11], does not satisfactorily decide on the proper treatment of fistulas.

In our therapeutic strategy, dCCFs are classified into two groups according to presentation and the pattern of venous drainage.

1. The benign group shows antegrade drainage to the IPS or only retrograde drainage into the superior ophthalmic vein (SOV). Clinically the orbital symptoms of congestion are minimal, and intraocular pressure can be controlled medically. In this group, according to the natural history, spontaneous regression can be expected. In particular, if the SOV is not visualized during manual compression, delayed SOV thrombosis can be anticipated. Patients are then advised to perform this maneuver. Usually, invasive treatment is not required (Fig. 9.5) [7].
2. The aggressive group includes dCCFs with the presence of cortical venous reflux, or even dCCFs with SOV drainage only but uncontrolled elevated intraocular pressure. It is necessary to treat aggressive dCCFs to prevent permanent brain damage, intracranial hemorrhage, or secondary glaucoma (Figs. 9.1 and 9.6).

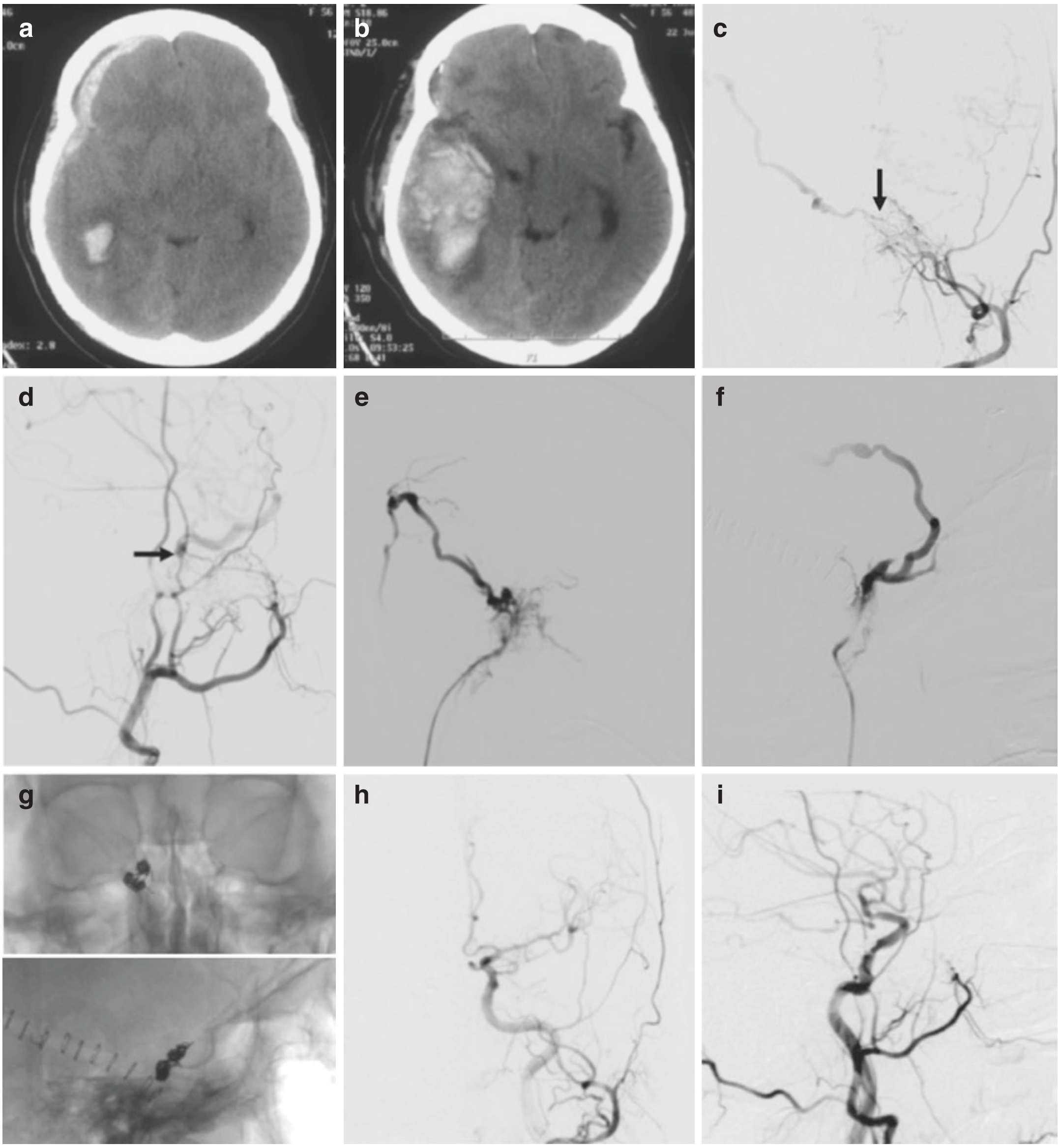


Fig. 9.1 Hemorrhagic presentation of an aggressive dCCF. (**a**) A 56-year-old male with nontraumatic right subdural hematoma and right temporal hemorrhage. (**b**) Expansion of right intraparenchymal hemorrhage after subdural hematoma removal. (**c**, **d**) AP and lateral projection of a left external carotid angiogram showing right dCCF (arrow) supplied from the contralateral middle meningeal artery and the artery of the foramen rotundum, draining into the right superficial middle cerebral vein with subsequent cortical reflux. (**e**, **f**) Blind recanalization of the right inferior petrosal sinus on AP and lateral views. (**g**) Fibered coil deposition in the right cavernous sinus on AP and lateral views. (**h**, **i**) AP and lateral views of controlled left common carotid angiogram revealing complete cure of right dCCF

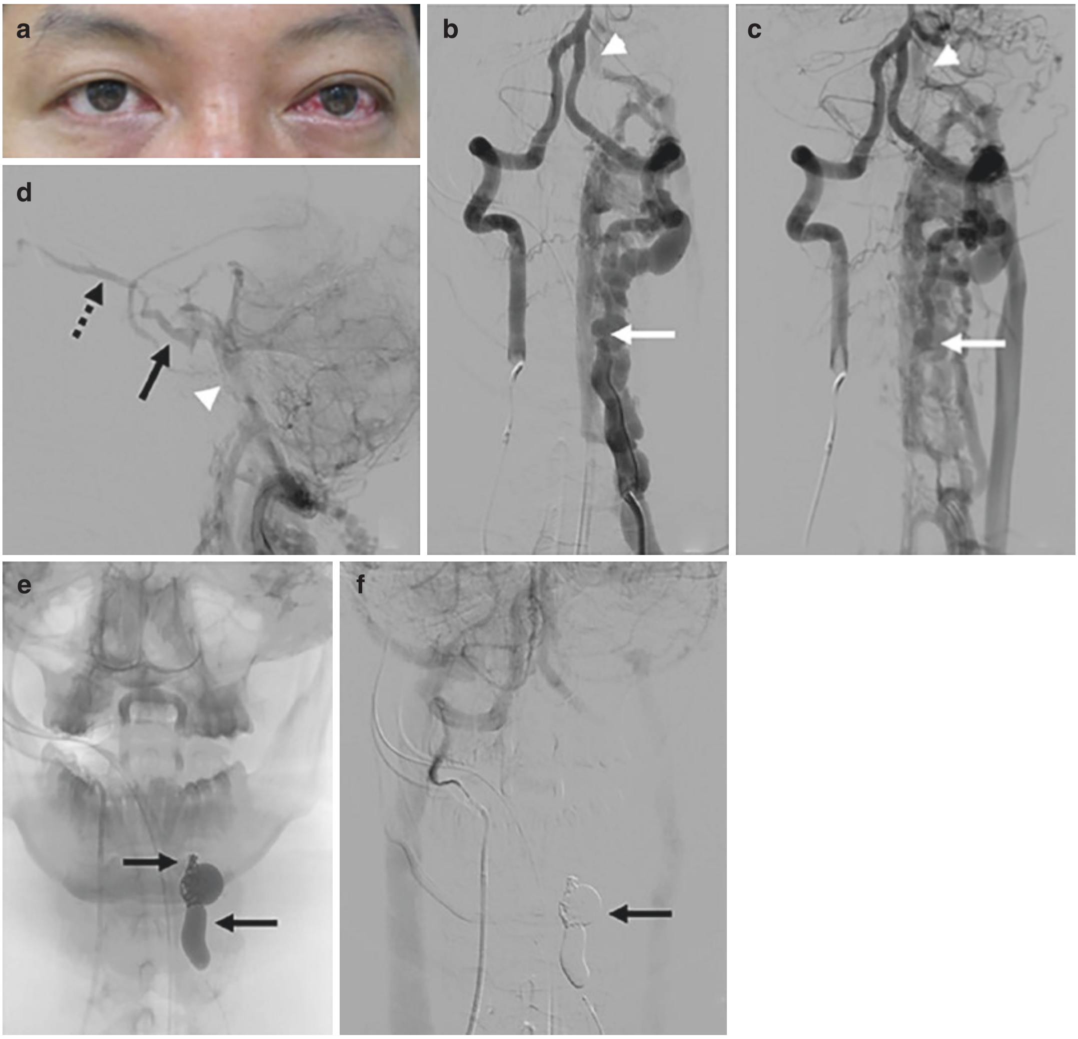
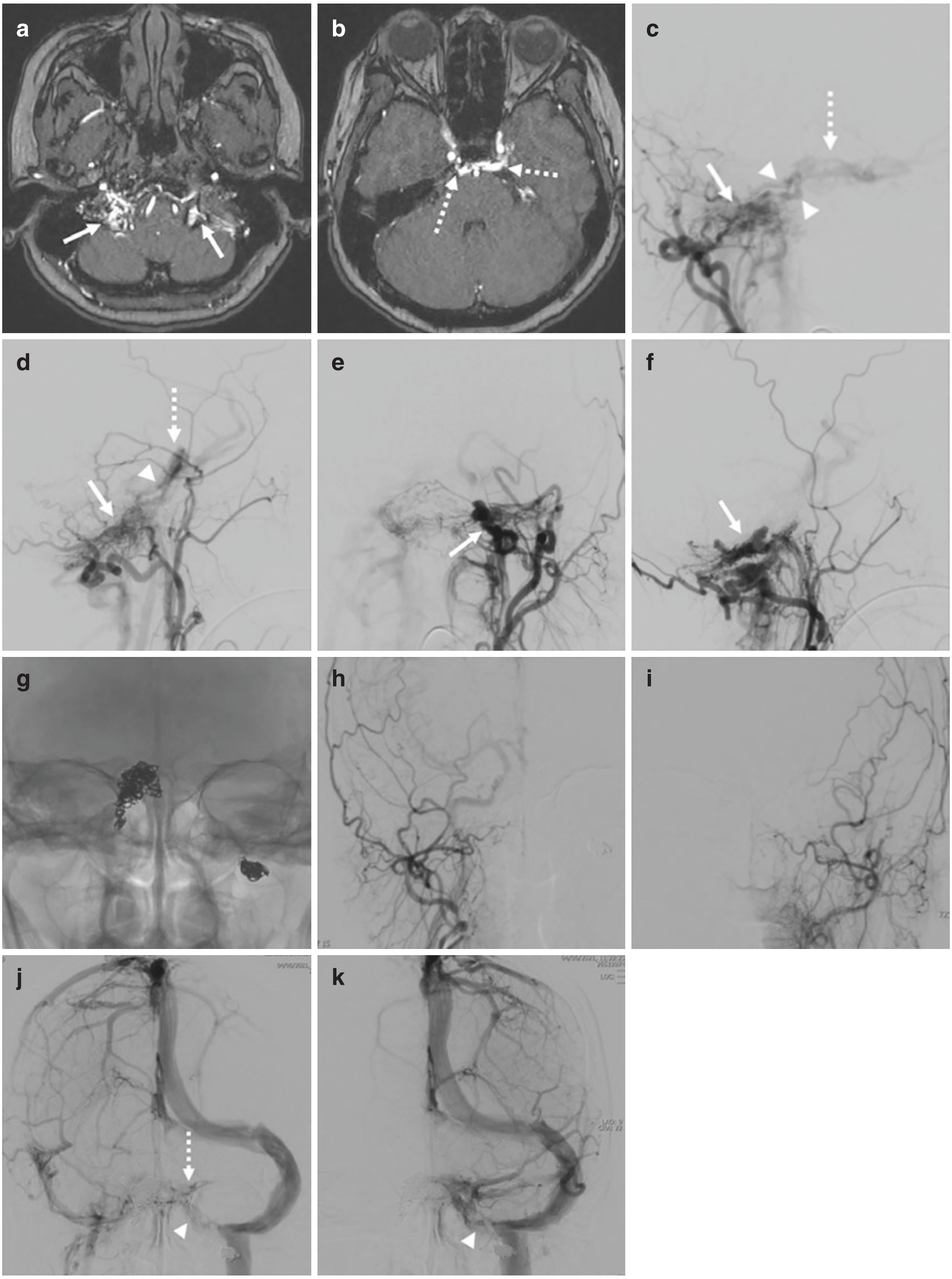


Fig. 9.2 Vertebro-vertebral fistula (VVF) with retrograde IPS drainage. (**a**) A 42-year-old male presented with left eye proptosis for 4 months. (**b**, **c**) AP and (**d**) lateral views of simultaneous injection of bilateral vertebral arteries revealing a VVF at V2 segment of left vertebral artery (white arrows) with drainage into the vertebral venous plexus and retrograde into the left inferior petrosal sinus (white arrowheads), cavernous sinus (black arrow), and superior ophthalmic vein (black dashed arrow) consequently. (**e**) Detachable balloons and coils were used to occlude the fistula and sacrifice the left vertebral artery (black arrows). (**f**) Controlled right vertebral artery injection demonstrating complete closure of the VVF

Fig. 9.3 Bilateral condylar dural AV shunts with retrograde IPS drainage. (**a**, **b**) TOF MRI of a 50-year-old female who had bilateral tinnitus for 5 months, right eye chemosis for 10 days, and diplopia for 4 days, demonstrating AV shunts at bilateral anterior condylar confluences (white arrow) with abnormal flow at the bilateral cavernous sinuses (white dashed arrow). (**c**, **d**) AP and lateral views of right ECA angiography showing dural AV shunt at right anterior condylar confluence (ACC) with retrograde drainage into the CS and consequently into the intercavernous sinus and left SMCV. White arrow = shunt location at right ACC, white arrowhead = right IPS, white dashed arrow = CS. Note two discrete vessels of right IPS. (**e**, **f**) AP and lateral views of left ECA angiography, white arrow = shunt location at left ACC with drainage into vertebral venous plexuses. (**g**) Coil deposition at right IPS and left ACC via transvenous access (not shown). (**h**, **i**) AP view of right ECA and left ECA injection to demonstrate total obliteration of bilateral shunts at 1-year follow-up. (**j**, **k**) Venous phase of the same right ECA and left ECA injection as in (**h**, **i**) showing visualization and function of left CS (white dash arrow) and IPS (white arrowhead)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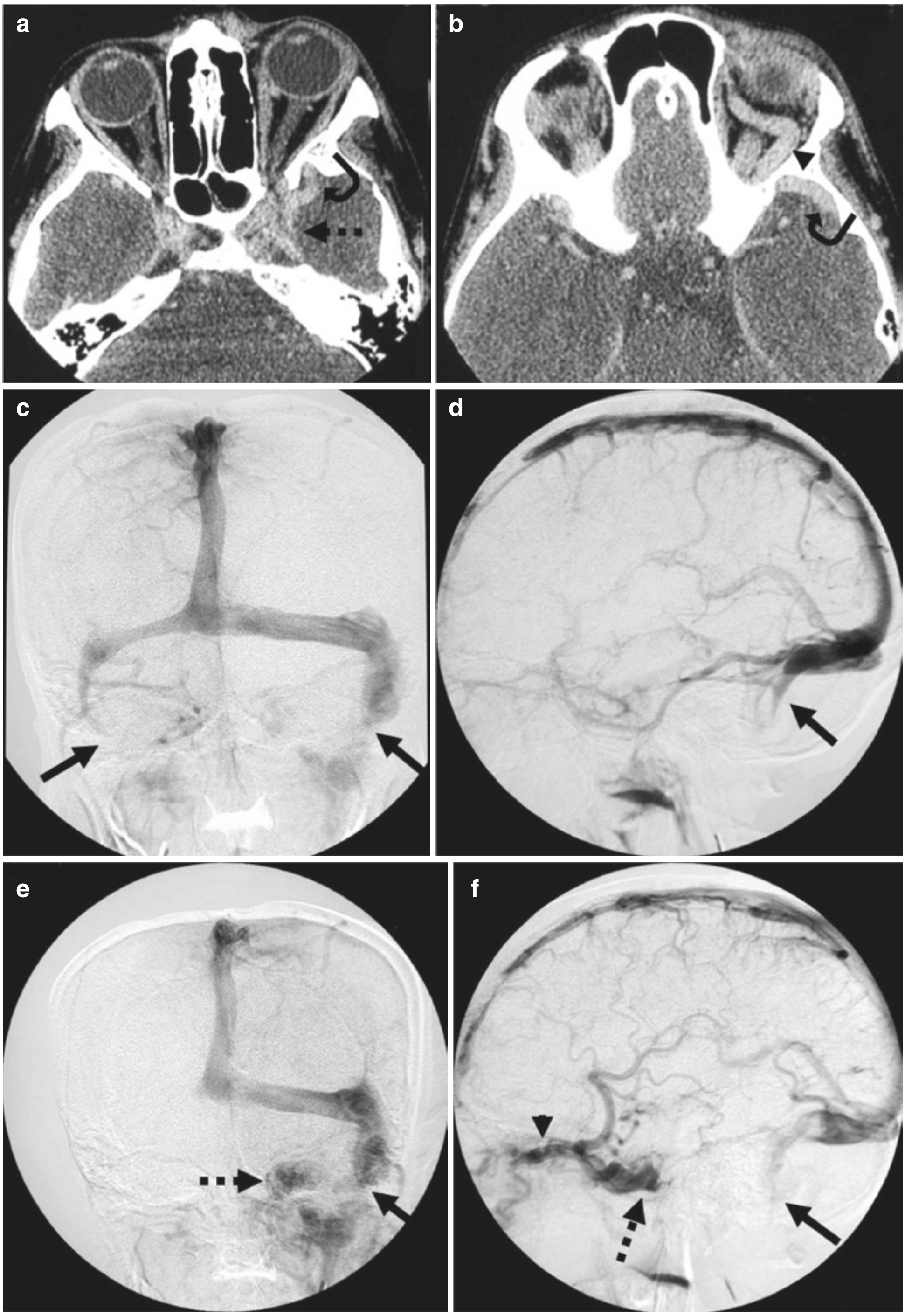

Fig. 9.4 Congenital jugular stenosis with rerouting of drainage pathway via the SOV. (**a**, **b**) Axial contrast CT scan of a 7-year-old girl who presented with mild proptosis and compressible mass at the medial canthus of the left eye, no chemosis, no limitation of eye movement, no history of trauma, revealing enlarged left cavernous sinus (dashed arrow), with dilatation of left SMCV (curved arrow) and SOV (arrowhead). Venous phase of right ICA (**c**, **d**) and left ICA (**e**, **f**) injection demonstrating rerouting of cerebral venous drainage to left CS (dashed arrow) and left SOV (arrowhead) as the consequences of jugular bulb occlusion on the right and severe stenosis on the left (arrows)

Table 9.1 Comparison between Borden and Cognard classifications according to venous drainage of intracranial dural arteriovenous fistulas

Borden classification	Cognard classification
Type I: DVS drainage or meningeal vein	Type I: DVS drainage with antegrade flow
Type II: DVS drainage with CVR	Type IIA: DVS drainage with retrograde flow
	Type IIB: DVS drainage with antegrade flow and CVR
	Type IIA + B: DVS drainage with retrograde flow and CVR
Type III: CVR only	Type III: CVR only (no venous ectasia)
	Type IV: CVR only (venous ectasia)
	Type V: CVR and drainage into spinal vein

DVS dural venous sinus, *CVR* cortical venous reflux

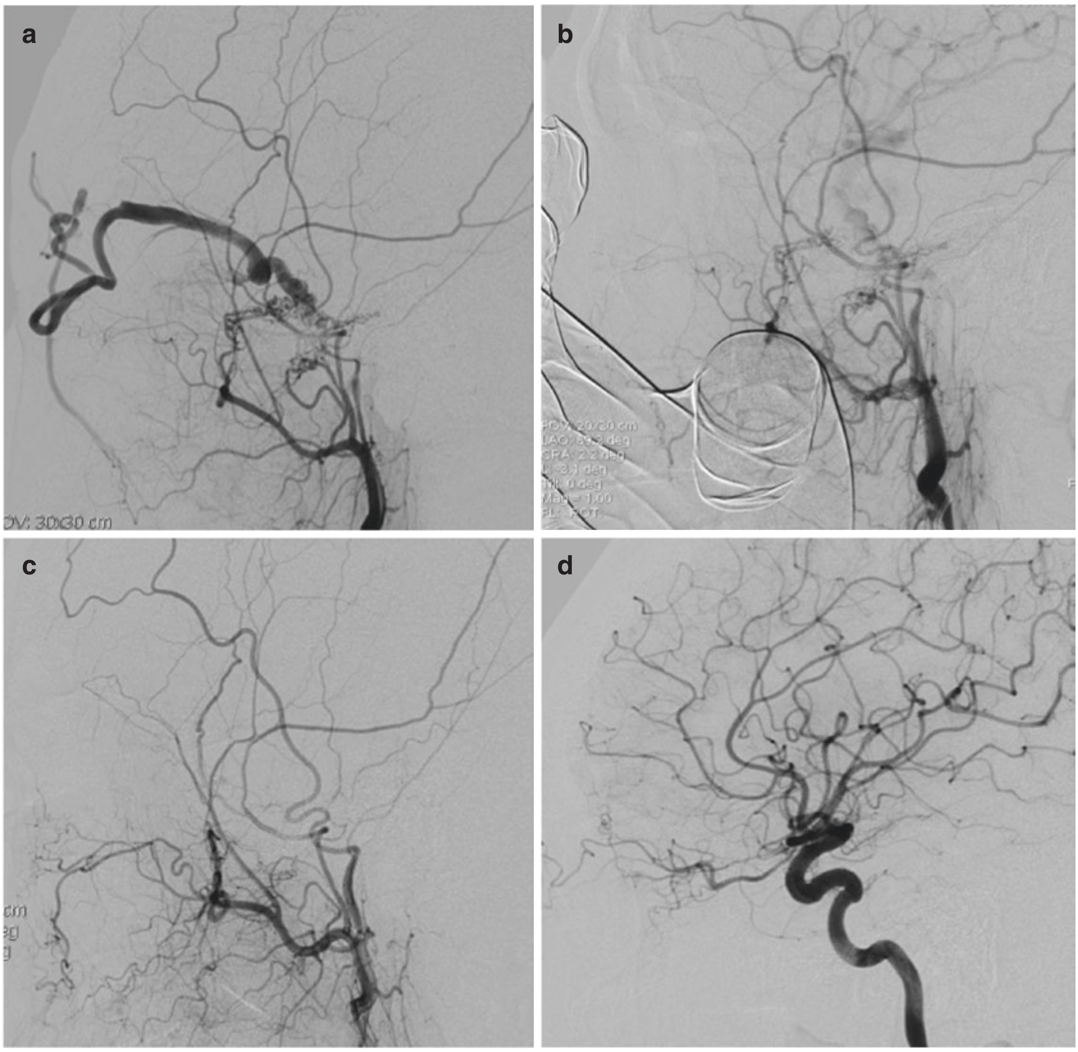

Fig. 9.5 Benign dCCF with spontaneous cure. (**a**) Right ECA angiography, lateral view of a 24-year-old woman who had right eye redness and proptosis for 2 months, showing a dCCF at the anterior cavernous sinus with sole drainage into the right SOV with no connection to the IPS. (**b**) No visualization of the SOV during manual compression at the right medial canthus. (**c**) Right ECA and (**d**) right ICA angiograms at 6-month follow-up after advice to do self-compression of SOV showing complete cure of the right dCCF

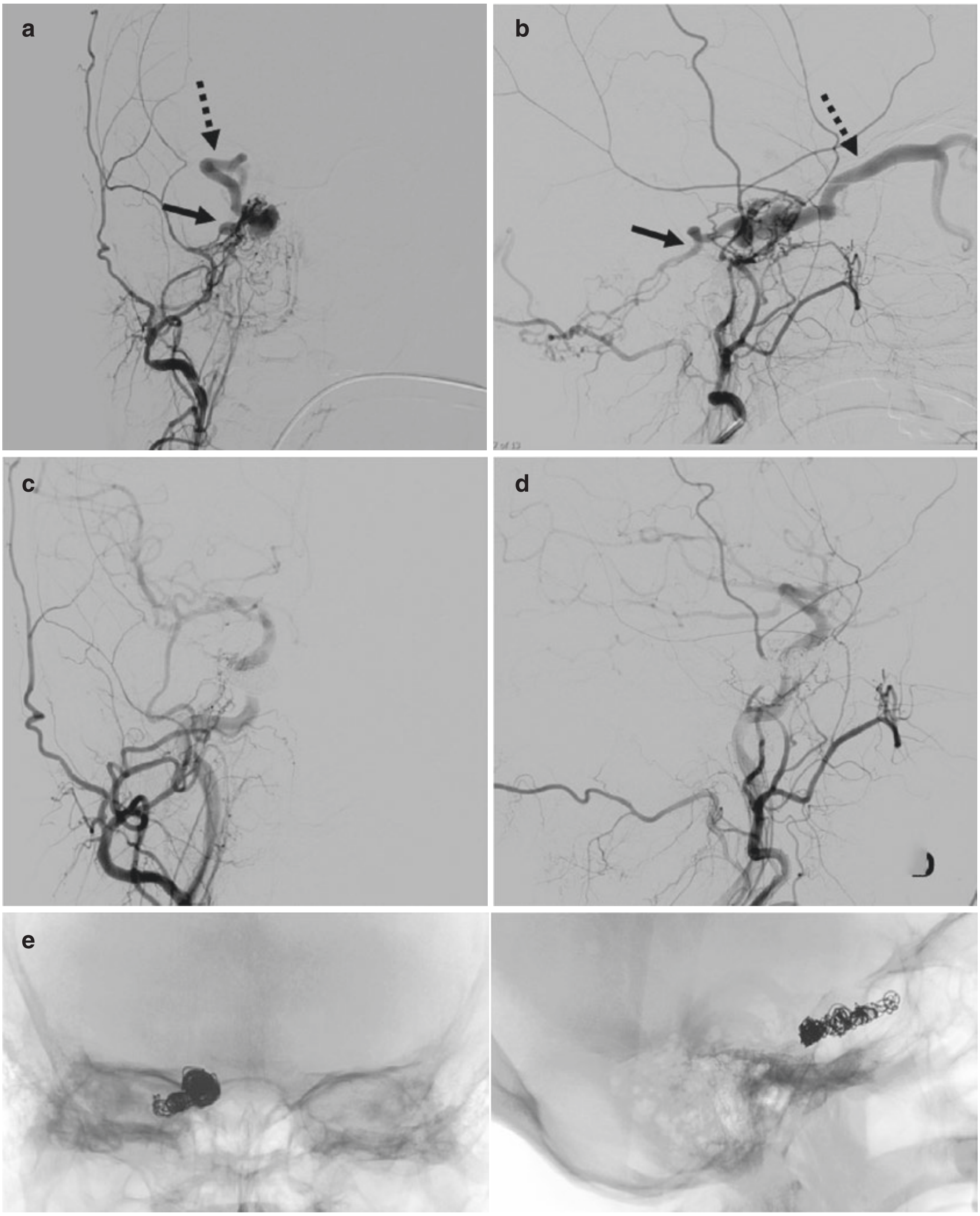

Fig. 9.6 Asymptomatic posterior fossa drainage of a dCCF. (**a**, **b**) Right ECA angiogram demonstrating right dCCF with drainage into the right SOV (dash arrow) with retrograde reflux into the right petrosal vein (arrow) and also into the cerebellar veins. (**c**, **d**) Controlled right ECA angiogram after coil embolization at the CS via blind recanalization of the IPS (not shown) revealing complete occlusion of the dCCF and no further filling of the right SOV and petrosal vein. (**e**) Coil deposition at the right CS

9.2 Cavernous Sinus Anatomy

To facilitate safety and effective treatment of dCCFs, it is essential to understand and recognize the morphology and functional anatomy of those afferent and efferent venous channels around the CS. The CS is a complex venous sinus with different embryological origins of its venous channels. It plays a major role in the contribution to venous drainage from both the cranial and extracranial structures, including the brain, orbit, pituitary gland, adjacent cranial vault, and nasopharynx.

Mitsuhashi et al. demonstrated the concept of CS anatomy in the patterns of longitudinal venous axes and their communication, which are separated into three axes [12].

1. The medial venous axis is a channel medial to the internal carotid artery and is the primary sinus for the chondrocranium and hypophysis that connects with the contralateral side through the anterior and posterior intercavernous sinuses.
2. The lateral venous axis is a venous channel situated lateral to the cranial nerves for venous drainage from the brain via the superficial middle cerebral vein (SMCV). The posterolateral part drains the superior petrosal sinus and also serves as bridging veins from the brainstem.
3. The intermediate venous axis is the remaining venous channel between the internal carotid artery (ICA) and cranial nerves that connects with the SOV and superficial petrosal vein and drains into the pterygoid plexus through emissary veins in the middle cranial fossa.

The medial and lateral venous axes drain posteriorly into the IPS, which also receives venous drainage from the labyrinth, brainstem, and inferior cerebellar surface through bridging veins (Figs. 9.7, 9.8, and 9.9).

According to this concept of cavernous sinus anatomy, if occlusion of the dCCF shunt is incomplete, the residual shunt flow may be redistributed into the cerebral or ocular venous drainage routes leading to focal brain congestion, hemorrhage, or the deterioration of ocular symptoms [13, 14].

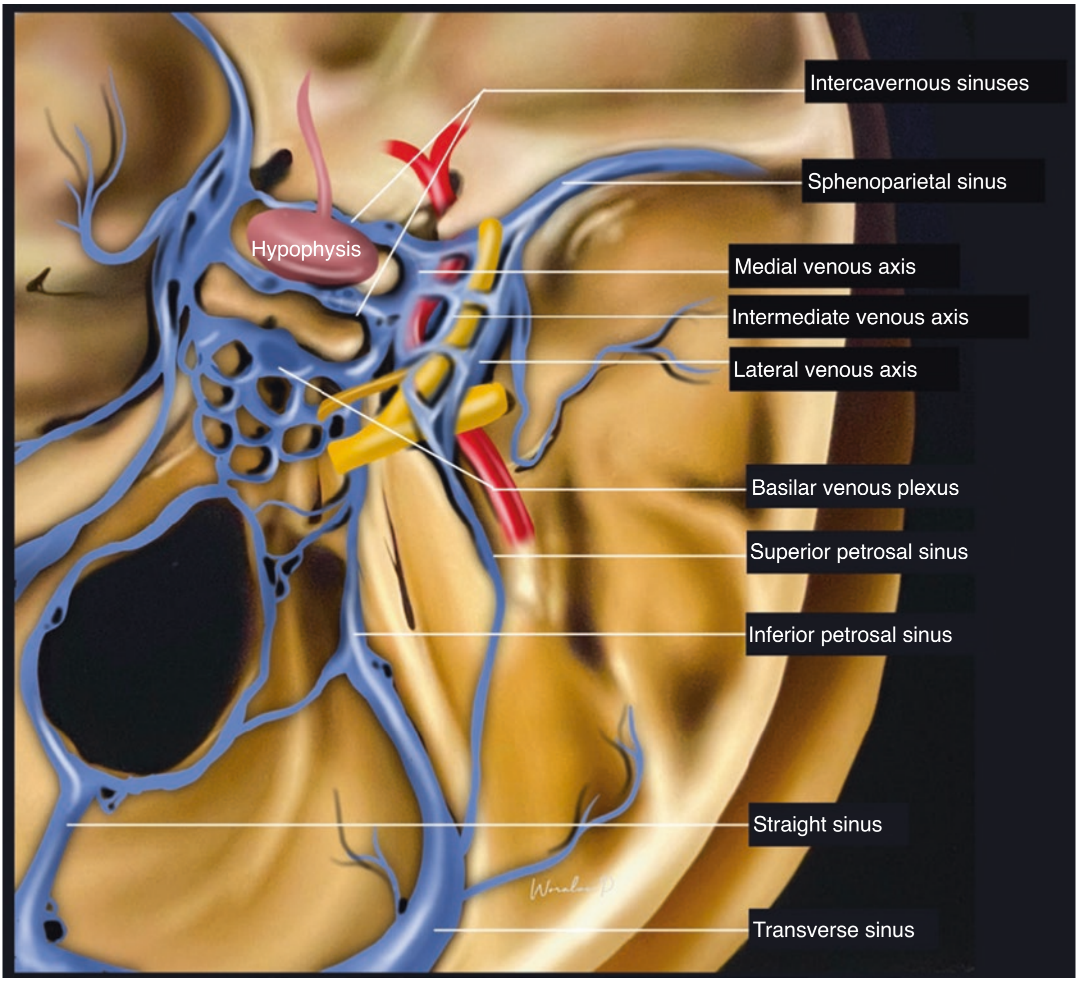

Fig. 9.7 Diagram illustrating the cavernous sinus anatomy and longitudinal venous axes

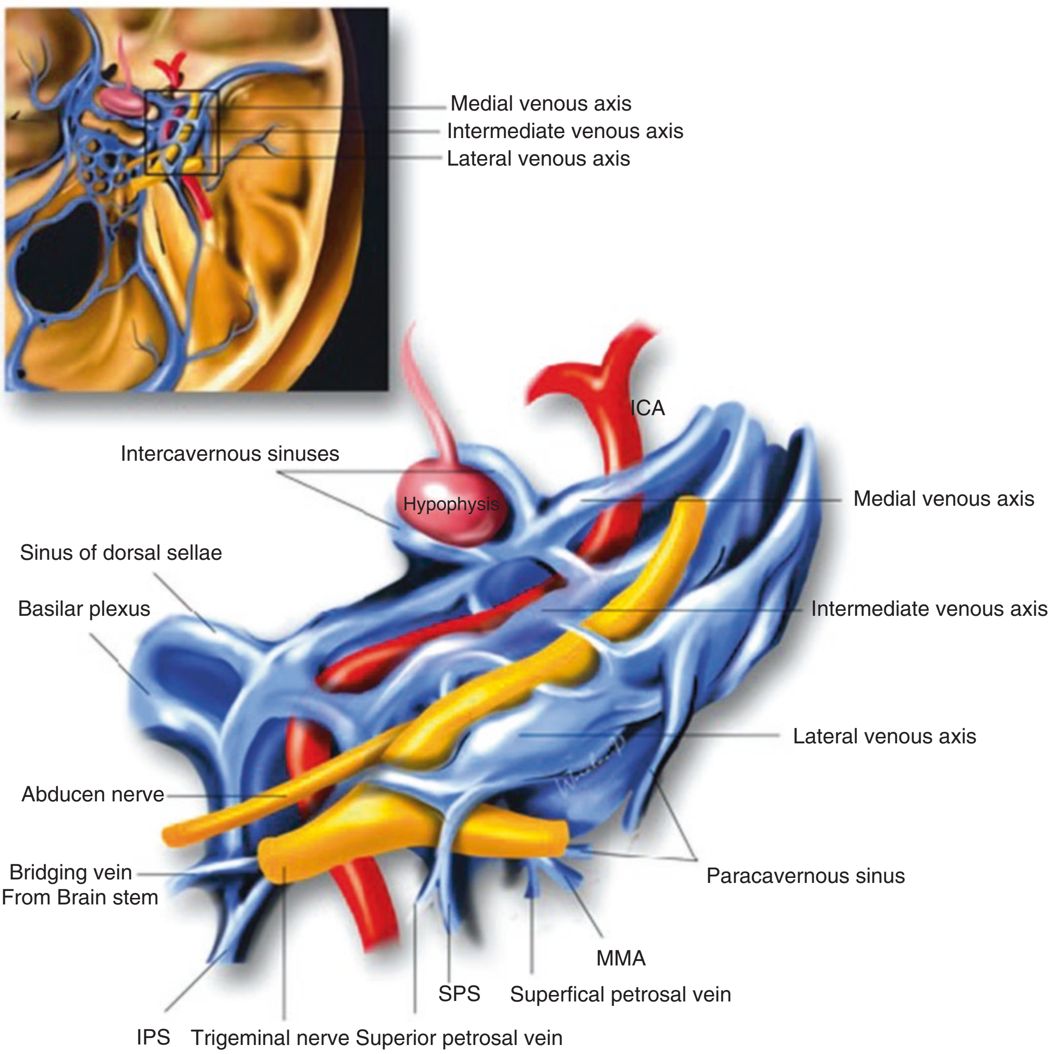

Fig. 9.8 Diagram illustrating the longitudinal venous axes and their communication

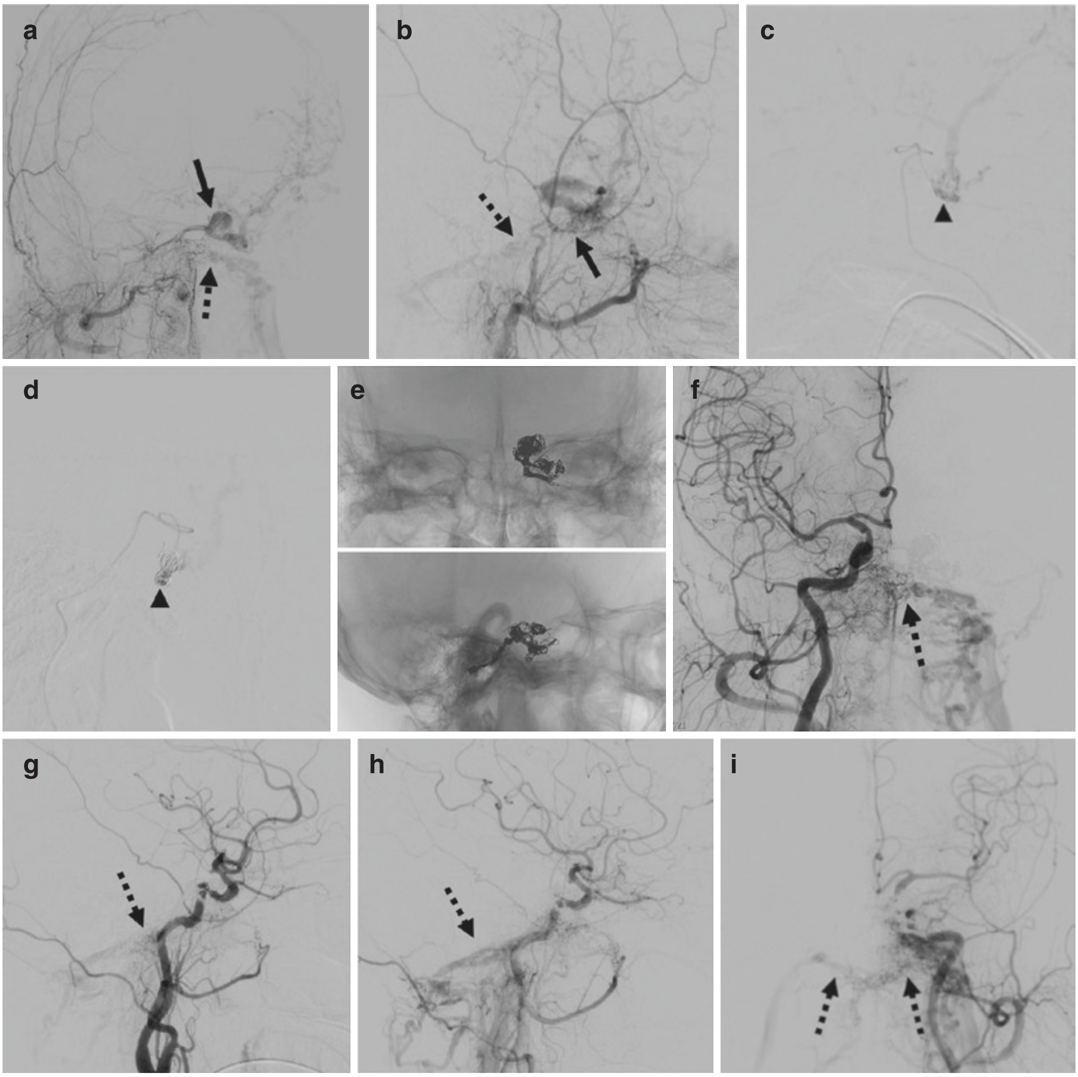

Fig. 9.9 dCCFs at different venous axes. (**a**, **b**) Right ECA injection of a 73-year-old female who had vision impairment of the left eye showing two locations of dCCFs. One at the left lateral venous axis with direct retrograde drainage into the SMCV (arrow) and the other at the basilar plexus of the medial venous axis (dashed arrow) with antegrade drainage to the left internal jugular vein. (**c**) AP and (**d**) lateral views of superselective injection of the left SMCV via transvenous access through the left IPS (arrowhead = tip of microcatheter). (**e**) Coil mass at lateral venous axis and IPS, post transvenous access for embolization. (**f**, **g**) Controlled right CCA angiograms showing complete obliteration of the dangerous reflux. Note the remaining benign shunts at the basilar venous plexus (dashed arrow). (**h**, **i**) Controlled left CCA angiograms also demonstrating shunts at the left basilar plexus connecting to the right side then eventual antegrade drainage to the bilateral internal jugular veins (IJV)

9.3 Arterial Supply to a dCCF

A dCCF usually acquires arterial feeders from meningeal arteries of the external carotid artery (ECA) and/or from the ICA around the CS, which can be ipsilateral, contralateral, or bilateral supply to the shunt.

The most consistent meningeal branches of the cavernous ICA are the meningohypophyseal trunk (MHT) and inferolateral trunk (ILT). There are four major pathways of anastomosis between the ICA and ECA: (1) lateral clival branch of the MHT and clival branch of the ascending pharyngeal artery at the foramen lacerum; (2) anterolateral branch of the ILT and artery of the foramen rotundum at the foramen rotundum; (3) posteromedial branch of the ILT and accessory meningeal artery at the foramen ovale; and (4) posterolateral branch of the ILT and middle meningeal artery at the foramen spinosum [4]. These anastomosis groups should always be kept in mind whenever transarterial embolization is desirable (Fig. 9.10).

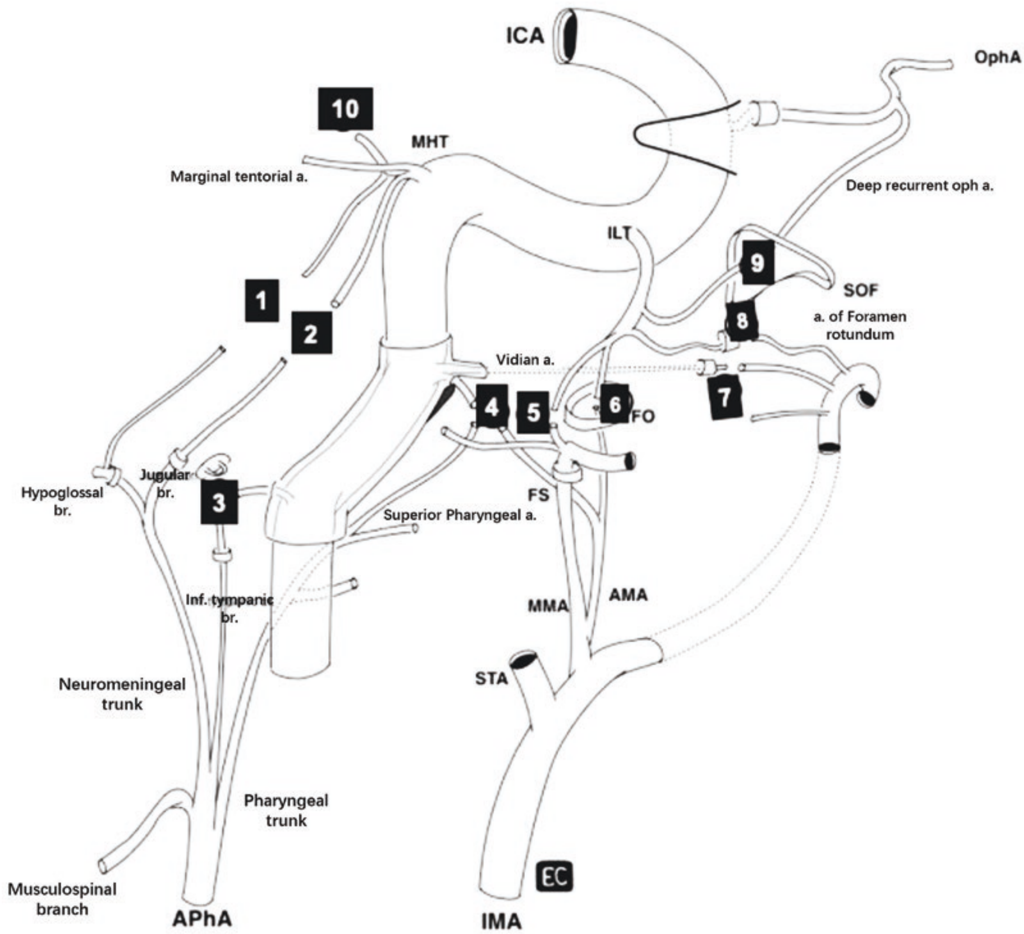

Fig. 9.10 Anastomosis between the ICA-ECA around the cavernous sinus. (1) Medial clival anastomosis. (2) Lateral clival anastomosis. (3) Tympanic anastomosis. (4) Eustachian tube anastomosis. (5) ILT-MMA anastomosis. (6) ILT-AMA anastomosis (at F. ovale). (7) Vidian anastomosis (at vidian canal). (8) ILT-A. of F. rotundum anastomosis. (9) ILT-deep recurrent ophthalmic A. anastomosis. (10) Contralateral clival anastomosis. *Abbreviations*: *ICA* internal carotid artery, *EC* external carotid artery, *MHT* meningohypophyseal trunk, *ILT* inferolateral trunk, *Oph A* ophthalmic artery, *MMA* middle meningeal artery, *AMA* accessory meningeal artery, *STA* superficial temporal artery, *IMA* internal maxillary artery, *APhA* ascending pharyngeal artery, *SOF* superior orbital fissure, *FO* foramen ovale, *FS* foramen spinosum

9.4 Endovascular Treatment of a dCCF

Any dCCF should be considered for endovascular treatment if there is at least one of the following reasons.

1. Cortical venous reflux into the SMCV or posterior fossa despite no clinical symptoms of venous congestion (Figs. 9.6 and 9.9).
2. A benign type with uncontrolled orbital symptom(s) such as severe proptosis, chemosis, and especially increased intraocular pressure (IOP) because it may lead to secondary glaucoma or impaired visual function (Fig. 9.11).

The goal of treatment is to obliterate the affected shunt compartment. If it is not feasible, the alternate goal is to achieve complete occlusion of the

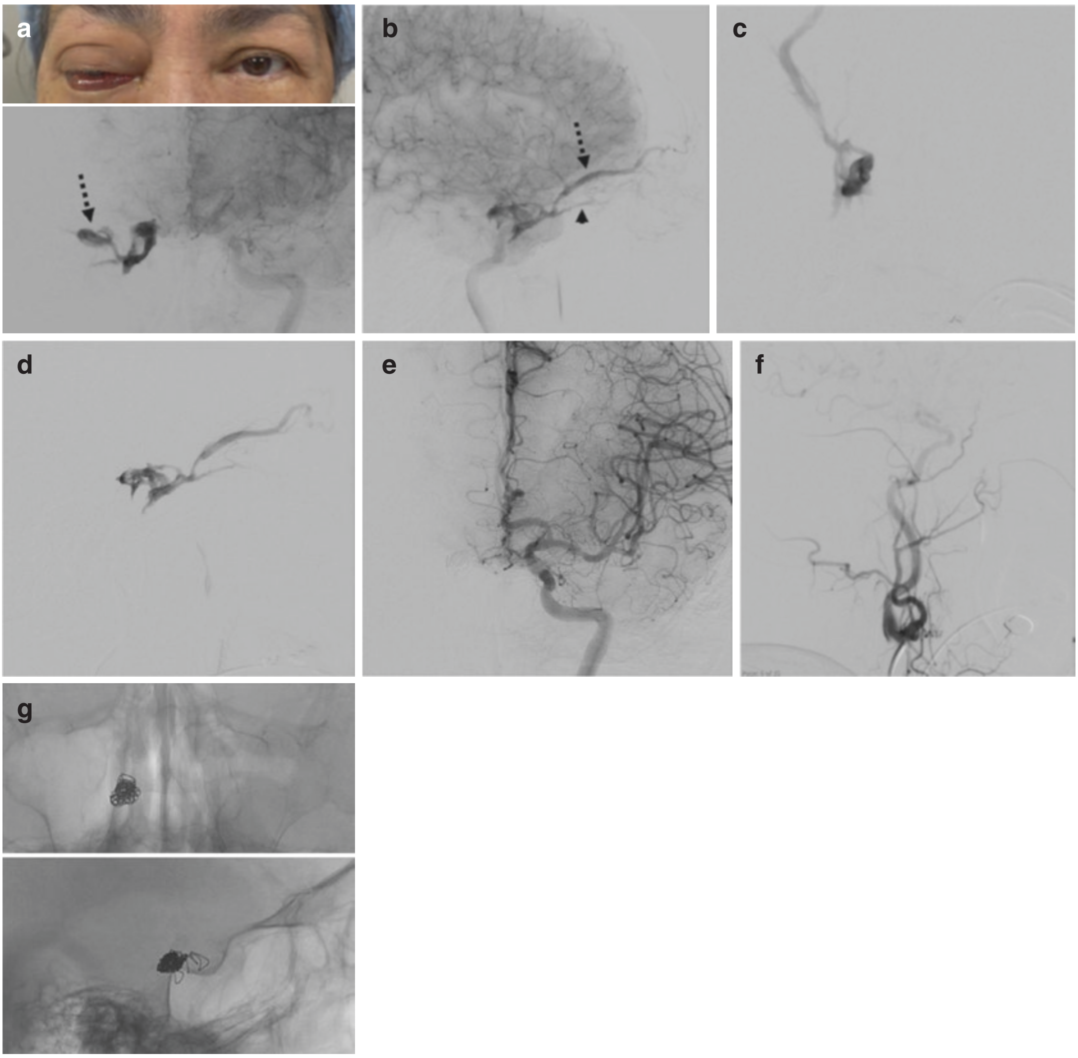

Fig. 9.11 Benign dCCF with uncontrolled eye symptoms. (**a**, **b**) Left ICA angiography of a 65-year-old woman who presented with proptosis, tenderness, and increased IOP of the right eye revealing right dCCF supplied from cavernous branches of the left ICA, right accessory meningeal artery, and C5 branches of the right ICA (not shown), draining into both the superior (dashed arrow) and inferior ophthalmic veins (arrow head) without visualization of the IPS. (**c**) Frontal and (**d**) lateral projections of CS venography, which was performed through blind recanalization of the right IPS showing the venous channel draining the dCCF. (**e**, **f**) Controlled angiogram after coiling via trans-IPS access exhibiting complete obliteration of the right dCCF. (**g**) Coil deposition in the CS

outflow of cortical reflux. Once partial closure of a dCCF is obtained, a follow-up angiogram is required to confirm there is no new acquired dangerous venous drainage.

By reason of the existence of anastomosis between the external and internal carotid systems, a transvenous approach to reach the shunt location of a dCCF is safer when the risk-benefit ratio is a concern. Usually, the embolic material using the transvenous route is a detachable coil; however, a combination of liquid embolic materials, such as n-butyl cyanoacrylate (NBCA) or dimethyl sulfoxide (DMSO) based products, can help to enhance the efficacy of the coil mass or eradicate the residual venous space. Although incomplete occlusion may initially occur, delayed thrombosis after complete curing can be expected (Fig. 9.12).

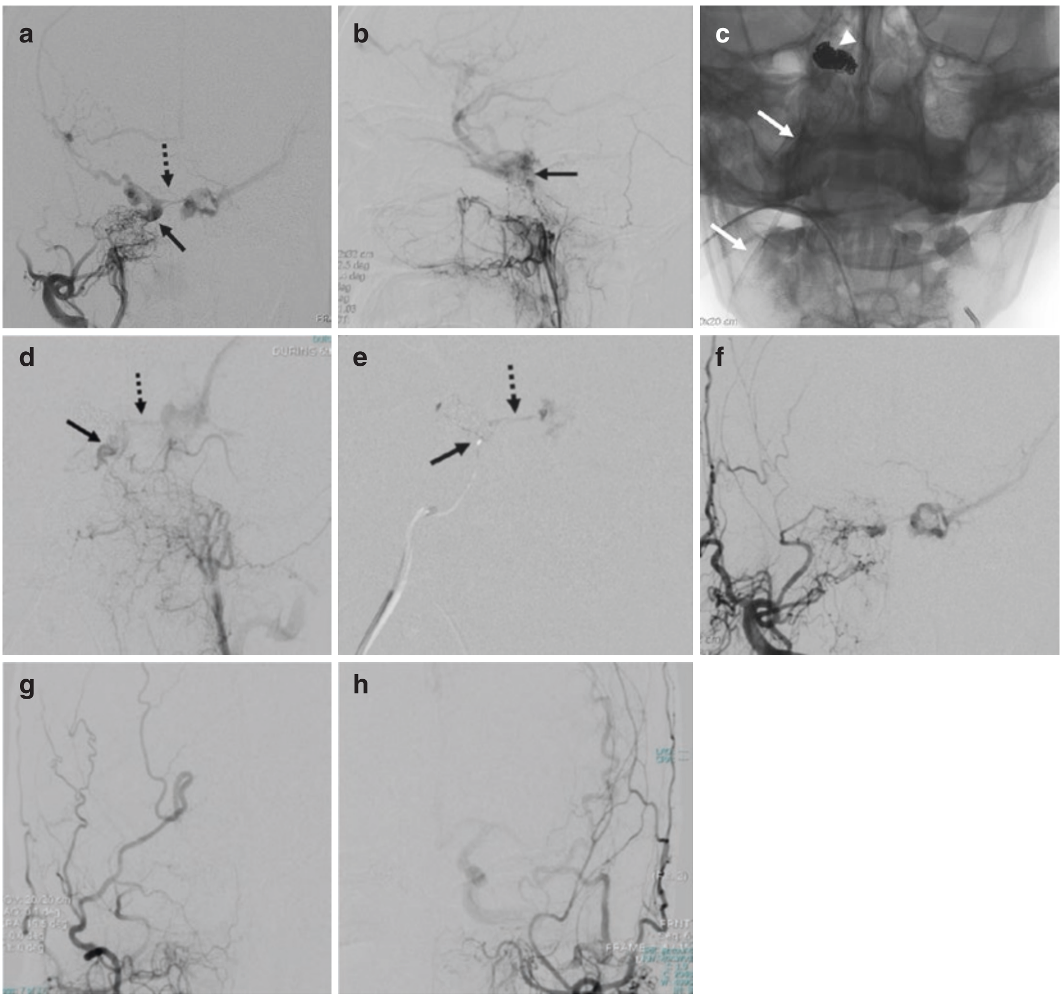

Fig. 9.12 Combined transvenous coil and NBCA embolization. (**a**, **b**) AP view of the right ECA and (**b**) lateral view of the left ascending pharyngeal (APA) angiogram of a 50-year-old woman who had right eye proptosis and ptosis for 8 months showing a right dCCF (arrow) supplied from the right ECA and bilateral APAs, draining into the right SOV with reflux into the right SMCV as well as through the intercavernous sinus (dashed arrow) to the left SMCV. (**c**) Transvenous access (arrows) via right IPS with coil embolization at the right CS (arrowhead). (**d**) Left APA injection showing residual right dCCF (arrow) with intercavernous drainage (dashed arrow) to the left SMCV. (**e**) Decision to use NBCA or glue (NBCA:Lipiodol = 1:3) injection through the same microcatheter to obliterate residual venous space, arrow = tip of microcatheter, dashed arrow = glue passing to intercavernous sinus. (**f**) Residual shunt draining to intercavernous sinus and left SMCV on right ECA controlled angiogram. (**g**) Right ECA and (**h**) left ECA follow-up angiogram at 3 months demonstrating further complete obliteration of the shunt and cortical reflux

Much more caution is required when using liquid embolic materials, even when injected into the venous channels, because these materials can penetrate into a dangerous anastomosis.

A suggested decision-making algorithm for treatment of a dCCF is illustrated in Fig. 9.13.

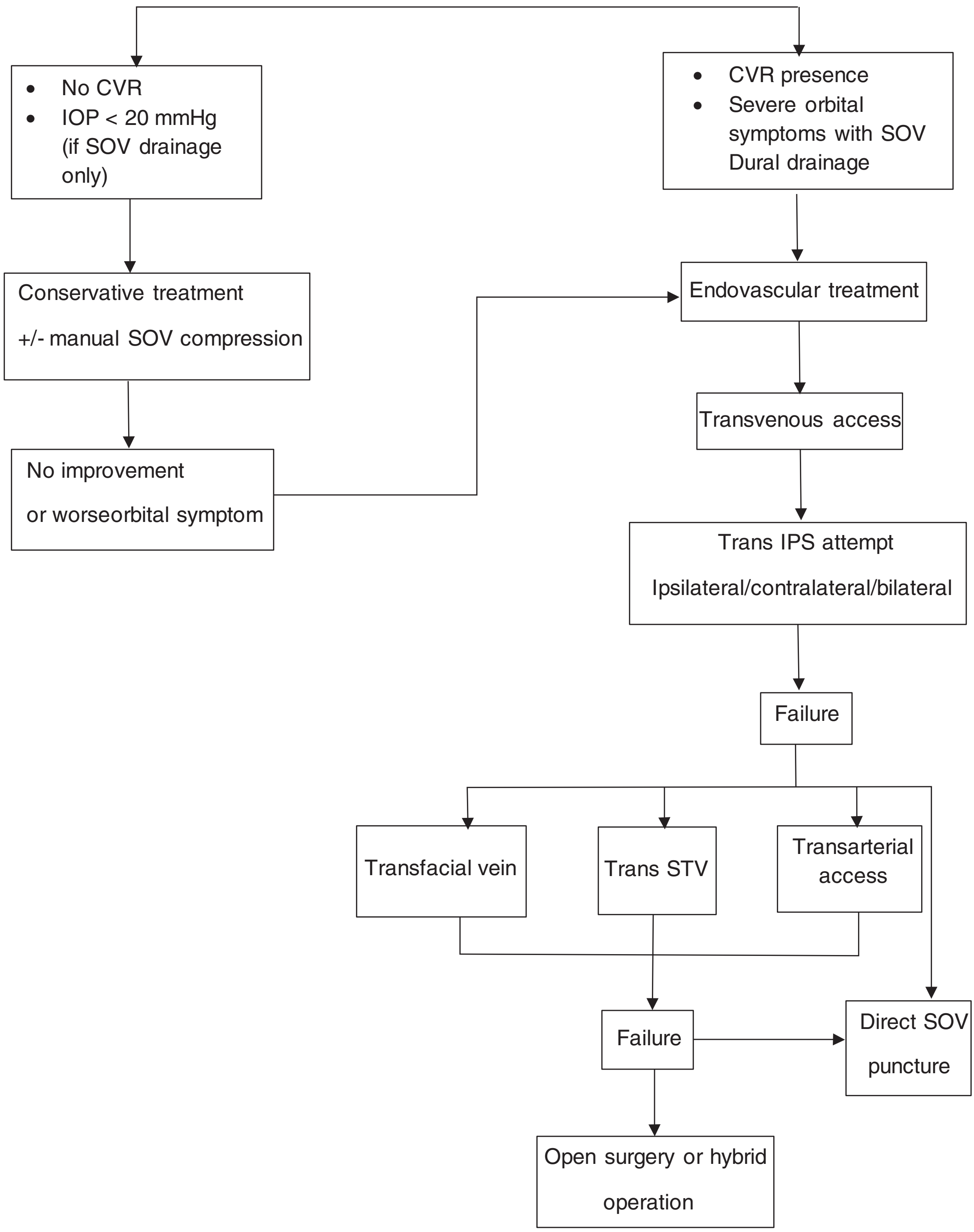

Fig. 9.13 Algorithm flow diagram for the treatment of dCCFs

9.5 Transvenous Access

Several venous pathways are available to reach the CS. The shortest and easiest route is the IPS because it can be navigated retrogradely via the internal jugular vein (IJV) without difficulty if it presents. The alternative routes include the anterior facial vein and middle temporal vein to gain access via the SOV. However, the superior petrosal sinus can be reached via the sigmoid sinus is some cases.

9.5.1 Inferior Petrosal Sinus Approach

If the IPS can be visualized as a drainage from the shunt, it is the perfect direct pathway to reach the shunt at the CS. Nevertheless, if it is thrombosed, we can perform blind recanalization without much fear on the basis of anatomy of the IPS which is the tract along the osseous structure (Figs. 9.1, 9.6, and 9.9). In our experience, the trans-IPS is the initial attempt to access the shunts with an 80% success rate of treatment.

9.5.1.1 Ipsilateral IPS Approach

Both arterial and venous femoral punctures are prepared. Once the venous guiding catheter (5F is preferable) reaches the jugular bulb, biplane roadmap fluoroscopy is achieved by injection into the arterial catheter to demonstrate the dCCF and IPS. The working projection of the frontal X-ray tube is recommended to move some degree caudally in Water's view or semi-Water's view projection. Using a 038 guidewire to select the IPS, the guiding catheter is then moved forward to keep stability at the IPS. A microcatheter can now easily navigate into the CS for selection of the targeted venous channel or shunting site. A test injection via the microcatheter is necessary to confirm the exact venous channel to be embolized (Fig. 9.14). Selection for coil packing at different positions may be needed depending on the morphology and appearance of the venous drainage outlet from the shunts (Fig. 9.15). In general, coil deployment is suggested from the anterior to posterior while carefully preventing inadvertent coil placement or catheter kickback. If one of these events occurs and it is not possible to reselect the SOV or CS, the contralateral IPS or another route of access must be tried.

If the IPS is not demonstrated, blind recanalization of the IPS should be attempted initially using a 038 guidewire to search for the IPS outlet in the antero-medial direction. If successful, a 5F guiding catheter can be advanced forward at least to the IPS-IJV junction. Then a microcatheter can be advanced over a microguidewire using the "drilling" manipulation gently through the thrombus. A test contrast injection should be repeated every time the microcatheter tip changes position. In our experience, this technique has been successfully used in 70% of cases on average in reaching the posterior part of the CS. Once the posterior CS is reached, it is possible to advance the microcatheter into the anterior compartment of the CS and the outlet of the SOV. Initial packing should be started at the SOV-CS junction. Occlusion at the outlet of the SMCV is also necessary in those cases with cortical reflux (Fig. 9.16). However, in some patients with unfavorable anatomy it is impossible to reach the SOV outlet.

9.5.1.2 Contralateral IPS Approach

This approach is usually desired when the dCCF drainage is contralateral or when ipsilateral IPS access has failed. Using a microcatheter over the microguidewire it is essential to pass through the intercavernous sinus under roadmap fluoroscopy. Upon entering the contralateral CS, a test venogram is suggested. If it is similar to the shunt drainage, superselection is then pursued into each targeted venous channel for coil packing in the same manner as mentioned earlier (Fig. 9.17). The obstacle of this technique is non-visualization of the intercavernous sinus on angiogram. If that is the case, another alternative route of access is required.

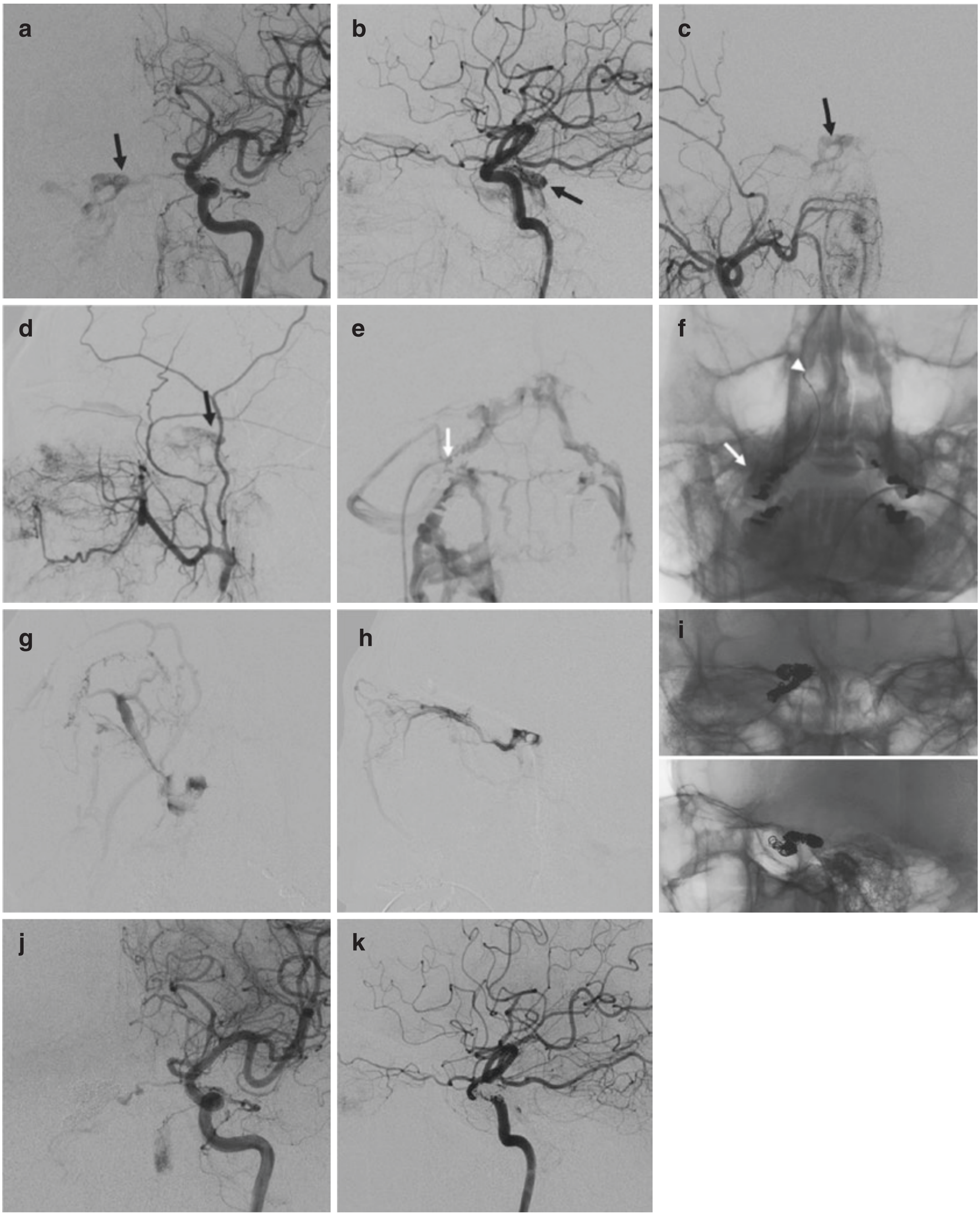

Fig. 9.14 Ipsilateral IPS approach with selection into the SOV. (**a**, **b**) Right dCCF supplied from cavernous branches of the left ICA. (**c**, **d**) Small pedicles of the right middle meningeal artery and artery of the foramen rotundum with drainage into the right SOV. Note the thrombosis of the right IPS. (**e**) Blind recanalization of the right IPS; however, the right SOV is not visualized. White arrow = tip of guiding catheter in the right IPS. (**f**) Further superselection using a microcatheter with successful entry to the SOV outlet, white arrowhead = tip of microcatheter. (**g**) AP and (**h**) lateral views of injection through the microcatheter in (**f**) confirming the SOV outlet, prior to coil embolization. (**i**) Coil mass at anterior CS and SOV outlet. (**j**, **k**) Controlled left ICA angiogram showing complete occlusion of the right dCCF

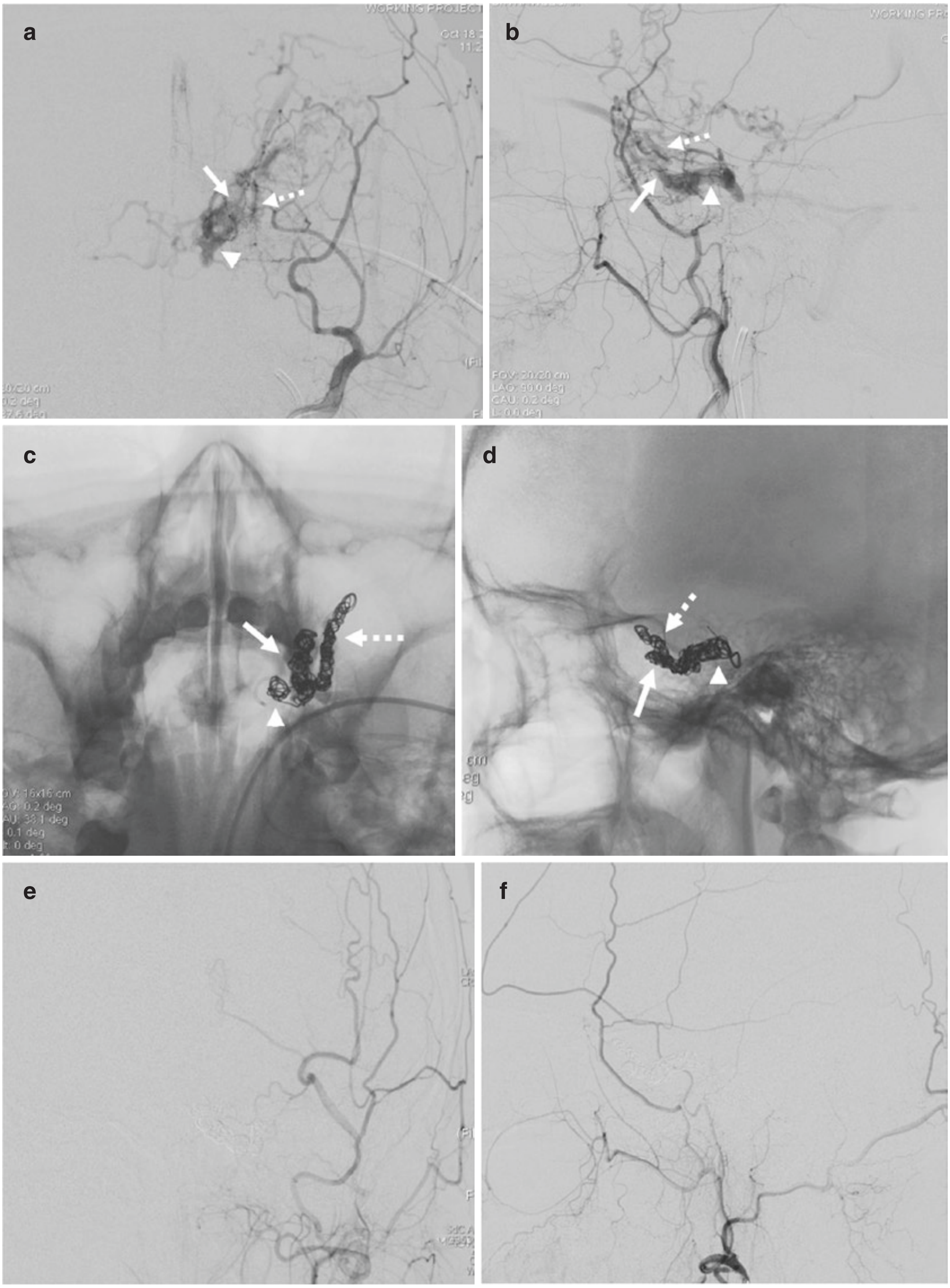

Fig. 9.15 Selective venous channel embolization. (**a**, **b**) Left ECA angiogram showing left dCCF (arrowhead) with drainage to the left SOV (arrow) and left SMCV (dashed arrow) with thrombosis of the IPS. (**c**, **d**) Demonstration of coil deposition from selective embolization in each venous channel, arrowhead = CS, arrow = SOV, dash arrow = SMCV. (**e**, **f**) Controlled left ECA injection showing total occlusion of the left dCCF

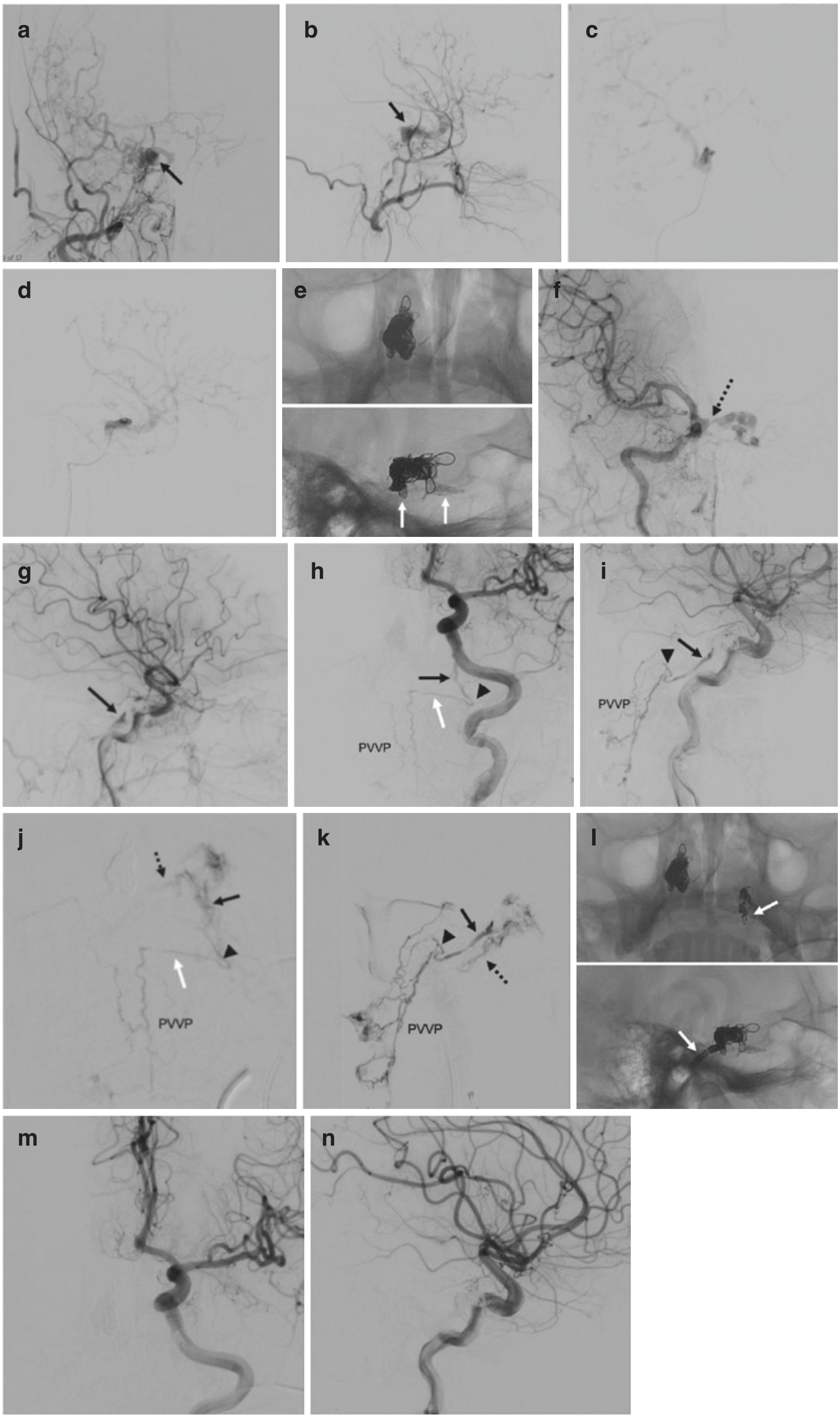
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Fig. 9.16 Aggressive dCCF and IPS dural AVF. (**a**, **b**) Right ECA angiogram demonstrating right dCCF (arrow) with direct drainage to the right SMCV and intercavernous sinus. The SOV and IPS are not visualized. (**c**, **d**) Superselection of lateral venous axis of the right CS via the recanalized IPS. (**e**) Combined coil and Onyx embolization via transvenous access in (**c**, **d**), white arrows = Onyx cast in the right CS. (**f**, **g**) Right ICA controlled angiogram revealing complete obliteration of SMCV reflux with residual antegrade intercavernous drainage (dashed arrow) into the left IPS (arrow). (**h**, **i**) Follow-up left ICA angiogram at 3 months showing progression of dural AV shunt at left IPS with reflux into the anterior condylar confluence (ACC) and posterior vertebral venous plexus (PVVP). Note thrombosis at the IPS-IJV junction, black arrow = IPS, arrowhead = ACC, white arrow = marginal sinus (**j**) AP and (**k**) lateral views of left IPS venogram via a microcatheter that was navigated through a recanalized IPS-IJV thrombosis showing similar venous channels as shown on (**h**, **i**). Note opacification of basilar venous plexus (dashed arrow) connected to the cranial end of the IPS, black arrow = IPS, arrowhead = ACC, white arrow = marginal sinus, dash arrow = basilar venous plexus. (**l**) Transvenous coil embolization in the left IPS (white arrow). (**m**, **n**) Controlled left ICA showing complete obliteration of shunt and abnormal venous drainage. Note: Three difference venous channels drained the dural shunts in this patient: (1) CCF drained the lateral venous axis to the SMCV; (2) CCF drained the medial venous axis to the intercavernous sinus; and (3) proximal IPS shunt drained into the anterior condylar confluence, marginal sinus, and posterior vertebral venous plexus

9.5.1.3 Approach for Bilateral Dural CCFs

The definition of bilateral dCCFs is shunts at the bilateral cavernous sinuses where each side has separate feeding arteries and each has its own venous drainage. The disease is not uncommon. It was reported in 26% of patients with dCCFs in our series [2]. The concept of endovascular treatment is not different from the unilateral shunt. The trans-IPS approach is still the initial choice of access. If the intercavernous sinus is recognized from an angiogram, the success of embolization of bilateral shunts through the single IPS approach can be expected with side-by-side embolization. The dangerous venous outlet should be accomplished first, followed by the symptomatic venous outlet. Then shunt occlusion will be obtained lastly in the sequence. If bilateral IPSs are available, we usually choose to access the contralateral IPS of the more aggressive side. Under roadmap fluoroscopy, a microcatheter is navigated across the intercavernous sinus to select each targeted venous channel for coil packing. It is then withdrawn back into the ipsilateral CS and followed by the same steps of the maneuver. Coil deployment at the intercavernous sinus may not be needed (Figs. 9.18 and 9.19).

9.5.2 Facial Vein Approach

The superior ophthalmic vein communicates with the angular vein via the nasofrontal vein. The angular vein continues as the anterior facial vein (AFV) and then joins the anterior branch of the retromandibular vein to form the common facial vein which empties into the internal jugular vein at about its mid-cervical segment. However, in the case of an undivided retromandibular vein, the AFV drains directly into the IJV (Fig. 9.20).

Retrograde catheterization along the course of the AFV should be tried under roadmap fluoroscopy by catching an image at late venous phase of the shunt drainage. The guiding catheter should be placed in the AFV as far as possible. A microcatheter is then navigated over the microguidewire to access the angular vein, SOV, and CS in that order. Usually, the most difficulty is at the angular vein and SOV junction due to much angulation and tortuosity. Once the CS is reached, coil deployment should be started as close as possible to the shunt location at the CS to CS-SOV junction until complete occlusion of the dCCF is achieved from the test angiogram.

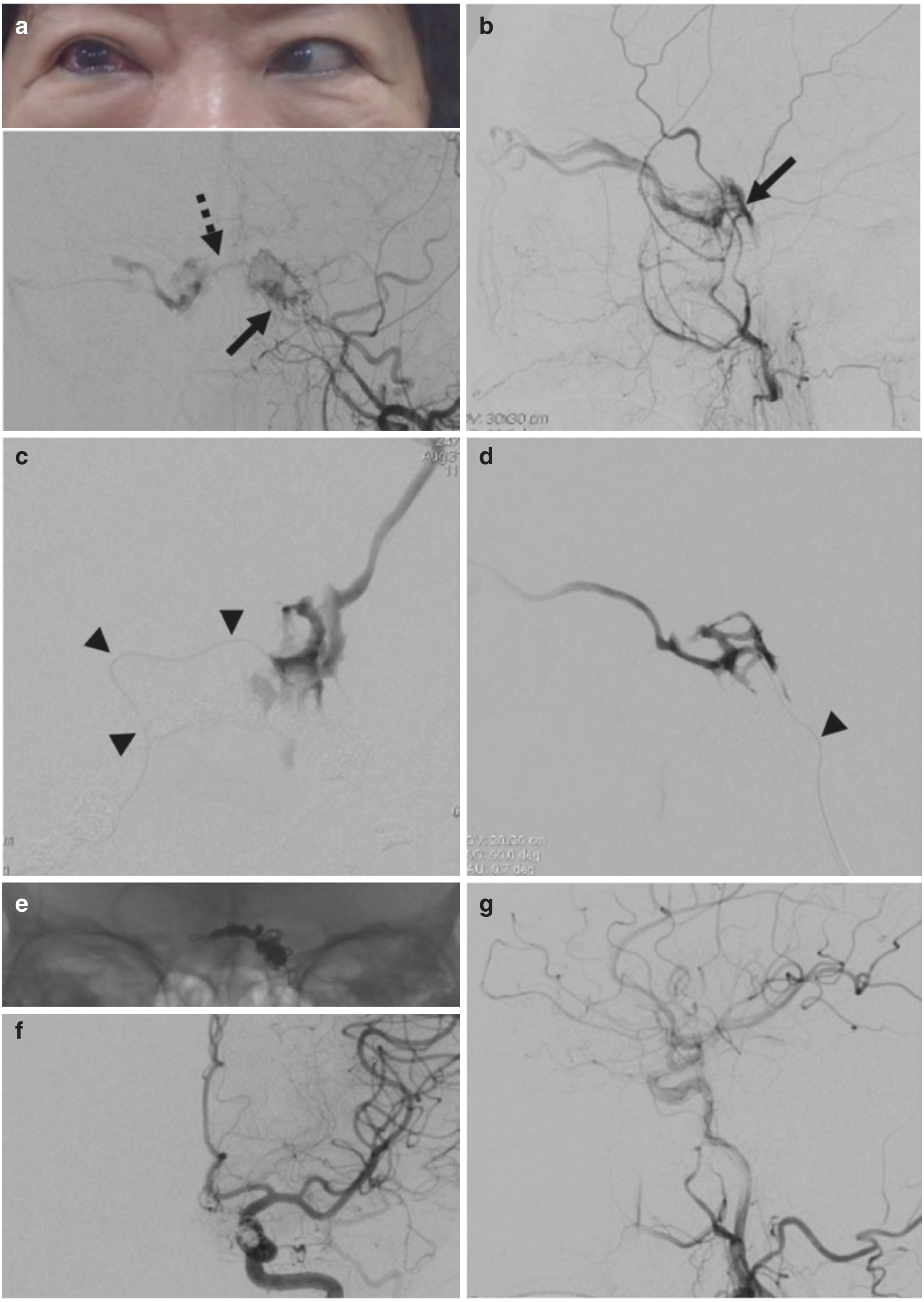


Fig. 9.17 Contralateral IPS approach. (**a**, **b**) Left dCCF of a 69-year-old female with injection of the right eye, limitation of right lateral rectus movement, and increased intraocular pressure of both eyes (29 mmHg on the right and 20 mmHg on the left) showing drainage into the SOV and intercavernous sinus with eventual drainage into the contralateral SOV. Note the thrombosis of the bilateral IPS. (**c**, **d**) Catheterization via the right IPS passing the intercavernous sinus to the left SOV, arrowheads = course of catheter. (**e**) Post-coil embolization in the left CS and intercavernous sinus. (**f**, **g**) Controlled angiogram showing cure of the dCCF

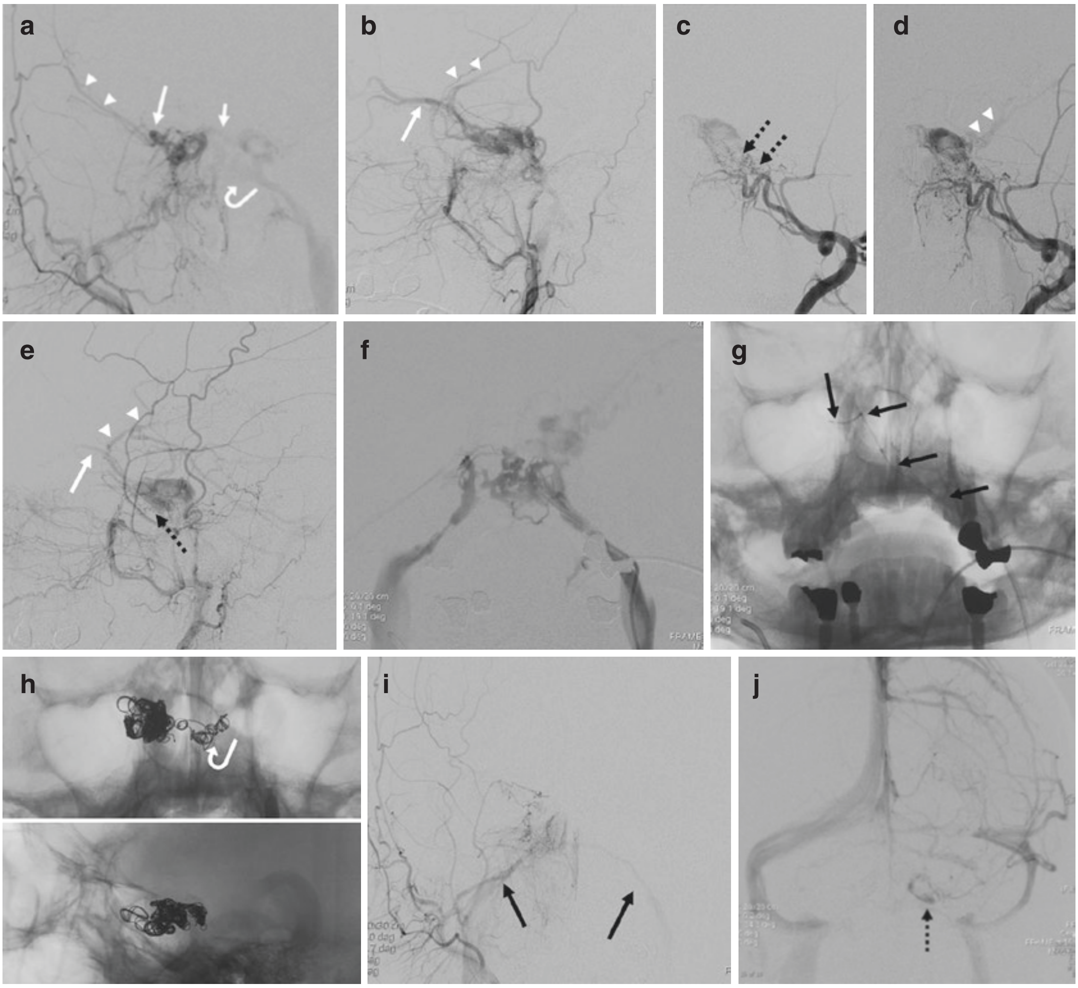


Fig. 9.18 Bilateral dCCFs. Bilateral dCCFs in a 52-year-old female. (**a**, **b**) Right ECA and (**c**–**e**) left ECA angiograms. The right dCCF had retrograde drainage to the SOV (white arrows) and SMCV (white arrowhead) including contralateral drainage via both anterior (white short arrow) and posterior (white curve arrow) intercavernous sinuses, then consequently retrograde to the left SOV. Note the left shunt supply from the artery of the foramen rotundum and middle meningeal artery at the inferior-medial aspect of the left cavernous sinus (dashed arrow). Transvenous access was planned via the visualized left IPS to pass the intercavernous sinus to occlude the right SMCV and SOV outlets as the first priority. (**f**) Venography of the CS as the roadmap for coil embolization. (**g**) Microcatheter (arrows) superselection to the right SOV. (**h**) Coil deposition at the right CS, left inferomedial CS, and partially posterior intercavernous sinus (curve arrow). (**i**) Controlled right ECA angiogram revealing small residual right dCCF with bilateral IPS drainage. (**j**) Venous phase of left ICA injection demonstrating return of normal venous drainage to the left CS (dashed arrow)

This alternative route is usually applied after failure of IPS recanalization or failure of a forward microcatheter from the posterior CS to the anterior compartment. Either AFV should be demonstrated to be large enough for retrograde catheterization (Fig. 9.21).

9.5.3 Superficial and Middle Temporal Vein Approach

The supraorbital vein connects to the angular vein and communicates to the middle temporal vein (MTV). The MTV joins the superficial tem-

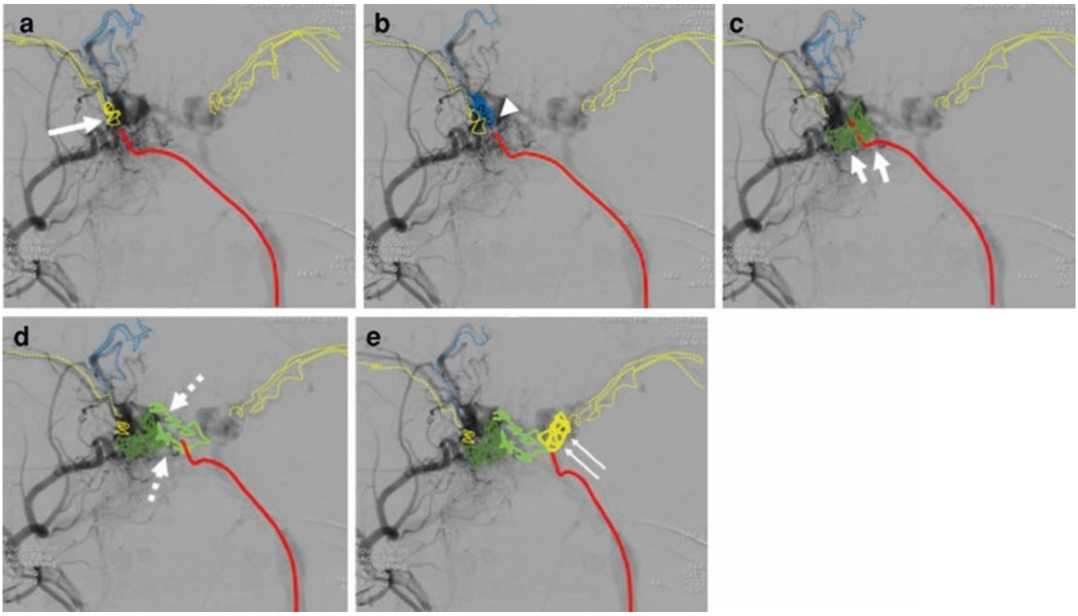


Fig. 9.19 Diagram of transvenous access to embolize bilateral dCCFs (same case as in Fig. 9.17). (**a**) From visualized or dominant IPS access, superselection was done passing the intercavernous sinus to the contralateral SMCV for the first target to embolize the most dangerous venous outlet. (**b**) Moving then toward the SOV outlet which was the symptomatic drainage. (**c**) Closing right dCCF shunt location. (**d**) Superselection of the IC. (**e**) Coiling at the ipsilateral SOV outlet and partially at the ipsilateral dCCF. Red = course of microcatheter along left IPS where its tip in each target, yellow = SMCV and cortical reflux, blue = SOV, arrow in (**a**) = coil mass at right SMCV outlet, arrowhead in (**b**) = coil deposition at right SOV outlet, double short arrows in (**c**) = coil packing at right CS, dashed arrows in (**d**) = coil at anterior and posterior IC, double thin arrows in (**e**) = last coil mass embolized at left SOV outlet and CS

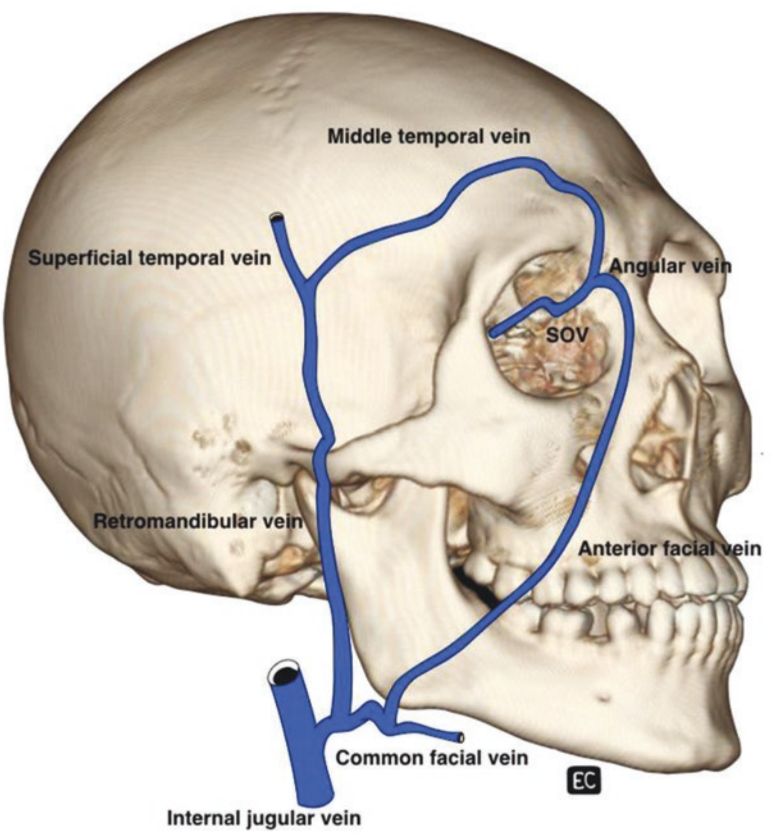
poral vein (STV). At the level of the parotid gland, the STV is joined by the maxillary vein to form the retromandibular vein. The retromandibular vein divides into the anterior and posterior branches. The anterior branch anastomoses with the AFV, and the posterior branch anastomoses with the posterior auricular vein to be the external jugular vein. In some circumstances, the retromandibular vein is undivided and continues as the external jugular vein.

This is another alternative route to access the SOV. An angiogram in delayed venous phase with projection at the neck is the key to understand the venous outlet and plan for retrograde catheterization. The guiding catheter should be placed as far as possible in the MTV to facilitate movement of the microcatheter to reach the CS (Figs. 9.22 and 9.23).

9.5.4 Superior Petrosal Sinus (SPS) Approach

The SPS approach is considered if the IPS fails recanalization and it is not possible to reach the SOV via the AFV or MTV. The SPS originates in the posterior and superior portion of the CS at the petrous apex, and runs posteriorly and laterally in

Fig. 9.20 Diagram of the connections between the superficial veins and SOV



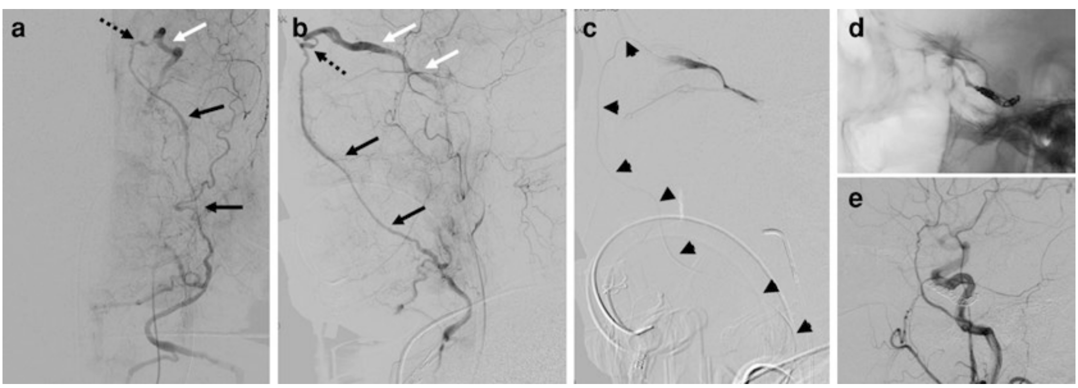


Fig. 9.21 Trans-anterior facial vein approach. A benign left dCCF of a 72-year-old female who had left eye proptosis, conjunctival injection, and increased intraocular pressure up to 22 mmHg for 2 months with failed attempts to recanalized the IPS (not shown). (**a**, **b**) Left ECA angiogram at neck level to identify facial vein for route of access. White arrow = SOV, white arrow head = middle temporal vein, black arrow = superficial temporal vein, curved arrow = retromandibular vein, dashed arrow = angular vein, black arrows = facial vein. (**c**) Retrograde catheterization via the external jugular vein into the facial vein, SOV, and then the CS. (**d**) Coil deposition at the CS and proximal SOV. (**e**) Post-embolization showing complete dCCF occlusion

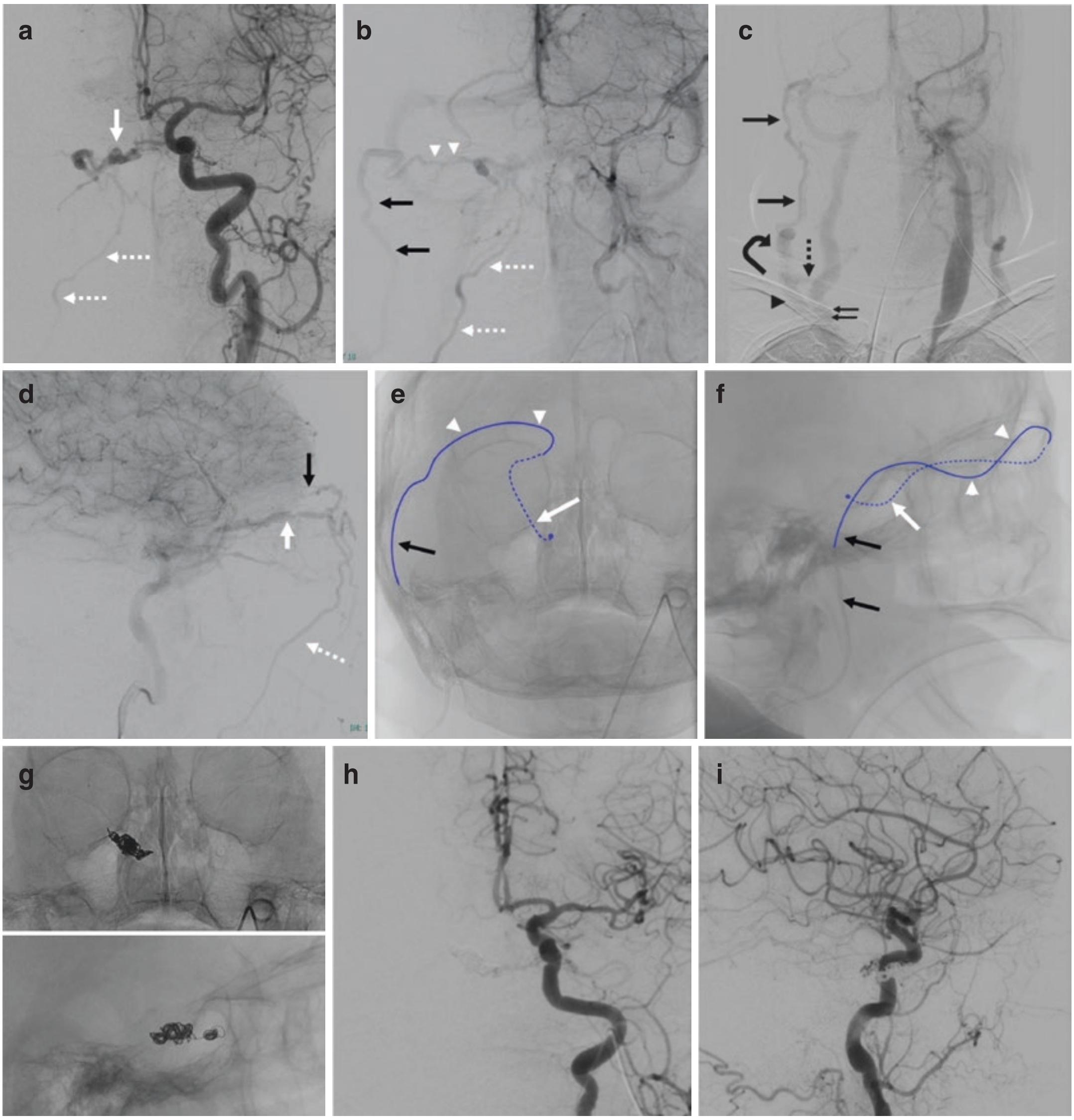


Fig. 9.22 Trans-middle temporal vein access. A right dCCF of an 83-year-old female with failed attempt to recanalize the IPS. (**a**–**d**) Left ICA angiogram for determination of venous route access. Note more prominent right STV and lesser angulation compared to the right facial vein. White arrow = SOV, dashed white arrow = anterior facial vein, dashed black arrow = common facial vein, white arrowhead = MTV, black arrow = STV, curved black arrow = retromandibular vein, black arrowhead = right external jugular vein, double arrows = IJV. (**e**, **f**) Course of the microcatheter. (**g**) Coil mass in the right CS and SOV outlet. (**h**, **i**) Complete occlusion of the right dCCF

the superior petrosal sulcus and empties into the distal transverse sinus or transverse-sigmoid junction.

In this maneuver, the guiding catheter is placed in the sigmoid sinus. The SPV is then catheterized with a microcatheter over a microguidewire to the CS. Special consideration is needed, particularly at the acute angle between the sigmoid sinus and the small size of the SPV. Injury during catheterization may lead to subarachnoid hemorrhage. Therefore, a soft microwire with gently manipulation is required.

9.5.5 Direct SOV Puncture

This procedure should be the last option whenever the other routes fail to access the SOV. The procedure is performed under general anesthesia in the hybrid operating room (if available) by an experi-

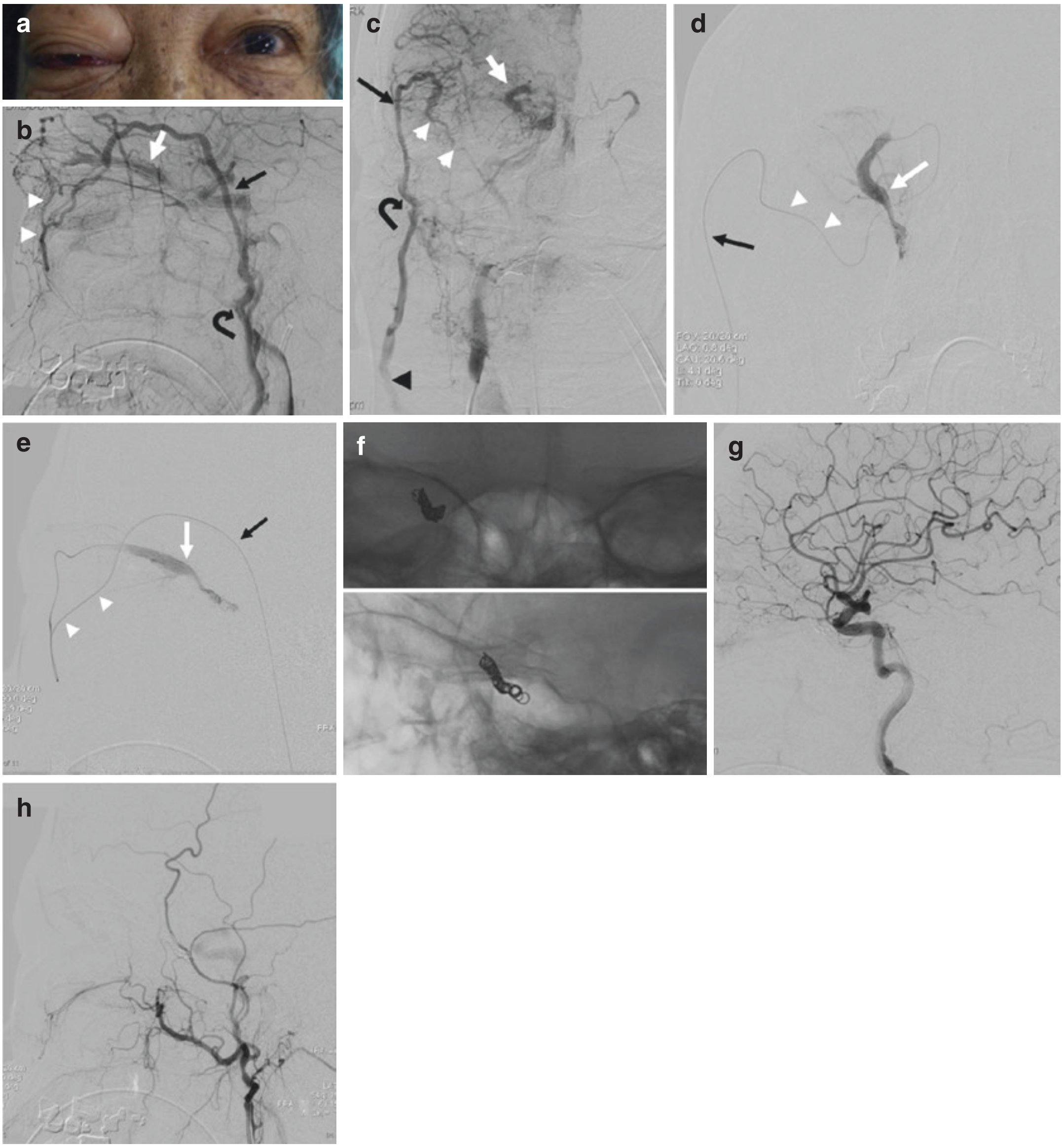


Fig. 9.23 Trans-middle temporal vein access. (**a**) A 72-year-old female presented with progressive right eye redness and diplopia for 2 months. (**b**, **c**) Right CCA angiogram demonstrating right dCCF with drainage into the right SOV, angular vein, MTV, STV, and retromandibular vein. Note the retromandibular vein continues to be the external jugular vein, the small facial vein, and no visualization of the IPS in this case. White arrow = SOV, white arrow head = MTV vein, black arrow = STV, curved arrow = retromandibular vein, black arrowhead = right external jugular vein. (**d**, **e**) Retrograde catheterization via right external jugular vein to the MTV, SOV, and CS. (**f**) Coil deposition at the anterior CS and SOV junction. (**g**, **h**) Complete occlusion of the right dCCF

enced surgeon. The incision is performed at the upper lid or sub-eyebrow to mobilize the angular vein. Using blunt dissection, the SOV is located just below the superior orbital rim. Ultrasound may be useful to identify the SOV. Once SOV is exposed, this vessel is then gently held with a suture and cannulated with a 21G needle. A micropuncture wire is then introduced through the needle into the CS under live fluoroscopy. The SOV runs medial to lateral. A small microguidewire and a microcatheter are then carefully navigated into the dilated SOV. The suture material should be stabilized with a plastic tube during the procedure. Once catherization of the CS is achieved, coil embolization is carried out in the same manner of selection through the SOV as in other pathways. However, if a hybrid operating room is not available, the patient should be transferred to the angiosuite after proper fixation of the introducer sheath. After finishing the procedure, the SOV is manually compressed and followed by suturing (Fig. 9.24).

9.5.6 Transarterial Access

Transarterial embolization is preserved only in dCCF when venous access fails (Fig. 9.25). Much attention and awareness of anastomosis with the ICA must be considered (Fig. 9.7). Liquid embolic materials, such as NBCA and ethylene vinyl alcohol (EVOH), are always the embolic agents of choice. To prevent penetration of the embolic material through the anastomosis, consider using balloon protection at the cavernous ICA when injecting EVOH. In any case, in some particular dCCFs which have a single dilated arterial feeder, the transarterial coil embolization technique can be applied with occlusion at the cavernous inlet and distal artery (Fig. 9.26).

9.5.7 Open Surgery

Open surgery exposure for CS occlusion should be considered as the last option only in cases with cortical reflux when all routes of access to reach the CS by catheterization have failed. A pterional craniotomy and intradural approach to the lateral wall of the CS is performed for the purpose of surgically disconnecting the dangerous venous outlet (Fig. 9.27).

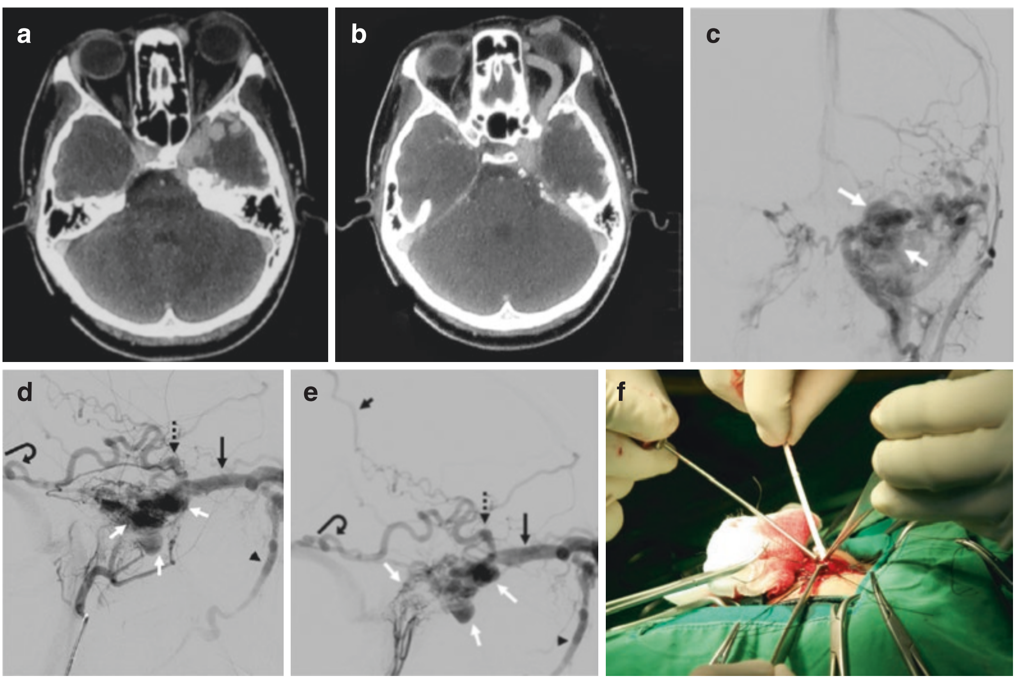


Fig. 9.24 Direct SOV puncture. (**a**, **b**) Axial contrasted CT of a 20-year-old female who presented with left eye proptosis and bruit without a history of trauma revealing enlarged left CS, dilated left SOV, and SMCV. (**c**–**e**) Left ECA angiogram showing huge left dCCF (white arrow) supplied from all meningeal arteries, especially the ascending pharyngeal branches with drainage to the left SOV (black arrow) and significant cortical reflux from the SMCV (dashed arrow) to Labbe's vein (curve arrow) and Trolard vein (short black arrow), arrowhead = facial vein. Note no demonstrable IPS. (**f**, **g**) Decision was made to puncture directly into the left SOV using a 5F introducer sheath. (**h**, **i**) Coil embolization in the enlarged left CS via direct puncture of the SOV. (**j**) During injection of transarterial glue (NBCA) into the residual pouch posteriorly via the ascending pharyngeal branch. (**k**, **l**) Post-embolization revealing significant diminished size and flow of the huge dCCF (white arrows); however, dural supply remained from the left middle meningeal artery (black arrows) and cortical reflux (dash arrows). (**m**) Onyx cast (white dash arrows) after repeated transarterial embolization via accessory meningeal artery using Onyx during inflation of a protection balloon in the cavernous ICA. (**n**, **o**) Follow-up angiogram showing minimal staining at left CS without abnormal venous drainage

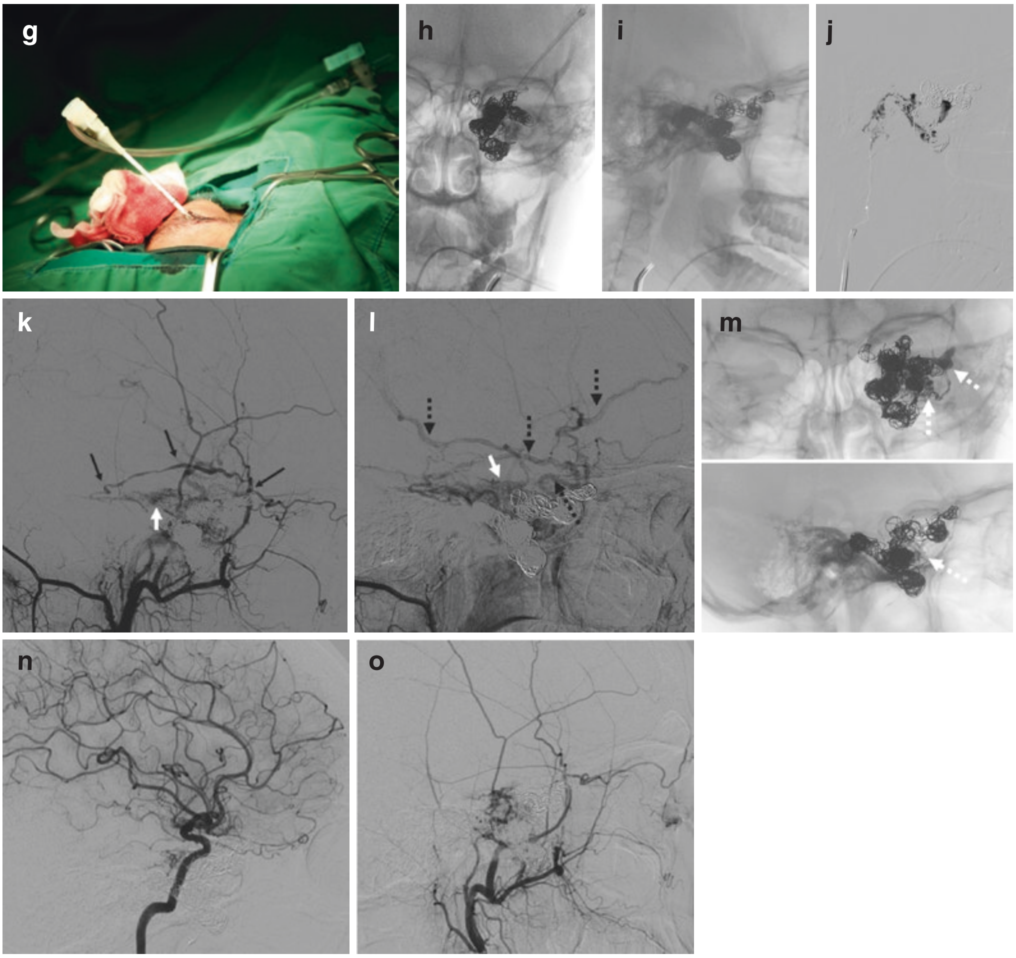


Fig. 9.24 (continued)

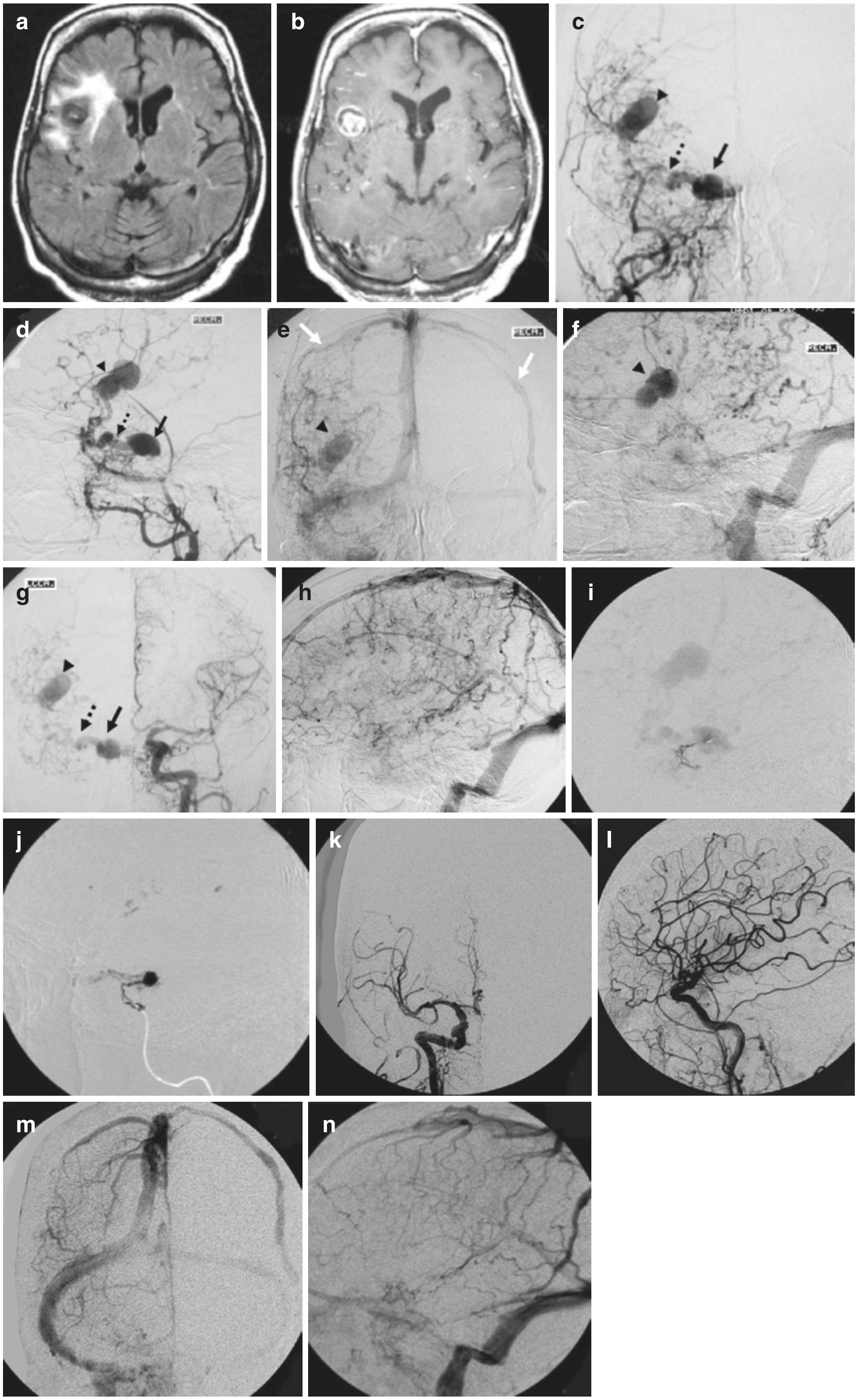

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Fig. 9.25 Transarterial glue embolization. (**a**, **b**) MRI of a 78-year-old female who presented with headache, diplopia, and right lateral rectus palsy showing a partial thrombosed aneurysmal mass with perifocal edema at the right frontal operculum. (**c**, **d**) Right ECA angiogram revealing right dCCF (arrow) with SMCV (dashed arrow) drainage only, causing significant cortical reflux with dilated venous pouch (arrowhead). Note no visualization of the SOV or IPS. (**e**, **f**) Same injection as in (**c**, **d**) showing stagnation of venous pouch (arrowhead) with retrograde cortical reflux draining into the superior sagittal sinus and epidural veins (white arrows). (**g**) Supply of the right dCCF from the dural arteries of the left ICA and ECA with the same venous drainage as in (**c**, **d**). (**h**) Significant venous congestion of the right hemisphere. Note no drainage of normal brain into the right SMCV. (**i**) Superselective injection of the right artery of foramen rotundum which is a supplying pedicle. (**j**) During glue injection at the same position as in (**i**) showing glue cast in the right CS with some spillage into the SMCV. (**k**, **l**) Complete obliteration of the dCCF and SMCV on right CCA angiogram at 1-month follow-up. (**m**, **n**) Significant resolution of venous congestion compared to (**h**)

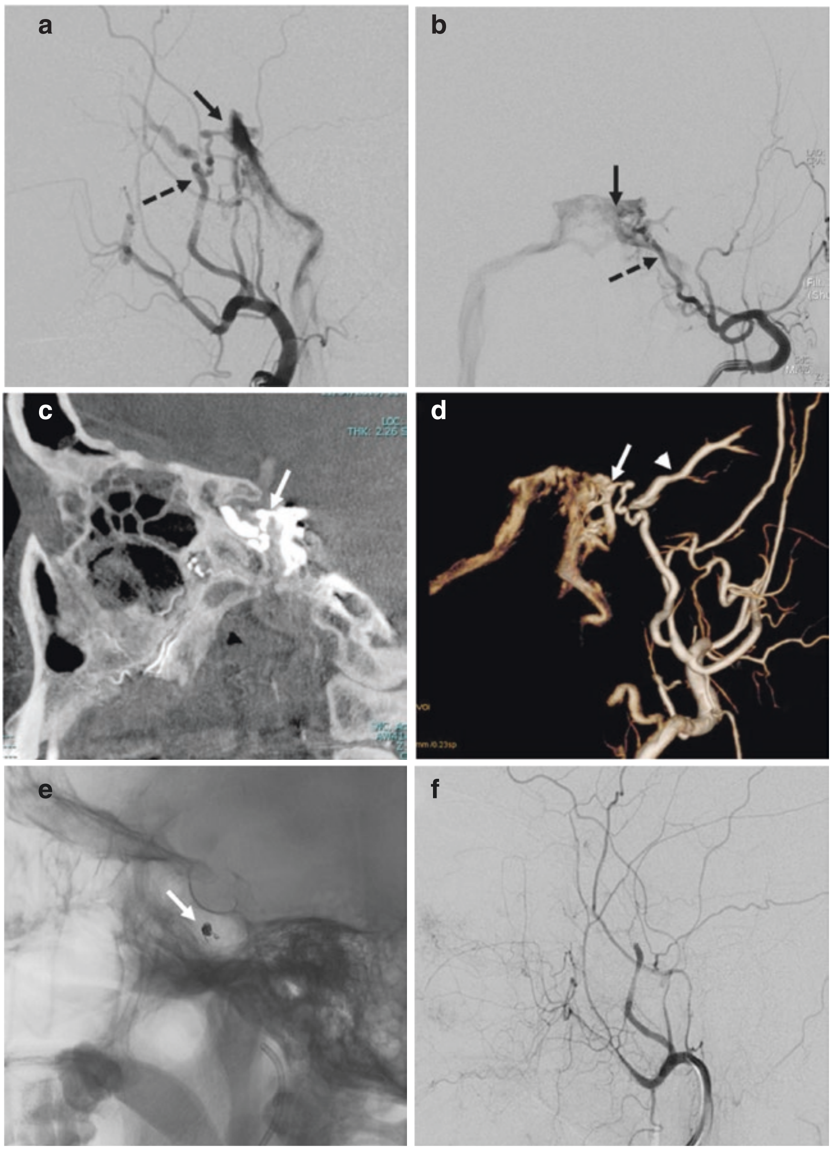

Fig. 9.26 Transarterial coil embolization. (**a**, **b**) Left dCCF showing single supply from accessory meningeal artery (dashed arrow) to medial venous axis with drainage into the posterior IC and contralateral IPS. Also note retrograde flow into the left SOV. (**c**, **d**) 3D angiogram demonstrating fistulous point (arrow), arrowhead = left SOV. (**e**, **f**) Post-coil embolization via left accessory meningeal artery with complete cure

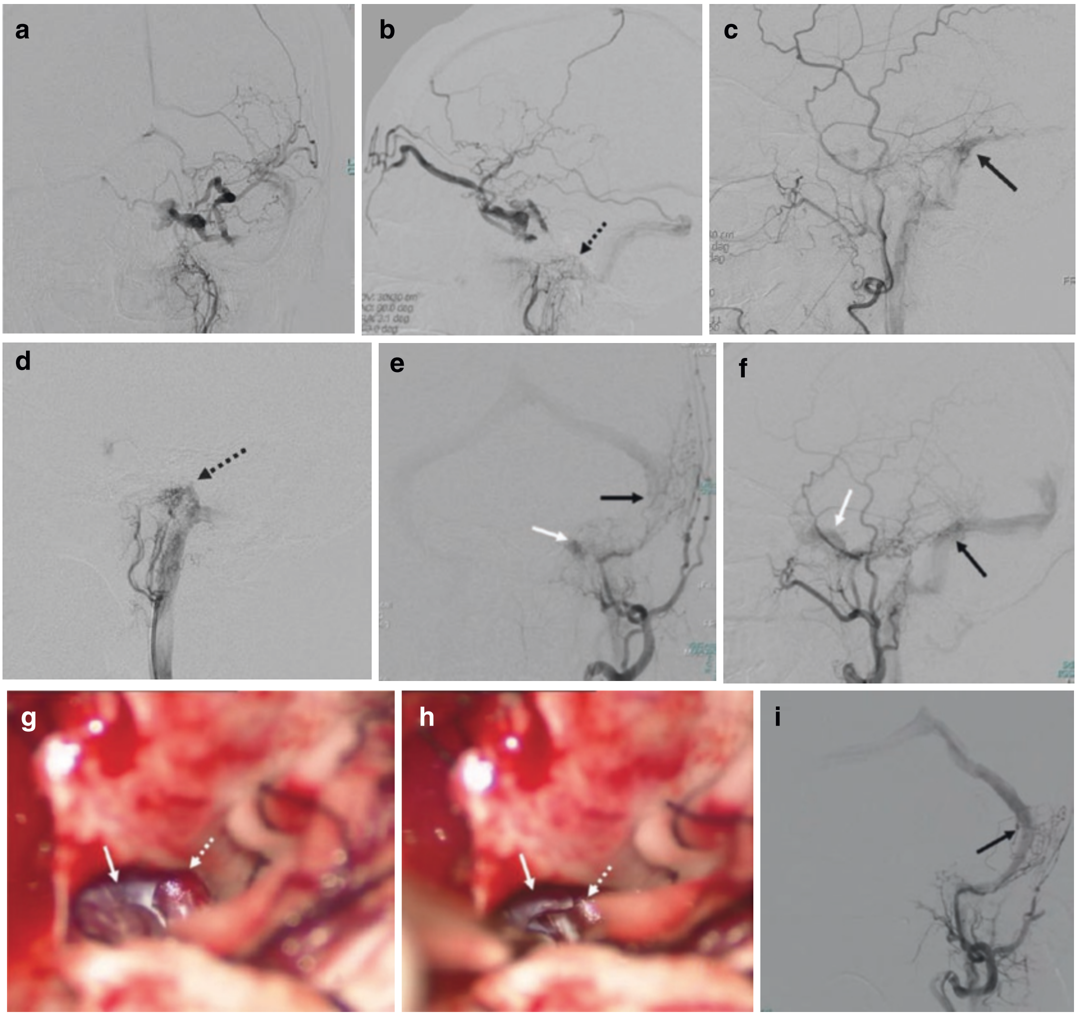

Fig. 9.27 Open surgery for cavernous sinus. (**a**, **b**) Left ECA angiogram of a 64-year-old female who presented with proptosis and chemosis of left eye showing left dCCF with ipsilateral SOV and SMCV drainage. Note occlusion of the IPS and another benign dural shunt at left sigmoid-jugular junction (dashed arrow). The patient had failure of recanalized IPS and access to the CS. (**c**, **d**) Left ECA angiogram at 3 months with planning to retry embolization, revealing unexpected spontaneous occlusion of the SOV and dangerous drainage; however, persistence of the shunt at the sigmoid-jugular junction (dashed arrow) with a new acquired shunt at left sigmoid sinus (arrow). (**e**, **f**) Re-appearance of the left dCCF with SMCV drainage (white arrow) and persistence of the left sigmoid dural shunt (arrow) on follow-up angiogram at 1 year 6 months. After a failed attempt to access the CS again, surgical disconnection of the SMCV was planned. (**g**) Intraoperative pictures of the left frontotemporal approach of a craniectomy. (**h**) Post-coagulation of the sphenoparietal sinus white arrow = sphenoparietal sinus, dashed white arrow = SMCV. (**i**, **j**) Immediate post-surgical angiogram showing complete obliteration of the dCCF; however, increased retrograde sinus drainage of the left sigmoid dural shunt occurred, which would receive endovascular treatment in the next session. During the hospital stay, the patient had progressive left eye chemosis during the next 2 days. (**k**, **l**) Left ECA angiogram revealing rerouting of drainage of the left dCCF (white arrow) via the SOV (white dashed arrow). Surgical CS exposure was again performed in the hybrid operating room for direct puncture at the SOV outlet for coil embolization. (**m**, **n**) Intraoperative pictures. Arrow = SOV. (**o**) Needle puncture at the SOV (arrow). (**p**) Direct catheterization via the SOV for coiling at the CS. Dashed arrow = microcatheter. (**q**) Coil deposition at the CS and SOV outlet. (**r**) Controlled angiogram showing complete obliteration of the left dCCF. The dural AV shunt at the left sigmoid sinus was scheduled for embolization later with complete cure (not shown)

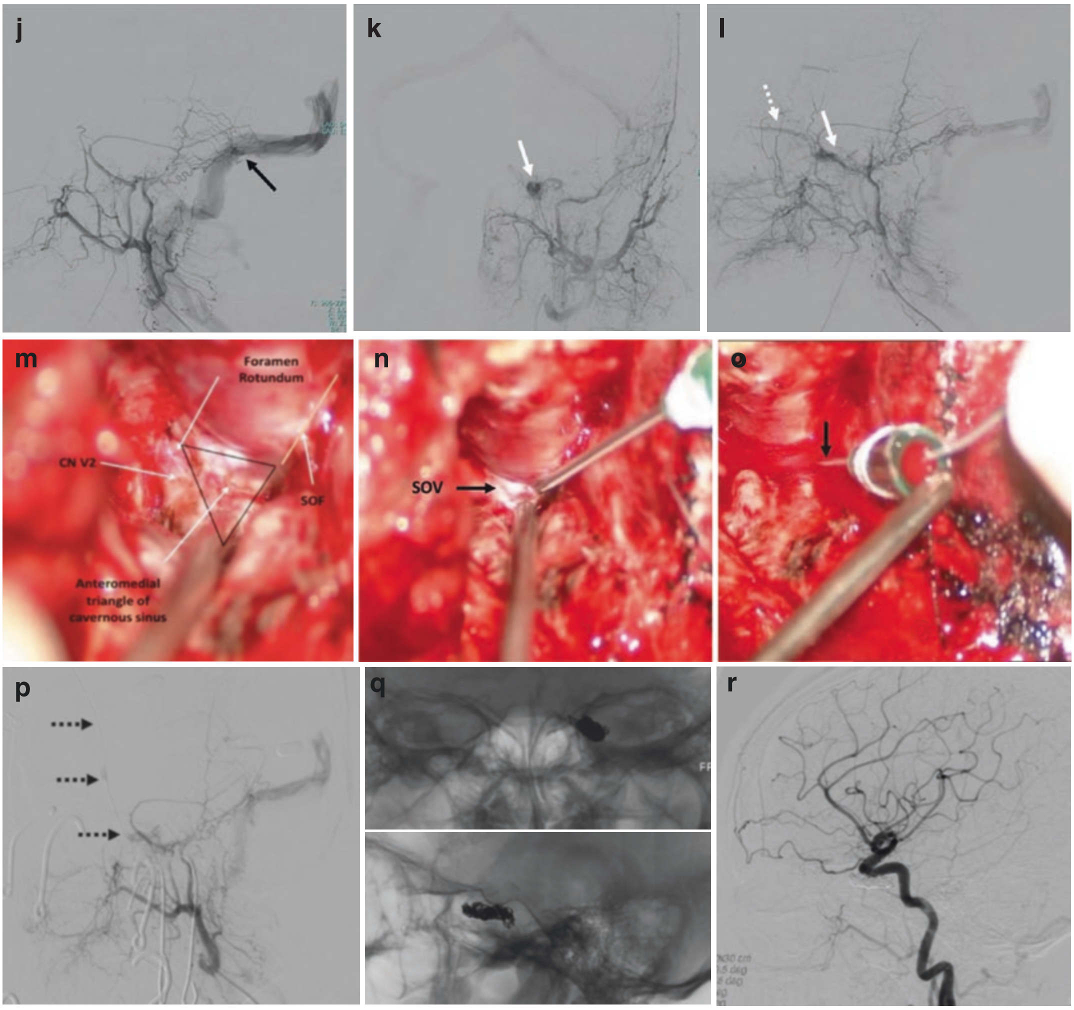

Fig. 9.27 (continued)

9.6 Complications of Endovascular Embolization

Complications need to be considered in endovascular treatment of dCCFs.

1. Cranial nerve palsy: The coil mass in the CS may cause mass effect to cranial nerves III, IV, and VI resulting in ptosis or ophthalmoplegia [15, 16], particularly when combined with liquid embolization. Nevertheless, most of those ocular symptoms from mass effect will recover within 6 months. Conversely, toxicity of DMSO was reported to cause cranial nerve damage with permanent deficit [17]. Thus, selective coil packing only in the affected venous channel is essential to avoid this undesirable consequence.
2. Iatrogenic vascular injury during blind catheterization through the occluded IPS: Hemorrhaging can occur as a subdural hematoma, direct carotid-cavernous fistula, or subarachnoid hemorrhage, or even intraparenchymal hemorrhage depending on the location of vessel injury (Fig. 9.28).
3. Neurological deficit from arterial occlusion: This is the most dangerous sequela from transarterial embolization using liquid embolic materials. They may easily reflux through the anastomosis between the ECA and ICA that may lead to cerebral infarction or permanent cranial nerve palsy [18].
4. Rerouting drainage into the deep venous system of the brainstem or spinal cord veins after incomplete closure of a dCCF: A follow-up angiogram with planning for complete treatment at least within a few months is recommended in patients with residual venous drainage in the aggressive type of dCCF.

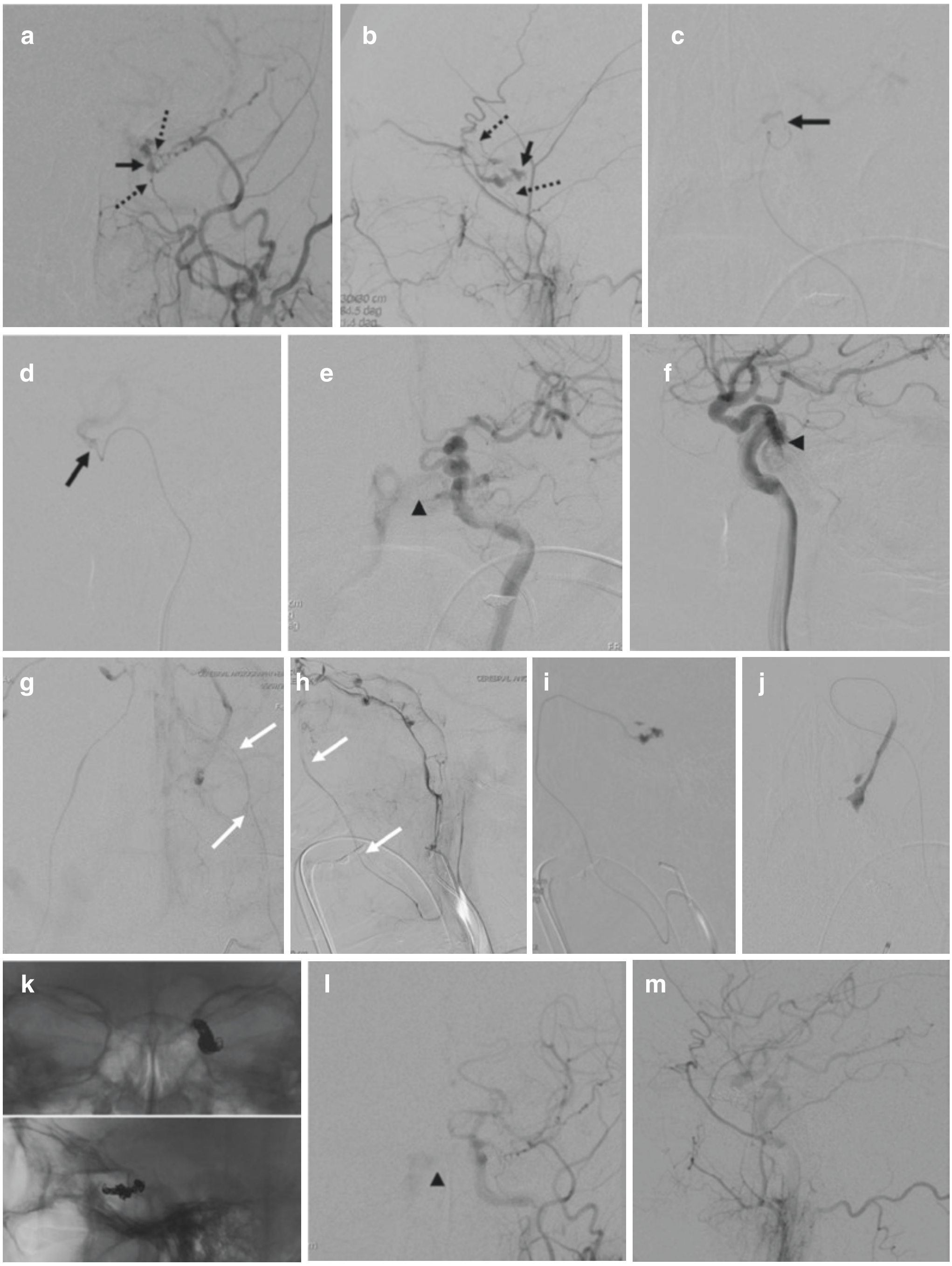

Fig. 9.28 Perforation complication. (**a**, **b**) Left dCCF (arrow) supplied from tiny pedicles from the middle meningeal and accessory meningeal arteries (dashed arrows) with drainage to the SOV. Note no visualization of the IPS. (**c**, **d**) Transvenous catherization via blind recanalized left IPS. The catheter tip (arrow) indwelling in the CS. Test injection showing perforation into the cavernous ICA. (**e**, **f**) Injection of the left ICA subsequently demonstrating direct CCF (arrowhead) with intercavernous drainage. (**g**, **h**) Left ECA angiogram at neck level to identify left facial vein (white arrows) for an alternate route of access. (**i**, **j**) Retrograde navigation of the microcatheter in the facial vein to the SOV and CS. (**k**) Coil deposition in the CS. Compare the morphology in (**a**–**b**). (**l**, **m**) Controlled angiogram revealing complete obliteration of left dCCF; however, persistent iatrogenic direct CCF (arrowhead). On 3-month angiogram follow-up, this direct CCF demonstrated spontaneous healing (not shown)

9.7 Conclusion

The aggressive type of dCCF requires treatment with the goal of curing or at least obliterating the dangerous venous outlet and/or symptomatic venous outlet. The transvenous approach to access the CS for coil embolization is a more favorable treatment method to achieve this goal with safety and effectiveness. Selective embolization at the affected venous channel of the CS is feasible. The IPS is suggested as the initial route of access, even though it is not visualized. The other alternative pathways include the anterior facial vein and middle temporal vein as routes to access the SOV. If transarterial embolization is desired, a dangerous anastomosis between the ECA and ICA along with the risk of complications should always be kept in mind. Direct puncture of the SOV and surgery is the option in a dCCF when it is not safely accessible by the endovascular approach.

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