# 11 Cranial Dural Arteriovenous Fistulas: The Role of Transarterial and Transvenous Balloon-Assisted Embolization

Felipe Padovani Trivelato,
Alexandre Cordeiro Ulhôa,
and Marco Túlio Salles Rezende

**Abstract**

The treatment of dural arteriovenous fistulas (DAVFs) consists of occluding the venous component related to the fistula. The arterial route, the venous route or a combination of both can be used. The great challenge of endovascular treatment, especially through the arterial route, is to control the progression of the liquid embolic agent. It should reach the fistulous point and the draining vein but without excessive reflux on the arterial side. Additionally, extensive occlusion of the draining vein or inadvertent occlusion of a venous sinus should be avoided. To obtain a better control of the liquid embolic agent progression, transarterial double-lumen balloon catheters have been used with or without transvenous balloon catheters to protect the dural sinus. Transarterial treatment of DAVFs assisted by double-lumen balloon catheters is safe and effective. The use of the balloon makes the occipital artery an excellent access route, since the problem of excessive reflux and greater resistance of the transosseous branches is overcome. This route presents results as good as when the middle meningeal artery is used. The transvenous balloon catheter is also safe and can prevent inadvertent occlusion of the dural venous sinus. Complications related to temporary sinus occlusion are rare. The association of transvenous and transarterial balloon catheters is very effective, determining high rates of total occlusion of DAVFs. The introduction of two balloons simultaneously, through the middle meningeal artery and the occipital artery, seems to be a very promising approach, since it provides greater control over the flow toward the fistula.

**Keywords**

Dural arteriovenous fistula · Balloon Embolization · Endovascular

F. P. Trivelato (✉) · A. C. Ulhôa · M. T. S. Rezende
Division of Interventional Neuroradiology,
Felício Rocho Hospital,
Belo Horizonte, Minas Gerais, Brazil

Division of Interventional Neuroradiology,
Rede Mater Dei Saúde,
Belo Horizonte, Minas Gerais, Brazil

Neurovascular Institute,
Belo Horizonte, Minas Gerais, Brazil


X. Lv (ed.), *Intracranial and Spinal Dural Arteriovenous Fistulas*,
https://doi.org/10.1007/978-981-19-5767-3_11

**Key Points**

- DAVFs can be treated by transarterial or transvenous approaches.
- The transarterial approach is the first choice for treating most DAVFs with direct leptomeningeal venous drainage.
- Transarterial balloon-assisted embolization improves the rate of cure in high-grade DAVFs.
- Dural sinus occlusion is associated with higher rates of angiographic cure for sinus wall DAVFs.
- Occlusion of a dural sinus might lead to a substantial risk of complications.
- Dural sinus preservation with a transvenous balloon catheter is safe and very effective.
- The association of transvenous and transarterial balloon catheters offers flow/pressure control in the treatment of DAVFs.

## 11.1 Introduction

The first authors to correlate the clinical behavior of cranial dural arteriovenous fistulas (DAVFs) with the pattern of venous drainage and to propose a classification based on this drainage were Djindjian and Merland in 1978 [1, 2]. The classifications currently used, especially those of Cognard and Borden, are based on this same concept, and they allow an accurate comparison between clinical manifestations and radiological patterns [1, 3].

The endovascular treatment of DAVFs consists of occluding the venous component related to the fistula [3]. The drainage pattern guides the therapeutic management of these lesions. Therefore, DAVFs with direct drainage to a leptomeningeal vein should be treated by occluding the draining vein at the point closest to the fistulous zone, called the "foot of the vein" [2, 4, 5]. On the other hand, the treatment of DAVFs draining to a dural sinus wall should be treated by occluding the lumen of this sinus or the fistulous point located in the wall of the sinus [2, 6].

The arterial route, the venous route or a combination of both can be used [3]. However, the great challenge of endovascular treatment, especially through the arterial route, is to control the progression of the liquid embolic agent. It should reach the fistulous point and the draining vein but without excessive reflux on the arterial side. Additionally, extensive occlusion of the draining vein or inadvertent occlusion of a venous sinus should be avoided [2, 3, 6].

To order to obtain a better control of the liquid embolic agent progression, transarterial double lumen balloon catheters have been used with or without transvenous balloon catheters to protect the dural sinus [7–15]. This strategy allows the injection of the embolic agent through the arterial route without extensive reflux, since the retrograde flow is blocked by the inflated balloon inside the arterial feeder. The risk of inadvertent venous sinus occlusion is minimized, as the inflated balloon inside the sinus protects its lumen.

## 11.2 Pros and Cons of Transarterial and Transvenous Approaches

### 11.2.1 Transarterial Approach

Most DAVFs can be treated through an arterial approach [2, 6]. This route has been successfully used to treat DAVFs with direct leptomeningeal drainage [4, 5].

In the pre-ethylene vinyl alcohol (EVOH) copolymer era, with the use of polyvinyl alcohol (PVA) particles and glue, the results of transarterial treatment were disappointing. PVA particles were associated with a high chance of recanalization. Similarly, there was great difficulty in controlling the anterograde progression of the glue in such a way that it reached the venous side, but without migration too distally inside the drainage vein [4].

Since the introduction of EVOH in 2006, for the treatment of DAVFs, this scenario has changed [4]. Because of the better control of embolic agent progression, high cure rates have been reported [2, 5].

The failures are mainly related to the impossibility of obtaining adequate arterial access. A position close to the fistulous zone, which allows the injection of the embolic agent, especially through the middle meningeal artery, provides a better progression of EVOH.

Another limiting factor is reflux inside the arterial feeder. This reflux is expected to occur, as it is part of the EVOH injection technique, allowing the formation of a proximal plug that will favor the anterograde progression of the liquid embolic agent [7].

However, depending on the position of the microcatheter, a delicate balance must be respected between the anterograde progression of the embolic agent and reflux. Usually, the more extensive the reflux is, the greater the chance that the embolic agent will reach the draining vein and the more likely it is to obtain angiographic cure of the lesion. On the other hand, the more extensive the reflux is, the greater the rate of complications, especially those related to the filling of dangerous anastomoses of the external carotid artery and those related to the occlusion of cranial nerve feeders [7–9].

### 11.2.2 Transvenous Approach

Transvenous access has been classically used to treat DAVFs located in the wall of a sinus. Sinus occlusion is associated with a higher chance of complete obliteration of the fistula compared to selective treatment by the transarterial access. However, complete obliteration of a dural sinus can lead to a substantial risk of complications if the occluded sinus impairs normal brain drainage [3].

Thus, when the involved dural sinus participates in normal venous drainage, transvenous access is quite limited. It has been used when an accessory dural sinus or a compartmentalized sinus are present [3, 6]. In these cases, venous access can still be used to selectively occlude the involved compartment, preserving the main sinus [3, 6].

Another limitation of the venous route for treating dural sinus wall fistulas is the isolated sinuses. In such cases, there is some obstacle, most often a thrombus inside the dural sinus, which obstructs the sinus lumen both proximal and distal to the fistulous zone [6, 10]. Thus, access to the involved segment of the sinus cannot be reached directly. It is necessary to recanalize the sinus lumen or even perform direct access to the sinus through a craniotomy.

Regarding DAVFs with direct leptomeningeal venous drainage, transvenous access is usually not preferred [2, 4]. This has been avoided in this type of fistula since venous navigation within a leptomeningeal vein is usually challenging from a technical point of view and has considerable risks [2, 4, 5]. Exceptions would be fistulas in the anterior cranial base and fistulas in the hypoglossal canal region.

## 11.3 Dural Sinus Sacrifice Versus Dural Sinus Preservation

Dural fistulas located in the wall of a sinus can be treated in two completely different ways, either by occluding the segment of the dural sinus involved, or by preserving the sinus lumen [3]. Sinus occlusion can be performed via a venous approach, using coils with or without the association of liquid embolic agents, or via an arterial approach, through the injection of liquid embolic agents that will migrate to the venous side [3, 6].

The strategy of preserving the lumen of the dural sinus is associated with a lower risk of complications, especially those related to the impairment of venous drainage. However, lower rates of total occlusion of the fistulas are expected in the selective treatment [3, 4].

A major controversy occurs when the sinus is not functioning, whether there is a reason to still preserve its patency. The sinus may be nonfunctioning because of a hemodynamic competition, rather than anatomical disruption, a true occlusion [7, 11].

Based on the pathophysiological origin of DAVFs, multiple abnormal arteriovenous connections are present in the dural venous sinus wall and not within the sinus [7]. Consequently, occlusion of connections in the venous sinus wall seems to be more reasonable than occlusion of the entire lumen of the dural sinus, especially if the sinus is being used for normal venous drainage [3, 7, 11].

## 11.4 Specific Challenges While Treating DAVFs

### 11.4.1 DAVFs with Direct Leptomeningeal Venous Drainage

DAVFs with direct leptomeningeal venous drainage are preferentially treated through a transarterial approach because of the technical difficulty in navigating inside dilated and tortuous leptomeningeal veins. The middle meningeal artery is the access of choice for the treatment of most lesions, including fistulas of the tentorium, transverse and sigmoid sinuses, torcula and convexity [2, 4, 5].

In the best scenario, the microcatheter should be navigated to a position close to the fistulous zone. Thus, the migration of the liquid embolic agent toward the draining vein will occur earlier, before the occurrence of excessive reflux [5].

In most cases, with a single session through the middle meningeal artery, it is possible to treat most DAVFs with direct leptomeningeal drainage. However, very tortuous and thin arterial access may prevent the microcatheter from reaching a position close to the fistulous zone [2, 4, 5]. In this situation, excessive reflux may occur before the embolic agent reaches the draining vein. Complications related to excessive reflux include cranial nerve ischemia and microcatheter entrapment [5]. The advent of detachable tip microcatheters has partially solved this problem.

In some cases, the middle meningeal artery is not the main supply of the fistula, or it has been previously occluded, or navigation within this vessel is not possible. In these scenarios, the occipital artery tends to be an important supplier of the fistula. This artery is usually quite large and tortuous. Thus, it is difficult to navigate the microcatheter distally and specially to form the proximal plug after the initial reflux of the embolic agent, which will determine the anterograde migration of the EVOH [7, 12].

Another complicating factor is that the occipital artery supplies DAVFs through transosseous branches, which have greater resistance [7]. The liquid embolic agent tends to preferentially penetrate into scalp branches instead of branches directly supplying the fistulous zone. Thus, long reflux of the embolic agent inside the occipital artery and excessive filling of scalp branches are necessary before EVOH reaches the fistula [12]. Numerous dangerous anastomoses exist in the most proximal portion of the occipital artery, which limits the amount of acceptable reflux.

The duration of the procedure and the radiation dose used are also limiting factors [12]. Therefore, access through the occipital artery is considered not ideal.

### 11.4.2 DAVFs Draining to a Dural Sinus

The treatment of DAVFs located in the sinus wall through the venous approach is technically easy. The sinus can be occluded with liquid agents, coils, or both [3]. We have adopted the strategy of using two microcatheters. One of these compounds, compatible with dimethyl sulfoxide (DMSO), is kept distally. Through a second microcatheter, coils are placed throughout the involved sinus segment until reaching the most proximal portion of the fistulous zone. If angiographic control still shows residual filling of the fistula, the first microcatheter, positioned in the most distal portion of the cast of coils, is used for the injection of a liquid embolic agent.

This two-microcatheter technique ensures that, after coil implantation, if there is still residual filling of the fistula, it is not necessary to gain new access to the fistulous point across the cast of coils.

The arterial route is commonly used when it is decided to preserve the sinus lumen [2, 3, 6]. In this situation, the aim is that the liquid embolic agent penetrates into the wall of the venous sinus, between the sheets of the dura mater without migrating into the sinus. Some migration is inevitable and occurs in most cases. Care must be taken to ensure that the amount of embolic agent that crosses to the venous side is minimal, avoiding dural sinus occlusion or distal embolism.

In most cases, it is possible to treat the fistula and to preserve the lumen of the dural sinus via an arterial approach. However, this technique requires a long fluoroscopy time, and the reflux inside the arterial feeder can be excessive [2, 6]. Multiple arterial accesses in multiple sessions may be necessary. Controlling the migration of the liquid embolic agent becomes very challenging in lesions with very high flow.

## 11.5 Rationale for the Use of Balloon Catheters in DAVF Treatment

### 11.5.1 Transarterial Double-Lumen Balloon

To order to improve the penetration of the liquid embolic agent inside the fistulous zone during the treatment of DAVFs, some strategies have been used, including the pressure cooker technique with coils or glue and the use of a balloon in parallel with a microcatheter to avoid reflux [16, 17]. When double-lumen balloon catheters are used, instead of these techniques, the navigation of a single device for each arterial access is sufficient.

The use of a double-lumen balloon catheter for the injection of liquid embolic agents was described for the first time in 2013 [13]. When the balloon is inflated, it is able to create a barrier, which will favor the anterograde migration of the embolic agent.

The balloon catheter allows more aggressive embolization, with a longer injection and larger volumes, without any reflux. Thus, the procedure becomes safer [9, 10].

### 11.5.2 Transvenous "Protective" Balloon

Although the double-lumen balloon catheter is an innovative solution for managing reflux, it does not provide any protection for the dural sinuses. In contrast, the balloon inflated in the arterial feeder tends to increase the migration of the embolic agent into the sinus at an early stage.

This unintentional migration of the liquid embolic agent into the sinus must be avoided. The use of a balloon inside the sinus to protect its lumen facilitates the management of these DAVFs. Without the presence of any barrier inside the sinus, the distal embolism of the liquid agent can only be controlled by stopping the injection [11, 15, 18].

The transvenous balloon catheter allows the embolic agent to penetrate the sinus wall, where multiple arteriovenous connections are located [11, 15, 18]. Once the sinus lumen is protected by the inflated balloon, the migration of the embolic agent occurs along the entire sinus wall circumferentially, occluding the fistulous zone.

In some cases, the use of a transvenous balloon catheter is impossible or unnecessary, including isolated sinuses, sinuses containing a thrombus causing partial occlusion, severe stenosis (>80%), or a very ectatic sinus [19]. In other cases, especially in fistulas involving the torcula, the dural sinus may be extremely dilated. The Copernic RC balloon catheter diameter is not sufficient to occlude the sinus; thus, it does not offer sufficient protection. In this situation, it is possible to use two balloons in parallel [19].

## 11.6 Technical Nuances for the Use of Transarterial and Transvenous Balloon Catheters

### 11.6.1 DAVFs with Direct Leptomeningeal Venous Drainage

There are several double-lumen balloon catheters available on the market, including Scepter (Microvention, Tustin, USA), Copernic 2L (Balt

Extrusion, Montmorency, France), Eclipse 2L (Balt Extrusion, Montmorency, France) and Ascent (Cerenovus, Irvine, USA) [20–25]. Such balloons have two lumens: the first is dedicated to the introduction of the guidewire (usually 0.014 in.), and the second lumen is used to inflate the balloon. Thus, after removing the guidewire, it is possible to inject the embolic agent through the lumen of the wire without deflating the balloon [9, 22] (Fig. 11.1a).

The balloon can be navigated through a 6F guiding catheter that will usually be positioned in the external carotid artery inside feeding branches of the DAVF. If the anatomy is complex, with very tortuous vessels and the need for very distal navigation, a triaxial system with a long sheath and a guide catheter with a flexible tip can be used [19] (Fig. 11.1b).

The middle meningeal artery should be used as the preferred access whenever possible. Usually, in the presence of DAVFs, the middle meningeal artery is the main supplying artery, and it has an increased caliber and a straighter path embedded in the dura mater [12, 19]. The

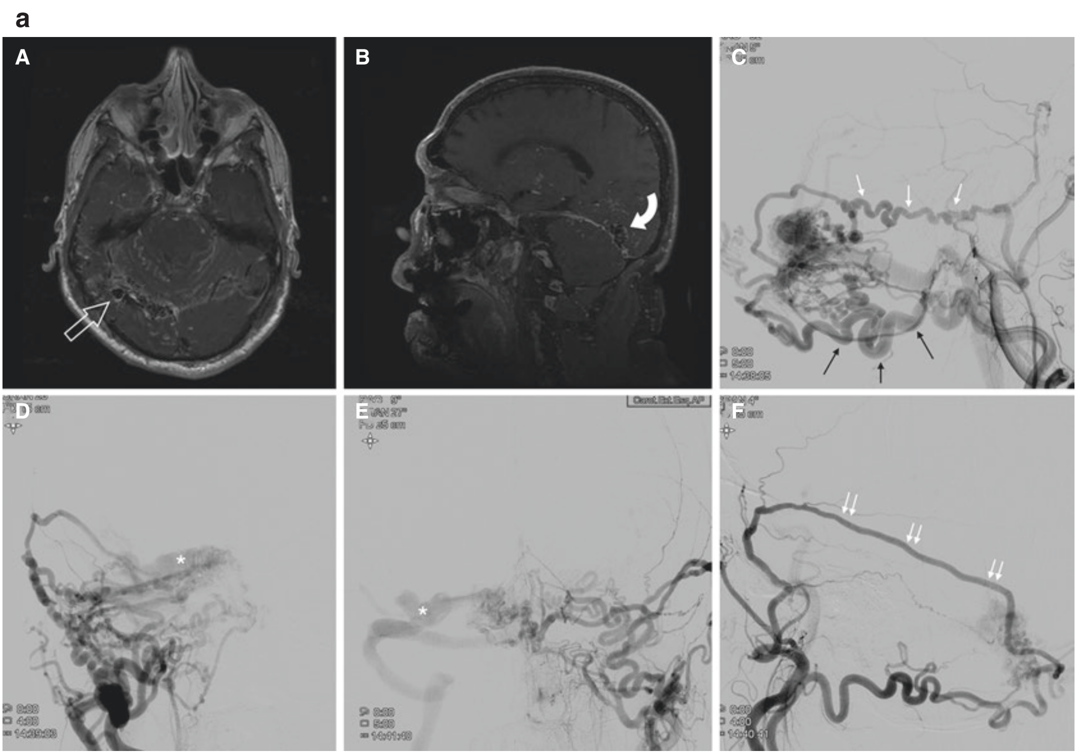


**Fig. 11.1** (**a**) (A) MRI shows an ectatic vein (open arrow) and multiple arterial feeders. (B) Note the tentorial location (curved arrow) of the lesion. (C) Right external carotid artery angiogram (lateral view) demonstrates a lateral tentorial DAVF supplied by a very tortuous MMA (white arrows) and a large occipital artery (black arrows). (D) Note the “foot” of the draining vein (asterisk). (E, F) Left external carotid artery angiograms (AP and lateral views) demonstrate a right tentorial DAVF supplied by a straight left MMA draining directly to an occipital vein (asterisk). (**b**) (A) Road mapping image shows a double-lumen balloon (open arrow) placed in the origin of the mastoid branch (black arrow) of the occipital artery. (B) Note the double-lumen balloon inflated (open arrow) and the position of the guide catheter with a flexible tip (large arrow). (C) Lateral fluoroscopy demonstrates two guide catheters inside the MMA and occipital arteries (large arrows). The tip of the balloon catheter (black arrow) is inside the mastoid branch and the tip of a standard microcatheter (white arrow) is in the MMA. (D) Double-injection through the microcatheter (whiter arrow) and balloon catheter (black arrow) shows the fistulous zone and the draining vein (asterisk). (**c**) (A) Control angiography (bilateral injection) after embolization reveals total occlusion of the DAVF. (B) Venous phase shows a patent right transverse sinus (double-arrows), with no migration of EVOH. (C) Note the cast of EVOH inside the draining vein (asterisk) of the fistula. (D) MRI after 6 months demonstrates total occlusion of the DAVF

**b**

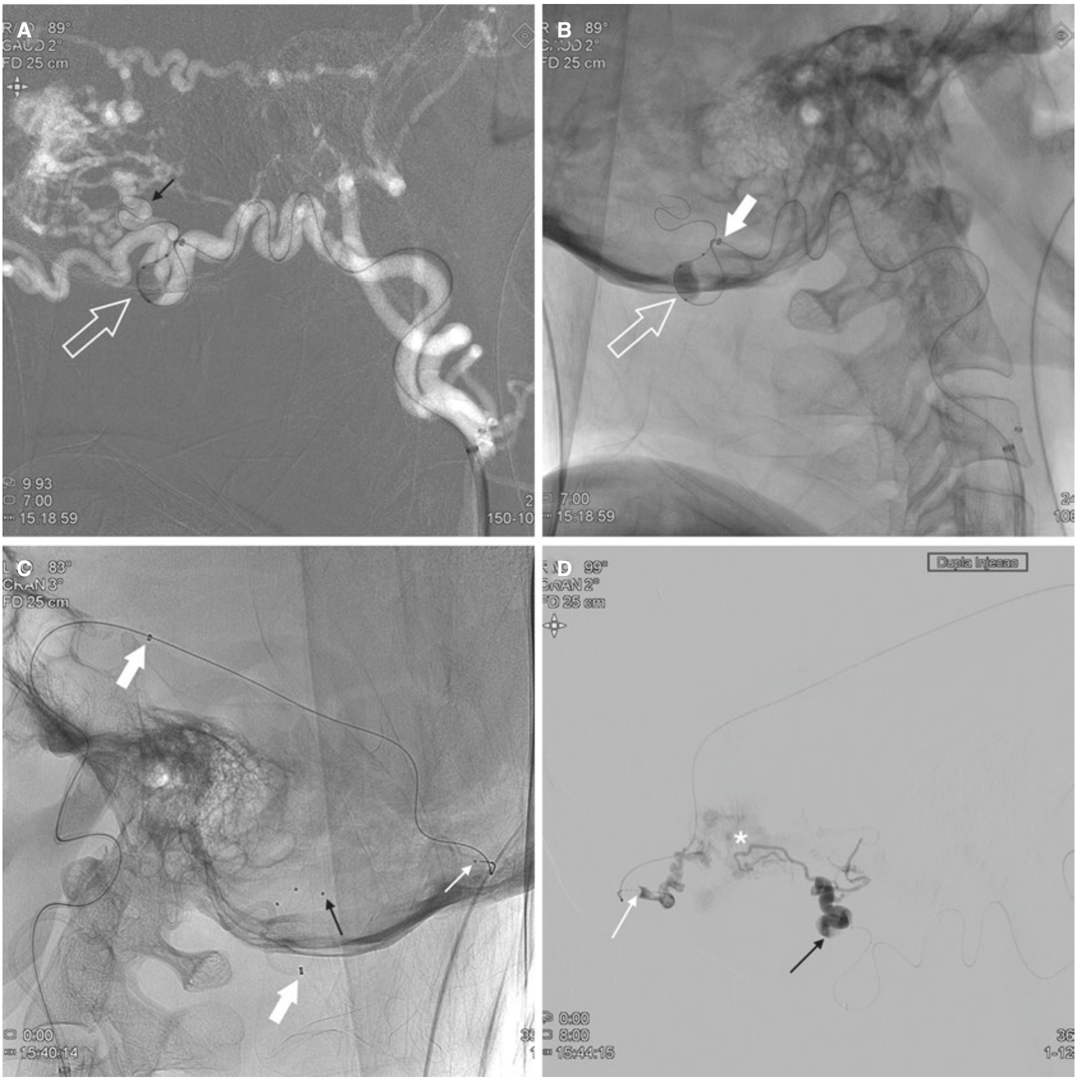


**Fig. 11.1** (continued)

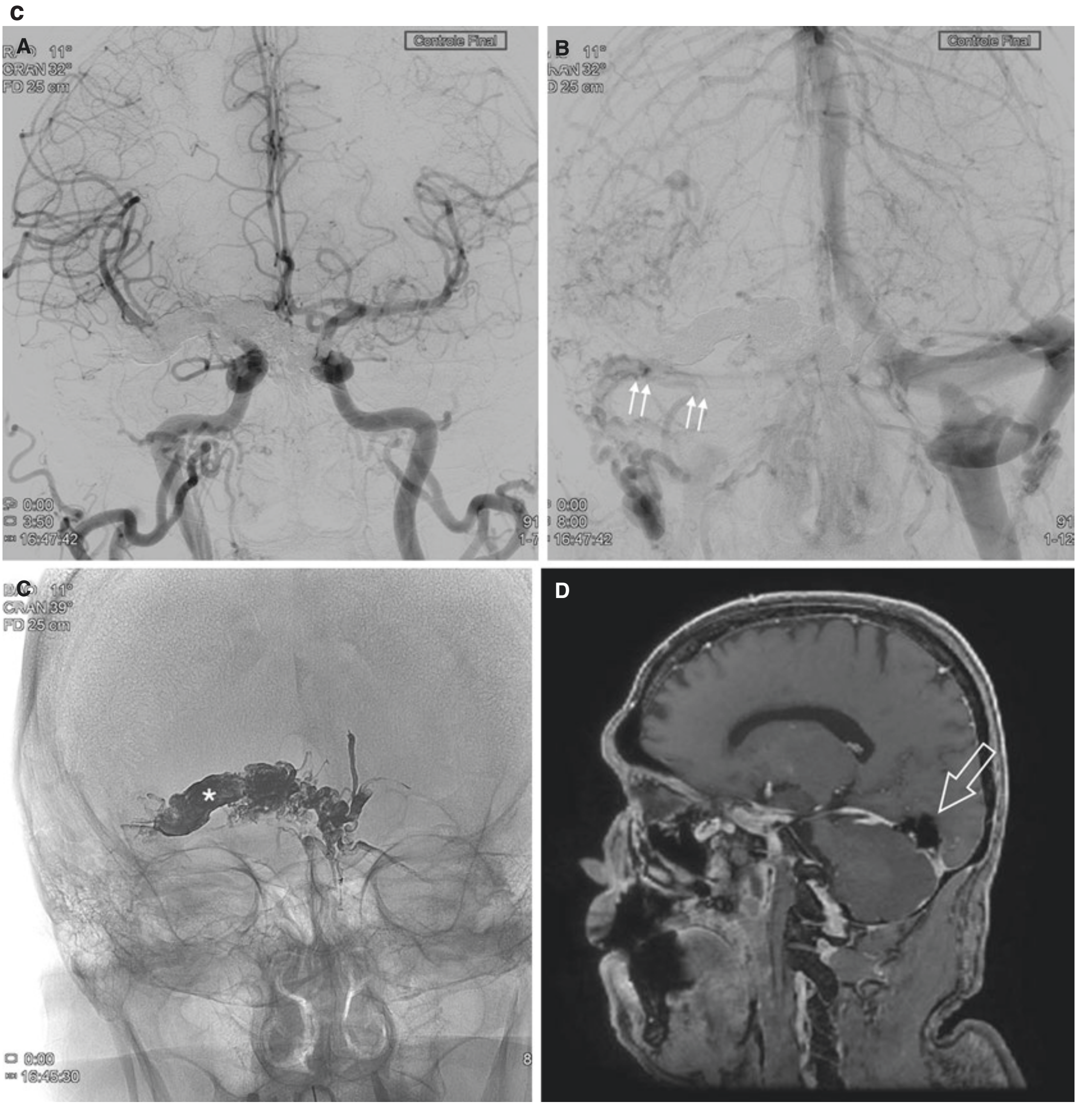


**Fig. 11.1** (continued)

occipital artery, which frequently supplies DAVFs, especially at the tentorial region, at the transverse/sigmoid sinuses and torcula, is often very dilated and tortuous, and the control of reflux is difficult due to the great resistance through the transosseous branches [12]. However, with the use of the double-lumen balloon catheter, this artery, which was previously considered a poor access route, can be used with great effectiveness. Ideally, the double-lumen balloon catheter should be positioned inside the mastoid branch; thus, it could prevent both reflux of the embolic agent inside the occipital artery and its distal migration to branches of the scalp [12] (Fig. 11.1c).

The use of two simultaneous arterial accesses, through the middle meningeal artery and occipital artery, should always be considered, since the simple inflation of two balloons promotes a significant reduction in the flow to the fistula, providing better hemodynamic control over the penetration of the embolic agent [12].

Often, during the procedure, spontaneous deflation of the balloon occurs, and depending on the resistance for anterograde migration of the embolic agent, backward movement of the balloon may occur. Thus, the balloon inflation volume must be frequently checked.

The main limiting factor for the use of the double-lumen balloon catheter is anatomical. Very thin and tortuous arteries can prevent navigation to a suitable point for embolization. In these cases, a conventional or detachable tip microcatheter may be preferable [19].

### 11.6.2 DAVFs Draining to a Dural Sinus

The only balloon on the market dedicated specifically for venous use is the Copernic RC (Balt Extrusion, Montmorency, France). Two sizes are available, 8 × 80 mm and 10 × 80 mm [26–29]. Such balloons are compatible with a 6F guiding catheter. They have only one lumen. Thus, a 0.014 in. guidewire is used for navigation and to occlude the lumen, allowing inflation [19]. Its manufacturer recommends the use of a Transend 14 guidewire (Stryker, Irvine, USA) since other guidewires could allow the leakage of contrast medium from inside the balloon. Contrast medium diluted to 50% should be used. The balloon is DMSO compatible.

The Copernic RC balloon catheter, compared to balloons of the same diameter but dedicated to peripheral angioplasty, has better navigability. It is more flexible and more compliant, conforming better to the sinus wall to seal it.

A careful evaluation should be performed in the preoperative period regarding the patency of the dural sinuses, their diameter and the best access route (ipsilateral jugular or contralateral to the fistula). The direct transjugular route can be an issue if it is necessary to change the side on which the balloon will be navigated.

The balloon is temporarily inflated during the transarterial injection of the embolic agent for a few minutes. A precise maximum time limit for sinus occlusion is not known. However, very prolonged inflations are not recommended [19].

When greater flow of the embolic agent into the dural sinus is desired, the balloon can be deflated intermittently. Attention should be given to the maximum inflation volume to avoid dural venous sinus injury [19]. This type of balloon is not suitable for use inside leptomeningeal veins.

The best scenario occurs when hemodynamic control over the main arterial feeders of the fistula is achieved, as well as over its venous drainage [17]. Therefore, in the case of DAVFs in the wall of a sinus, it would be desirable to position a balloon inside the dural sinus and balloons simultaneously inside the middle meningeal and occipital arteries [15, 19]. In this triple-balloon technique, the progression of the liquid embolic agent is rapid, with a low risk of dural sinus occlusion.

## 11.7 Results of the Balloon-Assisted Treatment of DAVFs

### 11.7.1 Transarterial Double-Lumen Balloon Catheter

Before the advent of double-lumen balloon catheters, strategies to control reflux had already been used. Deng et al. reported the treatment of 8 patients with DAVFs using, instead of a double-lumen balloon catheter, single-lumen remodeling balloons in parallel with a microcatheter [13]. Complete occlusion of the fistula was achieved in all cases.

The results of transarterial embolization using the double-lumen balloon catheter are very encouraging. Series with an increasing number of cases have been described [7–10, 14, 15, 18–25].

In a review of the literature, including fistulas with direct leptomeningeal venous drainage and fistulas that drain into the wall of a dural sinus, we gathered a total of 125 DAVFs treated through an arterial approach assisted by a double-lumen balloon catheter (Table 11.1). The most commonly used balloon was Scepter C, followed by Scepter XC. The Ascent balloon was only used in two series.

The most frequent location of DAVFs was in the wall of the transverse/sigmoid sinuses in 57 cases, followed by the superior sagittal sinus [13], tentorial region [12] and other locations. The artery most accessed with the double-lumen

**Table 11.1** Summary of major studies reporting the use of transarterial DLBC to treat DAVFs

| Author | *n* | Balloon | Location | Access with DLBC | Sessions/patient | Cure rate (%) | Complication |
|---|---|---|---|---|---|---|---|
| Paramasivam (2012) | 7 | Scepter XC<br>Ascent | TS (7)<br>Parasagittal (1) | MMA (5)<br>OCC (5) | 1.42 | 71 | 0% |
| Jagadeesan (2013) | 1 | Scepter XC | TS | IMA (2) | 1 | 100 | 0% |
| Kim (2013) | 1 | Scepter C | SSS | MMA (venous[a]) | 1 | 100 | 0% |
| Spiotta (2014) | 1 | Scepter C | Convexity | MMA | 1 | 100 | 0% |
| Chiu (2014) | 6 | Scepter C | Convexity (1)<br>SSS (2)<br>TS (2) | MMA (6) (venous balloon[b]—2) | 1 | 100 | 17%<br>(MMA rupture) |
| Dabus (2014) | 5 | Scepter C<br>Ascent | TS (1)<br>Parasagittal (2)<br>Tentorial (2) | OCC (2) (venous[a]—1)<br>MMA (3) | 1 | 100 | 0% |
| Clarençon (2016) | 2 | Scepter XC | TS (2) | OCC (3)<br>MMA (1)<br>STA (1)<br>(Venous balloon[b]—2) | 1.5 | 100 | 0% |
| Tao (2016) | 1 | Scepter C | SSS | MMA | 1 | 100 | 0% |
| Kim (2016) | 15 | Scepter C | TS (6)<br>Cortical (2)<br>Tentorial (3)<br>Sigmoid (3)<br>SSS (1) | MMA (7)<br>OCC (6)<br>STA (1)<br>MHA (3)<br>APA (1) | 1 | 87 | 7%<br>(Facial palsy) |
| Piechowiak (2017) | 9 | Scepter C | TS (6) | MMA (9)<br>(Venous balloon[b]—9) | 1 | 67 | 0% |
| Chen (2020) | 1 | Scepter C | LSW | MMA | 1 | 100 | 0% |
| Jang (2021) | 35 | Scepter | TS (13)<br>Juxta-sinus (13)<br>SPS (5)<br>Torcula (3)<br>LSW (1) | MMA (18)<br>OCC (15)<br>STA (1)<br>APA (1) | 1 | 97 | 5.7%(Facial palsy)<br>(Cerebral ischemia) |
| Zamponi (2021) | 41 | Scepter XC | TS (19)<br>Torcula (8)<br>Tentorial (7)<br>SSS (5)<br>LSW (1)<br>Convexity (1) | OCC (22)<br>MMA (14)<br>MMA + OCC (7)<br>STA (3)<br>APA (1)<br>(Venous balloon[b]—21) | 1.14 | 97.6 | 12%<br>(Facial palsy—2)<br>(Cerebellar ischemia—1)<br>(Alopecia—1)<br>(Scalp necrosis—1) |

*APA* ascending pharyngeal artery, *DLBC* double lumen balloon catheter, *IMA* internal maxillary artery, *LSW* lesser sphenoid wing, *MHA* meningohypophyseal artery, *MMA* middle meningeal artery, *OCC* occipital artery, *SPS* superior petrosal sinus, *SSS* superior sagittal sinus, *STA* superficial temporal artery, *TS* transverse/sigmoid sinus

[a] Embolization via venous approach

[b] Protective venous balloon associated

balloon catheter was the middle meningeal artery in 74 procedures, followed by the occipital artery in 60 procedures. In 7 cases, simultaneous access was used through the occipital and middle meningeal arteries with two double-lumen balloon catheters.

The number of sessions per patient ranged from 1 to 1.5 (in 76% of the series, a single session per patient was sufficient). Cure rates ranged from 67% to 100%. Of the 125 patients treated, total occlusion was achieved in 116 patients (92.8%).

Complications ranged from 0% to 12%. The series that reported the highest number of complications included minor, transient events [18, 19]. Of the 9 complications reported, the most frequent was facial palsy in 4 cases, followed by cerebral ischemia in 2 cases. Other complications described were alopecia and scalp necrosis. Arterial rupture related to balloon inflation is a rare event, occurring in only 1 case [8].

The only series comparing the use of double-lumen balloon catheters and conventional microcatheters for the treatment of DAVFs via the arterial route, but not randomized, was published by Kim et al. [10]. The balloon group showed complete occlusion of the DAVF in 13 patients and almost complete occlusion in 2 patients. In the microcatheter group, complete occlusion occurred in 5 patients, almost complete occlusion in 5 patients and incomplete occlusion in 4 patients. The balloon group had a shorter mean procedure time, shorter Onyx (Medtronic, Irvine, USA) injection time, and fewer arterial pedicles embolized than the microcatheter group. The complication rate was the same for both groups.

### 11.7.2 Transvenous "Protection" Balloon Catheter

The use of a transvenous balloon catheter to protect the lumen of the dural sinus in the treatment of DAVFs is relatively recent. In 2014, Jittapiromsak et al. reported 2 cases for the first time, and Ponomarjova et al. reported 4 cases [11, 26]. In these 6 cases, the Copernic RC balloon catheter was used, with complete occlusion of all DAVFs, without complications.

In 11 series reported in the literature, totaling 78 patients, the Copernic RC balloon catheter was used in all, except in one, in which the Hyperglide balloon (Medtronic, Irvine, USA) was used (Table 11.2). The reduced diameter of conventional remodeling balloons is an important limiting factor for their use [3, 7, 8, 11, 15, 18, 19, 26–29].

The balloon catheter was most frequently used to treat DAVFs of the transverse/sigmoid sinuses in 50 cases, followed by the superior sagittal sinus in 9 cases, torcula in 7 cases and marginal sinus in 1 case. The number of sessions per patient ranged from 1 to 2.

Complete occlusion rates ranged from 67% to 100%. In 8 (72.7%) of 11 series, total occlusion was achieved in all cases. In the two largest series in the literature, each including 22 patients treated with transvenous balloons, total occlusion of the fistulous zone was observed in 86% and 100% of cases [19].

The chance of inadvertently occluding the venous sinus is extremely low when a protection balloon is used inside the dural sinus. In 11 series in the literature, only one patient experienced unintentional occlusion of the dural sinus [18]. Volherbst et al. reported 5 (22%) complications, none of which caused a permanent deficit [18]. Two of these complications had venous etiology, including a venous infarction resulting from inadvertent embolization of the vein of Labbé and a hemorrhage secondary to the temporary occlusion of a temporal vein [18]. The intravenous balloon can protect the lumen of the dural sinus; however, it is unable to protect the tributary veins of this sinus. None of the complications reported by Zamponi et al. were related to the presence of a venous balloon [19]. No dural sinus rupture has been reported in the literature.

An arterial double-lumen balloon catheter was associated with a transvenous balloon in 7 of the 11 series. Zamponi et al. used an arterial double-lumen balloon catheter associated with a transvenous balloon catheter in 21 cases [19]. In all cases, complete DAVF occlusion was

**Table 11.2** Summary of major studies reporting the use of transvenous "protection" balloon to treat DAVFs

| Author | *n* | Balloon | Location | Arterial balloon[a] | Sessions/patient | Sinus occlusion (%) | Cure rate | Complication |
|---|---|---|---|---|---|---|---|---|
| Jittapiromsak (2014) | 2 | Copernic RC | TS (2) | No | 1 | 0 | 100% | 0% |
| Ponomarjova (2014) | 4 | Copernic RC | TS (4) | No | 1 | 0 | 100% | 0% |
| Chiu (2014) | 2 | Copernic RC | SSS (1)<br>TS (1) | Yes | 1 | 0 | 100% | 50%<br>(MMA rupture) |
| Zhang (2015) | 1 | Hyperglide | SSS | No | 2 | 0 | 100% | 100%<br>(Cortical blindness) |
| Clarençon (2016) | 2 | Copernic RC | TS (2) | Yes | 1.5 | 0 | 100% | 0% |
| Ertl (2016) | 11 | Copernic RC | NM | Yes | 1.5 | 0 | 71%<br>(General) | 0% |
| Piechowiak (2017) | 9 | Copernic RC | TS (9) | Yes | 1 | 0 | 67% | 0% |
| Alturki (2017) | 1 | Copernic RC | TS | Yes | 2 | 0 | 100% | 0% |
| Volherbst (2018) | 22 | Copernic RC | TS (19)<br>SSS (2)<br>Marginal (1) | No | 1.1 | 5 | 86% | 22%<br>(Infarction—2)<br>(Subdural hemorrhage—2)<br>(Intracerebral hemorrhage—1) |
| Lu (2019) | 2 | Copernic RC | Torcula (1)<br>TS (1) | Yes | 1 | 0 | 100% | 0% |
| Zamponi (2021) | 22 | Copernic RC | TS (11)<br>Torcula (6)<br>SSS (5) | Yes | 1.4 | 0 | 100% | 9%<br>(Alopecia—1)<br>(Scalp necrosis—1) |

*MMA* middle meningeal artery, *NM* not mentioned, *SSS* superior sagittal sinus, *TS* transverse/sigmoid sinus
[a] Embolization through a double lumen balloon associated

observed on control angiography after 6 months. In this same series, 6 of the 18 nonfunctioning dural sinuses that were preserved with the aid of the balloon were shown to be functional on late control angiography (Fig. 11.2a–c). Thus, we believe that the reestablishment of circulation within the nonfunctioning sinus should be a treatment goal.

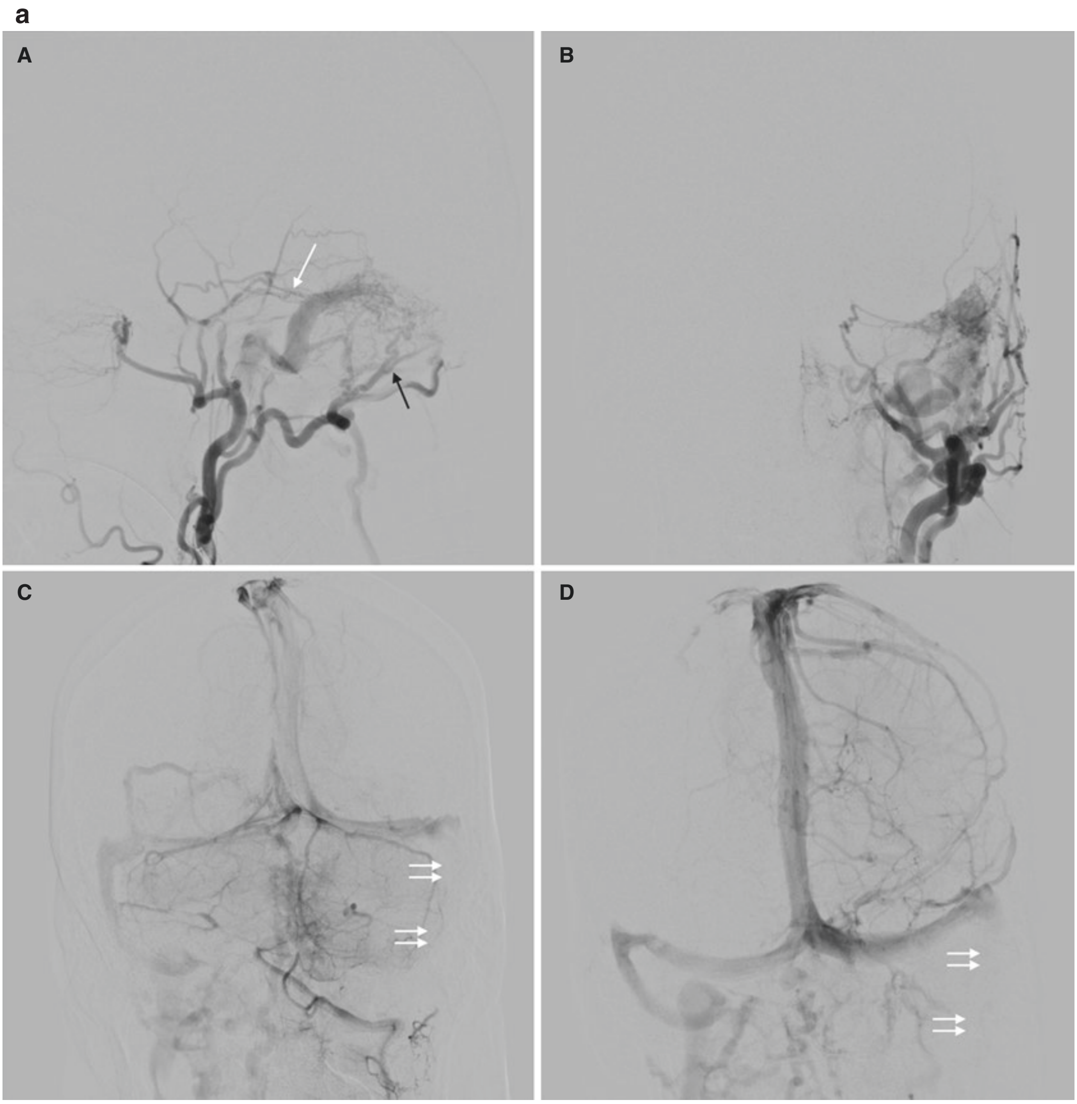


**Fig. 11.2** (**a**) (A, B) Angiography (lateral and AP views) shows a transverse/sigmoid sinus DAVF supplied by the occipital artery (black arrow) and the MMA (white arrow). (C, D) Venous phase of the vertebral artery and ICA angiograms demonstrate that the left transverse and sigmoid sinuses are nonfunctioning (double-arrows). (**b**) (A) Fluoroscopy shows the position of the microcatheter (white arrow) inside the petrous branch of the MMA, and the double-lumen balloon catheter (black arrow) inside the mastoid branch of the occipital artery. (B) Note the transvenous balloon catheter is inflated inside the transverse/sigmoid sinuses. (C) Double-injection through the microcatheter and double-lumen balloon catheter demonstrates the fistulous zone. (D) The migration of the embolic agent occurs along the entire sinus wall circumferentially, occluding the fistulous zone. (**c**) (A, B) Control angiography (AP and lateral views) after embolization reveals total occlusion of the DAVF. (C) Note the cast of EVOH along the sinus wall. (D) Venous phase of the ICA control angiogram demonstrates filling of the left transverse and sigmoid sinuses (double-arrows)

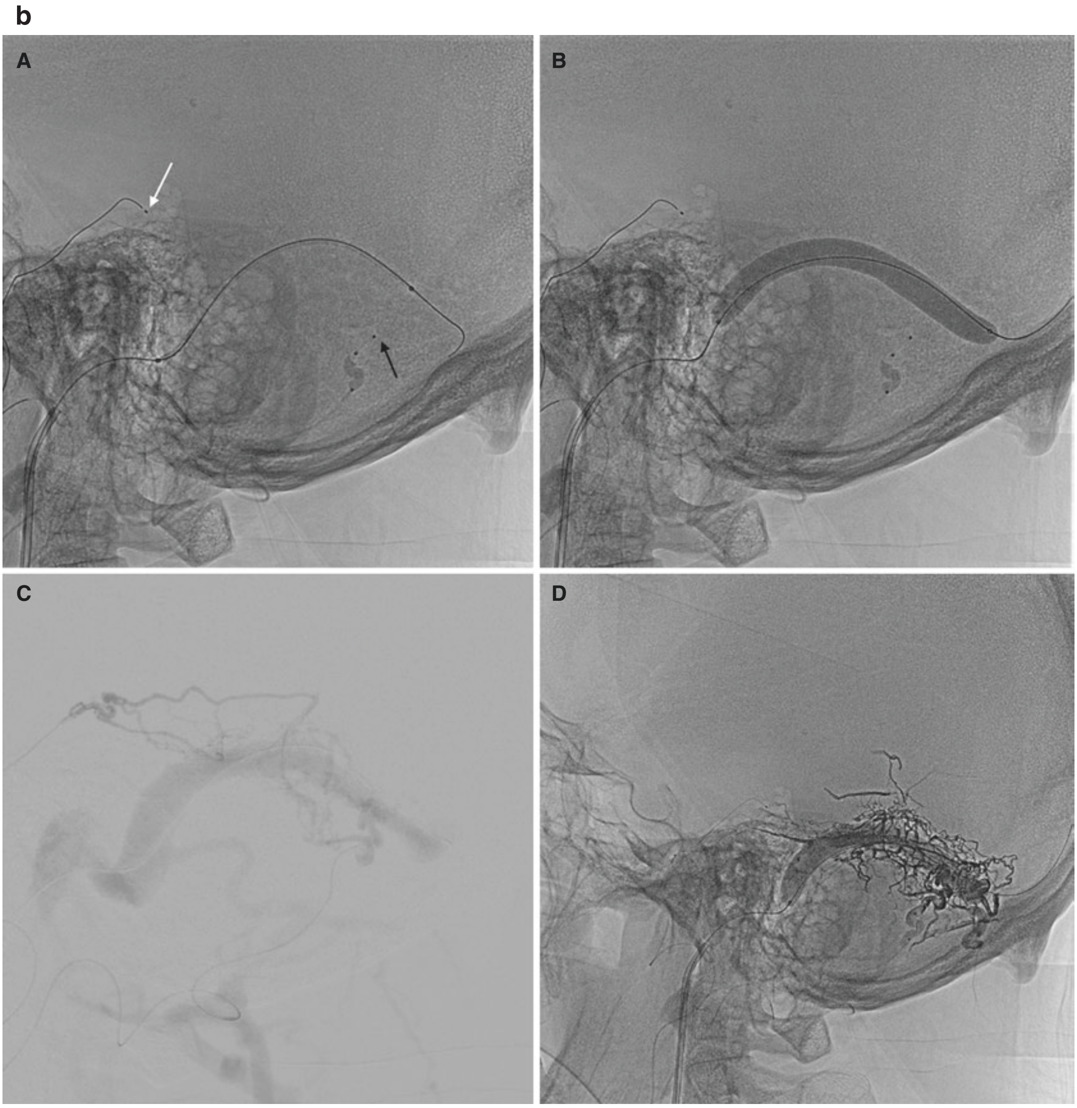


**Fig. 11.2** (continued)

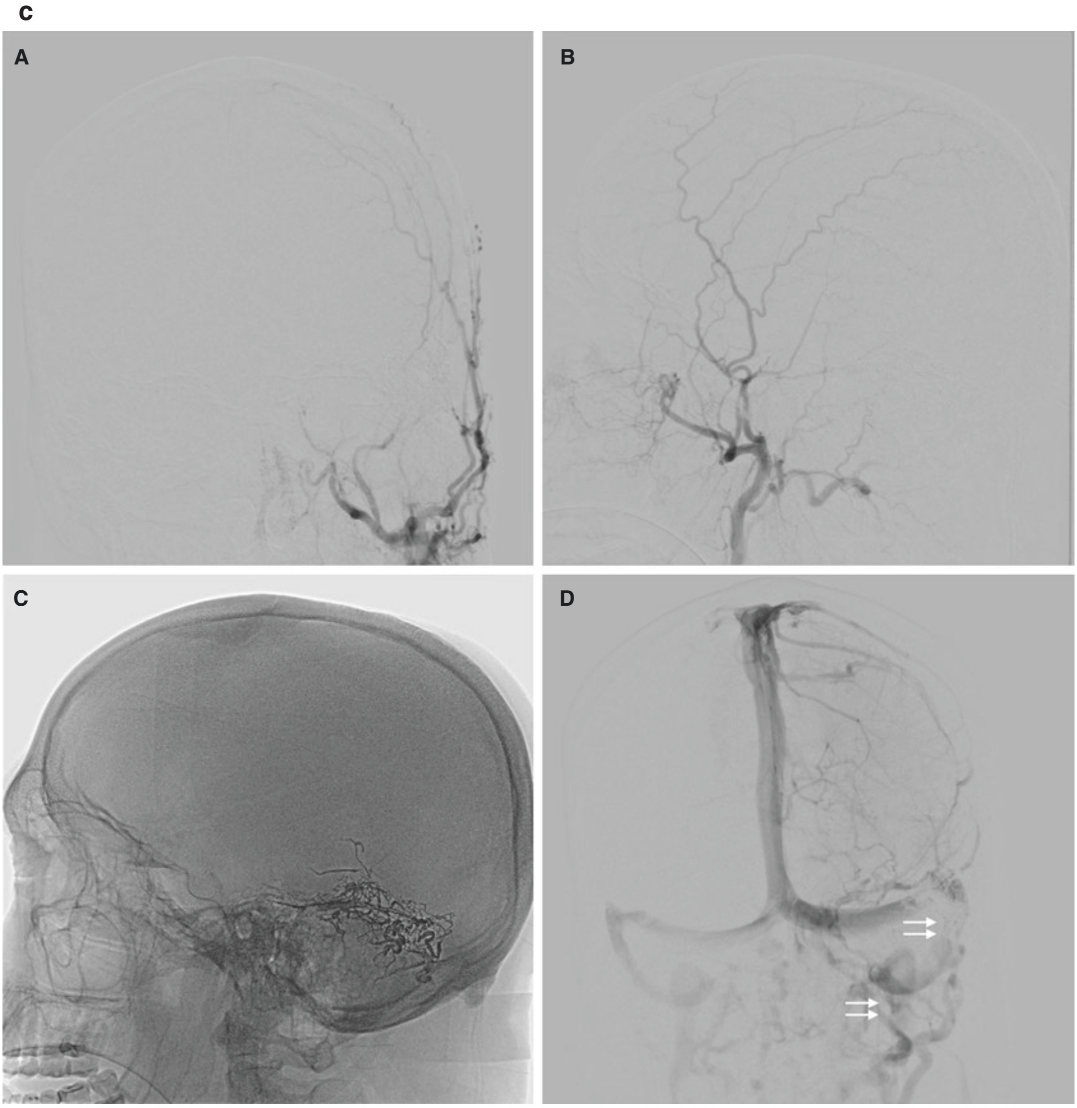


**Fig. 11.2** (continued)

## 11.8 Perspectives

There is no doubt that balloons for flow/pressure control in the treatment of DAVFs will be increasingly used, as well as balloons to protect the venous lumen. The benefit is unquestionable.

Improved flexibility of these balloon catheters and smaller profiles will be imperative, since navigability is still a limiting factor for their use. Attempts already exist, such as the Scepter Mini (Microvention, Tustin, USA).

The use of transvenous balloon catheters is still limited. A wider range of measurements is needed. Improvements in balloon technology will allow selective treatments, preserving the dural sinus lumen.

## 11.9 Conclusion

Balloon catheters represent an important advance in the management of DAVFs. Transarterial treatment of DAVFs assisted by double-lumen balloon catheters is safe and quite effective. The use of the balloon makes the occipital artery an excellent access route, since the problem of excessive reflux and greater resistance of the transosseous branches is overcome. This route presents results as good as when the middle meningeal artery is used.

The transvenous balloon catheter is also safe and can prevent inadvertent occlusion of the dural venous sinus. Complications related to temporary sinus occlusion are rare.

The association of transvenous and transarterial balloon catheters is very effective, determining high rates of total occlusion of DAVFs. The introduction of two balloons simultaneously, through the middle meningeal artery and the occipital artery, seems to be a very promising approach, since it provides greater control over the flow toward the fistula.

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