Case series

'An eye for an eye' therapeutic strategy for cavernous sinus dural arteriovenous fistula: a single-center experience

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ABSTRACT

Background  In cavernous sinus dural arteriovenous fistulas (CS-DAVF), ophthalmological symptoms are usually the main clinical presentation, caused by abnormal drainage of the superior ophthalmic vein (SOV). Early opacification of the SOV during cerebral angiography inevitably signifies the fistula’s shunt point at the confluence of the SOV and CS. We aimed to leverage this anatomical feature to achieve precise embolization, thereby enhancing the embolization success rate and preventing CS-related symptoms and complications resulting from overpacking.

Methods  This single-center, case series study was conducted between May 2017 and September 2023, and included the largest sample of CS-DAVF patients treated via the transfemoral vein-SOV approach. We retrospectively reviewed the data of 32 CS-DAVF patients with inferior petrosal sinus (IPS) occlusion.

Results  The study demonstrated an excellent immediate postoperative complete embolization rate (31/32, 97%). Only three patients (3/32, 9%) developed temporary endovascular treatment-related complications. The average operation time was 131.6±61.6 min, with an average of 1.2±1.1 coils and 1.8±1.2 mL Onyx glue used per patient. CS-DAVF-associated ophthalmological symptoms resolved in all patients. We also identified a rare anatomical variation, where 77% of the patients had a facial vein draining into the external jugular vein.

Conclusions  Transfemoral vein-SOV embolization should be considered a crucial alternative approach in CS-DAVF patients with occluded IPS and predominantly SOV drainage. This approach showed an excellent immediate postoperative complete embolization rate and satisfactory long-term outcomes along with clinical safety. We therefore strongly advocate for this ‘an eye for an eye’ treatment strategy.

INTRODUCTION

A cavernous sinus dural arteriovenous fistula (CS-DAVF) is defined as an abnormal arteriovenous shunt involving the dura mater within or near the CS.1 Venous drainage patterns are closely related to the clinical manifestations of CS-DAVF. When venous drainage diverts anteriorly into the superior ophthalmic vein (SOV), the initial symptoms and signs of a CS-DAVF usually include ophthalmological issues, such as proptosis and intolerable diplopia.2 Although the natural course of a CS-DAVF is relatively benign and it may regress spontaneously, timely surgical intervention is imperative for patients with intractable ocular symptoms.

Endovascular embolization is widely accepted as the curative treatment option for CS-DAVF. The aim of CS-DAVF treatment is to anatomically obliterate the abnormal shunts and eliminate the signs and symptoms caused by the fistula. The selection of the embolization route is an important factor affecting the therapeutic effect of CS-DAVF embolization. Due to the complex origins of the CS-DAVF feeding arteries, along with the slender and tortuous arterial branches, achieving complete occlusion of the fistula using the transarterial approach is often challenging.

Currently, embolization via the transvenous approach is preferred because of its excellent safety and efficacy. The inferior petrosal sinus (IPS) is considered the most direct and easily accessible channel for draining the CS, making it the first-line treatment approach.3 However, transvenous embolization of CS-DAVF using the IPS approach is sometimes infeasible. In cases of CS-DAVF with IPS occlusion, hypoplasia, or no venous communication between the IPS and the pathologic shunts, delivering the microcatheter to the pathologic shunts of the CS becomes quite difficult. It is worth noting that the microcatheter and microguidewire can also be successfully advanced into the CS near the fistula, even if the IPS is not visualized during angiography. However, our experience and previous studies indicate a certain rate of failed access,4 which has piqued our interest in investigating alternative access routes. The SOV provides an alternative option in these circumstances, though few studies have focused on the SOV approach for treating CS-DAVF.

Here we present our experience of treating CS-DAVF patients with IPS occlusion via the transfemoral vein-facial vein (FV)-SOV or transfemoral vein-superior temporal vein (STV)-SOV approaches. In this study, we aimed to evaluate the safety and efficacy of the SOV approach, in addition to describing the technical details for navigating the microcatheter into the SOV and presenting a new perspective on the anatomical structure of the FV-SOV route.
METHODS

Patients

Between May 2017 and September 2023, we retrospectively analyzed 32 consecutive patients with CS-DAVF and IPS occlusion who were treated using the transmesral vein-SOV approach (online supplemental figure S1) (online supplemental material). During this period, 104 CS-DAVF patients underwent endovascular treatment at our center. Among them, 79 patients were treated via transvenous approaches (SOV approach: 32 patients; IPS approach: 47 patients). In some cases treated via the IPS approach, the microdevices were also successfully advanced into the CS even when the IPS was not visualized during angiography. However, our experience and previous studies have indicated a certain rate of failed access.4 To explore an alternative approach, we opted for the SOV route as the primary method in 32 CS-DAVF patients, reserving the IPS route as a backup plan in case the microdevices could not be successfully advanced into the CS through the SOV route. Fortunately, the SOV route has been successful in all cases thus far. General patient characteristics are summarized in online supplemental table S1 (online supplemental material).

Inclusion criteria

Patients present with ophthalmological symptoms, which are the main clinical manifestations of CS-DAVF, including chemosis, proptosis, diplopia, facioplegia, headache, and pulsatile tinnitus. CS-DAVF with IPS occlusion (or an unavailable IPS approach) was confirmed using digital subtraction angiography (DSA).

Treatment was performed via the transfemoral vein-FV-SOV or transfemoral vein-STV-SOV approach.

Exclusion criteria

Patients have a disease that may seriously affect life expectancy, such as advanced cancer, severe cerebral injury, or heart disease.

Patients who previously underwent a craniotomy, radiotherapy, or other treatments.

Ethics approval disclosure statement

This study complied with the principles of the Declaration of Helsinki and was approved by the hospital’s ethics committee (The Second Affiliated Hospital of Zhejiang University, School of Medicine, approval ID: I20231308). Informed consent was waived due to the retrospective nature of the study.

Imaging data

Before endovascular treatment, bilateral selective internal carotid, external carotid, and vertebral artery angiography were performed on all patients to assess the feeding arteries, fistula sites, and venous drainage pattern.7 The results of cerebral angiography were evaluated, and the treatment plan was selected by two specialists with the title of associate chief physician or higher. Angiography confirmed that all patients in this group had CS-DAVF with IPS occlusion.

Endovascular procedure

After general anesthesia, an angiography catheter was placed in the external or internal carotid artery on the lesion side through the left femoral artery for diagnostic angiography. The guiding catheter was navigated to the jugular vein on the lesion side through the right femoral vein (see details in the Results section). The microcatheter was inserted into the shunt point or fistula components using the FV-SOV or STV-SOV approaches to avoid total sinus embolization. Embolization was then performed via the transfemoral vein-SOV approach using Onyx-18/Onyx-34 (Medtronic, Irvine, California, USA) alone or in combination with detachable coils. All endovascular procedures were performed using a Philips angiography machine, with systemic heparin administered as a single 3000 IU injection followed by an intravenous drip of 1000 IU of heparin every hour.

Surgical outcome assessment and follow-up

Angiography was performed immediately after embolization to evaluate the effects of embolization. Immediate angiographic results were classified as: (1) complete embolization: the fistula and arteriovenous shunt disappeared; (2) near-complete embolization: a small residual shunt with a marked reduction in volume and velocity; and (3) partial embolization: the residual fistula was larger, and the blood velocity of the sinus showed no significant change. In instances of near-complete or partial occlusion, ipsilateral carotid compression was recommended for at least 2 weeks. The curative effect was judged by imaging manifestations, clinical symptoms, and signs. Imaging studies such as DSA and magnetic resonance angiography are strongly recommended for patients who continue to experience clinical symptoms following interventional treatment. We advise all patients to undergo angiography at least once after endovascular treatment, if possible.

The clinical cure criteria were as follows: (1) improvement: the original symptoms and signs were significantly improved; (2) no improvement: no change, or aggravation of the symptoms and signs; and (3) recurrence: new onset of lesion-related symptoms during the follow-up period.

The primary outcomes of the study were defined as immediate postoperative embolization rate and operation-related complications, while the secondary outcomes included operation time, material used per treatment, symptom recurrence, and procedure-related mortality and morbidity.

RESULTS

The characteristics of each patient with CS-DAVF are summarized in online supplemental table S1 (online supplemental material). Transvenous embolization was successfully performed using the transfemoral vein-SOV approach in all 32 patients. Among these, 26 patients were treated via the transfemoral vein-FV-SOV approach, and six patients were treated via the transfemoral vein-STV-SOV approach.

Primary outcomes: The present study showed an excellent immediate postoperative complete embolization rate (31/32, 97%; online supplemental table S1) (online supplemental material), with the remaining patient nearly completely embolized. Although three patients (3/32, 9%, online supplemental table S1) (online supplemental material) developed new endovascular treatment-related complications, manifesting as third (n=2) or sixth (n=1) cranial nerve palsy, all symptoms resolved within 1 month after endovascular treatment.

Secondary outcomes: The average operation time was 131.6±61.6 min. Moreover, minimal amounts of coils and Onyx were utilized, with an average of 1.2±1.1 coils and 1.8±1.2 mL Onyx per patient (online supplemental table S1) (online supplemental material). Clinical follow-up results indicated that all CS-DAVF-associated ophthalmological symptoms were resolved (online supplemental table S2) (). There was no evidence of recurrent CS-DAVF in the 32 patients. Furthermore, there were no instances of procedure-related mortality, permanent morbidity, or serious neurological complications.
Anatomical variation
According to classic vascular anatomy (figure 1A and B), the SOV is connected to the angular vein, which continues as the FV. Typically, the FV descends obliquely in a straight line to continue as the common FV and drains into the internal jugular vein (IJV). In the present study (figure 1C and D; online supplemental table S1) (online supplemental material), 76.7% (23/30, excluding two patients without clearly visible FVs) of patients had FVs that drained into the external jugular vein (EJV). This revealed a meaningful anatomical variation from classic vascular anatomy. In addition, the FV directly drained into the anterior jugular vein-EJV in Patient 29.

Transvenous route selection
The unavailability of the IPS prompted the search for alternative optimal routes to the arteriovenous shunt point, based on the anatomical characteristics of venous drainage. The earliest vein to be visualized indicates the location of the fistula shunt point. Therefore, the clearly visualized venous (FV or STV) channel connected to the SOV was considered as an alternative route and targeted for treatment.

FV-SOV route and a special case
Of the 32 patients with CS-DAVF and IPS occlusions, transvenous FV-SOV access was selected as the therapeutic route in 26 patients.

Normally, a 6F guiding catheter cannot provide proximal support for the microcatheter and microguidewire. Thus, a 5F guiding catheter or a 4F headhunter angiography catheter was used. The guiding catheter was placed in the FV or advanced into the angular vein. Subsequently, the microcatheter was positioned in the CS via the SOV route.

The junction of the angular vein and SOV often exhibits a sharp tortuous angulation. The ‘wire-loop’ skill was performed to advance the microcatheter and microguidewire through this abrupt angle (online supplemental figure S2) (online supplemental material).

A special case of transvenous FV-SOV embolization (Patient 19) is presented. As shown in figure 2A, the merged image shows the venous drainage pattern in different angiographic phases. The FV is only partially visible, making microcatheter superselection of the FV very challenging. Interestingly, the transverse facial vein (TFV) served as a bridge connecting the STV and the visible part of the FV (figure 2A). The microcatheter and microguidewire were then catheterized into the FV via the EJV-STV-TFV route, and microcatheter angiography was performed to determine the entry point of the FV (figure 2B). ‘Roadmap’ imaging clearly showed the previously invisible part of the FV (figure 2B). Another microguidewire and microcatheter were then catheterized into the SOV via the EJV-FV-STV route (figure 2C). The transvenous FV-SOV route embolization was successfully completed with one coil and 0.7 mL Onyx-18 (figure 2D).

FV-STV route
In 6 of the 32 patients with CS-DAVF and IPS occlusion, transvenous STV-SOV access was selected as the therapeutic route. figure 3A and B show that both the FV and STV were clearly visible in the angiography image (Patient 28). Although both veins provided applicable vascular access, the STV provided a more convenient and direct path than the FV (figure 3A and B).
Figure 2  A special case of transvenous facial vein-superior ophthalmic vein (FV-SOV) embolization. (A) The merged image of the venous drainage pattern at different angiography phases: early arterial phase - red, late arterial phase - black, venous phase – blue. The transverse facial vein (TFV) (black arrow) connects with the angular vein (AGV) (hollow black arrow) and the visible part of the FV (white arrow). (B) The first microcatheter and microguidewire are catheterized into the FV via the external jugular vein-superficial temporal vein-transverse facial vein (EJV-STV-TFV) route. Subsequently, microcatheter angiography is performed to confirm position and indicate the previous invisible part of the FV. (C) The white dotted line indicates the EJV-STV-TFV route of the first microcatheter and microguidewire. The black dotted line indicates the EJV-FV-AGV route of another microcatheter and microguidewire. (D) The immediate postoperative anteroposterior and lateral angiography after embolization. AGV: angular vein (hollow black arrow); EJV: external jugular vein; FV: facial vein (white arrow); SOV: superior ophthalmic vein; STV: superficial temporal vein; TFV: transverse facial vein (black arrow).

DISCUSSION

‘An eye for an eye’ therapeutic strategy

Unlike previous case reports or case series with limited sample sizes, the present study analyzed the largest sample of patients with CS-DAVF treated via the SOV route. All patients presented with ophthalmic venous drainage and their initial symptoms and signs were ophthalmological. It is noteworthy that the venous drainage pattern is closely related to clinical manifestations and potential therapeutic modalities. When venous drainage diverting anteriorly into the SOV, it causes ophthalmological symptoms such as chemosis, proptosis, and intolerable diplopia. Alternatively, drainage into the superior petrosal sinus or the IPS can cause pulsatile tinnitus. CS-DAVF may manifest as headache, non-hemorrhagic neurological deficits, subarachnoid hemorrhage, or intracranial hemorrhage due to cortical venous reflux. Moreover, DAVF patients with non-hemorrhagic neurological deficits caused by cortical venous drainage have a higher risk of hemorrhage than asymptomatic DAVF patients. Therefore, timely interventional treatment is imperative for patients with CS-DAVF with intractable ophthalmic symptoms.

This study found favorable outcomes for transfemoral vein-SOV embolization in patients with CS-DAVF with IPS occlusion. Choosing the SOV route is appropriate based on the venous drainage characteristics. Our experience indicates that early opacification of the SOV during cerebral angiography inevitably signifies the fistula shunt point at the confluence of the SOV and CS. In this scenario, it is not necessary to fully pack the CS from the posterior section to the junction of the SOV. It is also worth noting that the microcatheter and microguidewire can be advanced into the CS even if the IPS is not visualized during angiography. When access to the SOV via the FV fails due to tortuosity or stenosis, direct puncture via a transorbital approach of the SOV can be considered a viable treatment option.

Leveraging this anatomical feature enabled us to achieve precise embolization, thereby preventing CS-related symptoms that may result from overpacking. Cranial nerve palsy is the most common complication associated with CS-DAVF endovascular embolization. Several factors may contribute to cranial nerve palsy, including the mass effect of the coils and Onyx, direct toxic effects of dimethyl sulfoxide, and direct axonometric injury. In the present study, two patients experienced transient third cranial nerve palsy and one patient had transient sixth cranial nerve palsy, although all symptoms resolved within 1 month following endovascular treatment. The incidence was significantly lower than those observed with complete CS embolization via the IPS route. Moreover, minimal amounts of coils and Onyx were utilized, averaging 1.2 coils and 1.8 mL Onyx per patient. Similarly, Fujita et al reported that transvenous embolization via the SOV significantly reduces the total number of coils in patients with CS-DAVF. We prefer embolization with Onyx and detachable coils together when conditions permit. In our opinion, the detachable coils could provide structural support for Onyx, often referred to as a ‘reinforced
concrete structure’. It may also help us to control the Onyx within the intended target range (shunt point), allowing us to achieve precise embolization and avoid complications such as pulmonary embolism caused by Onyx escape. Additionally, we showed an excellent immediate postoperative complete embolization rate compared with other routes,3 12 which benefited from the precise positioning of the shunt point via the SOV route. Furthermore, the operation time was not significantly increased compared with other approaches. Notably, the junction of the angular vein and SOV often presents a sharp tortuous angulation. Improper manipulation may lead to rupture of the SOV and intraorbital hemorrhage, potentially resulting in vision loss in severe cases. We recommend using the ‘wire-loop’ skill to advance the microcatheter and microguidewire through the abrupt angle. Importantly, none of the patients experienced intraoperative SOV bleeding or embolism. All patients in this study had significant SOV dilation, which facilitated the passage of the microcatheter. It is vital to evaluate the relationship among the SOV, frontal vein, supraorbital vein, and superior temporal vein to choose the most suitable approach based on intraoperative conditions.

In summary, we consider that the transient nerve palsies may be attributed to the mass effect of the embolic materials. This underscores the importance of precise embolization confined to the specific compartment of the CS involved in the fistula rather than the entire CS. Striking a balance between achieving complete obliteration and avoiding fistula overpacking is critical to ensure that the shunting point is adequately sealed without negatively affecting neurological function. This is why we strongly advocate the ‘an eye for an eye’ treatment strategy, focusing on addressing CS-DAVF-associated ophthalmological symptoms through the SOV route.

Anatomical variation of the FV
This study also revealed an anatomical variation quite different from textbook structures, as 76.7% (23/30) of patients had an FV that drained into the EJV. According to classic vascular anatomy, the SOV is connected to the angular vein, which continues as the FV. Typically, the FV descends obliquely in a straight line to maintain the common FV and drains into the IJV. Studies conducted in India by Choudhry et al13 and Gupta et al14 reported that 5% and 9% of the FVs drained into the EJV, respectively. Furthermore, Fujita et al found that 20% (2/10) of Japanese patients had FVs that drained into the EJV during CS-DAVF embolization via the transfemoral trans-FV-SOV route.11 Luo et al also indicated that 62% of patients from Taiwan and China had FVs that drained into the EJV.15 Thus, there may be racial/ethnic differences in the anatomical variations of the FV. Unlike in Europe and North America, where cases of transverse-sigmoid sinus DAVF are predominantly detected, a higher number of CS fistulas cases have been detected in Japan, indicating racial differences in the presentation of DAVF.16 Hence, the anatomical variation in the FV is an interesting finding. Whether such variations may partly contribute to the high incidence of CS-DAVF in Asian individuals needs further exploration.

CONCLUSIONS
In conclusion, transfemoral vein-SOV embolization should be considered a crucial alternative approach in CS-DAVF patients with an occluded IPS and predominantly SOV drainage. This approach showed an excellent immediate postoperative complete embolization rate and long-term outcomes with satisfactory clinical safety and efficacy. We strongly advocate an ‘eye-for-eye’ treatment strategy, focusing on addressing CS-DAVF-associated ophthalmological symptoms through the SOV route.
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