



# Clinical features, treatment, and outcomes of cavernous sinus dural arteriovenous fistulas: a cohort study of 141 patients

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## Abstract

**Purpose** The cavernous sinus (CS) region is a common region of dural arteriovenous fistula (DAVF). Over time, treatment strategies are gradually changing. In this study, we present our center's experience in managing CS-DAVF over the past 20 years.

**Methods** Medical records of patients diagnosed with CS-DAVF between 2002 and 2021 were collected for analysis. Patients meeting the predefined inclusion and exclusion criteria were included. This study summarized and analyzed their clinical characteristics, CS-DAVF angioarchitecture, treatment strategies, and outcomes.

**Results** A total of 141 patients (mean age 55 years, 46 males) were included in this study. Ocular/orbital symptoms were the most frequently reported initial symptoms, with 84 (59.6%) patients experiencing these symptoms first. Presentation with ocular/orbital symptoms as the first symptom was associated with thrombosis of the inferior petrosal sinus ( $p=0.032$ ). Presentation with headache/dizziness and tinnitus/intracranial murmur as the first symptom was associated with sphenoparietal sinus/superficial middle cerebral vein drainage ( $p=0.011$ ). Among the patients, 131 (92.9%) patients received endovascular treatment, with 114 (87.0%) undergoing transvenous embolization. Onyx (92.4%) and coil (74.8%) were the most used embolic materials. 17 (13.0%) of the patients who received endovascular treatment suffered intraoperative or postoperative complications, and 11 (64.7%) patients fully recovered within 6 months after discharge.

**Conclusion** Ocular/orbital symptoms were the most common first symptom of CS-DAVF. The mode of venous drainage played a significant role in determining the first symptoms. Transvenous embolization using Onyx or a combination of Onyx and coils was the primary treatment modality.

**Keywords** Dural arteriovenous fistula · Cavernous sinus · Transvenous · Embolization

## Introduction

Cavernous sinus dural arteriovenous fistulas (CS-DAVFs), also known as indirect cavernous carotid fistulas, refer to the abnormal communications between the dural branches of internal carotid artery (ICA) and/or external carotid artery (ECA) with the cavernous sinus [1, 2]. The cavernous sinus region is one of the most common sites of DAVFs, and patients with CS-DAVF typically present with conjunctival congestion, exophthalmos, oculomotor nerve palsy, intracranial murmur, diplopia, blurred vision, headache, cerebral hemorrhage, and other clinical symptoms [2, 3].

Currently, endovascular embolization is the mainstream methods, and intermittent internal carotid artery compression (IICAC) and stereotactic radiosurgery are also optional treatments for some patients with special conditions [3, 4]. As time progresses, the selection criteria and treatment

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approaches for different treatment methods are also changing. Therefore, we conducted a retrospective review of angioarchitecture data from CS-DAVF patients treated at our center over the past 20 years, aiming to analyze different treatment methods and outcomes.

## Methods

### Patients and follow-up

The study protocol was approved by the medical ethics committee of our hospital. Written informed consent was obtained from all patients for the use of their clinical data.

This retrospective study included 141 patients with CS-DAVFs who were treated at our institution between January 2002 and December 2021. All patients were advised to undergo outpatient follow-up at 3 and 6 months after discharge, and to undergo digital subtraction angiography (DSA) or magnetic resonance imaging (MRI) examinations at 6 months or 1 year after discharge. A total of 124 patients underwent DSA or MRI follow-up, with 80 patients undergoing DSA. For patients discharged for more than 1 year, annual telephone follow-up was conducted, with the most recent telephone follow-up occurring in May 2023. Exclusion criteria included incomplete data from radiological or clinical evaluations, and follow-up duration of less than 1 year. Clinical and radiological data were collected from the patients (Fig. 1).

### Symptoms and treatment

Symptoms were categorized into ocular/orbital symptoms (e.g., blurred vision, exophthalmos, increased intraocular pressure, ocular pain, chemosis, retinal hemorrhage,

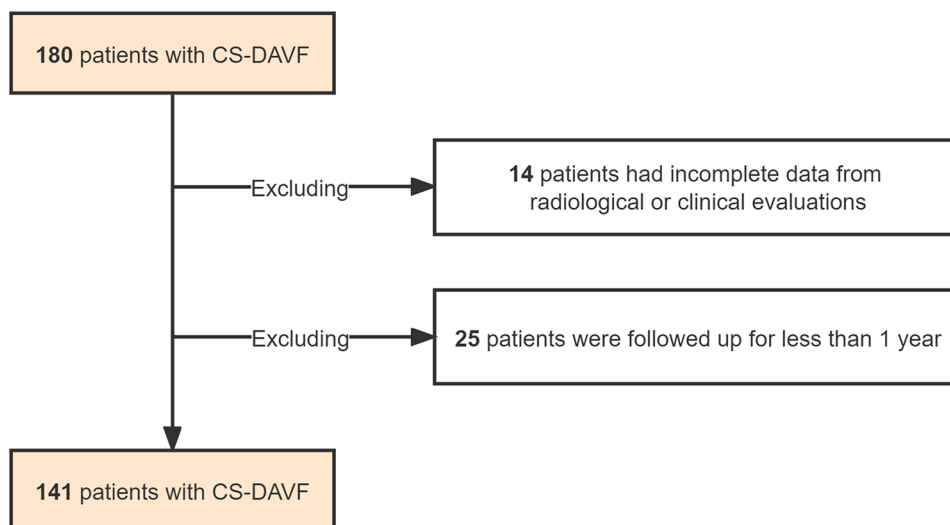
blepharedema), cavernous sinus symptoms (e.g., ptosis, ophthalmoplegia, diplopia, unequal pupils, facial numbness, and other cranial nerve palsy symptoms in the cavernous area), tinnitus/intracranial murmur, headache/dizziness, and hemorrhage. Treatment methods included IICAC and endovascular embolization. Endovascular embolization was further classified as transvenous embolization, transarterial embolization, and transvenous and transarterial embolization according to the approaches. Embolic materials employed included Onyx (ev3, Irvine, California, USA), *n*-butyl cyanoacrylate (*n*BCA)/Glubran (GEM Srl, Viareggio, Italy), polyvinyl alcohol (PVA), coils, and balloon-assisted techniques.

The degree of occlusion was assessed based on the immediate post-embolization angiography as follows: (1) complete occlusion: no residual; (2) subtotal occlusion: only a small portion ( $\leq 10\%$ ) of residual; and (3) incomplete embolization: a significant amount ( $> 10\%$ ) of residual. Clinical outcomes were evaluated after treatment as follows: (1) cure: the disappearance and non-recurrence of the patient's original symptoms; (2) improvement: a significant improvement in the patient's original symptoms; (3) no improvement: no significant improvement or worsening of the patient's original symptoms; and (4) recurrence: the reappearance of the patient's original symptoms after a period of remission or the demonstration of fistula reappearance on DSA. Patients who experienced new postoperative symptoms such as diplopia were considered to have complications. Each patient's diagnosis was confirmed by two neurointerventionalists with 20 years of experience in the field, based on angiography.

### Statistical analysis

Statistical analysis was performed using SPSS 24.0 software (IBM Corp., Armonk, New York, USA). The  $\chi^2$  test and

**Fig. 1** Research flow chart of the included participants



the Fisher exact test were used to compare categorical variables among different groups, one-way ANOVA was used to compare age, and Wilcoxon signed-rank test was used to compare the degree of occlusion and clinical outcomes. All statistical analyses were two sided, and  $p < 0.05$  indicated statistical significance.

## Results

### Clinical characteristics

Table 1 describes clinical characteristics of patients in this study. A total of 141 patients with complete data on CS-DAVF were included in this study, of whom 46 (32.6%) were male and 95 (67.4%) were female, with an age range of 10 to 82 years (mean age: 55 years). Among the patients, 84 (59.6%) patients presented with ocular/orbital symptoms initially, 15 (10.6%) patients presented with cavernous sinus symptoms initially, 25 (17.7%) patients presented with headache and dizziness initially, 16 (11.3%) with tinnitus/intracranial murmur initially, and only 1 (0.7%) patient presented with bleeding. During the subsequent course of the disease, 128 (90.8%) patients developed ocular/orbital symptoms, 50 (35.5%) patients developed cavernous sinus symptoms, 44 (31.2%) patients developed headache/dizziness, and 36 (25.5%) developed tinnitus/intracranial murmur.

### Angioarchitecture

Table 2 summarizes the angioarchitecture of CS-DAVF in the included patients. The unilateral cavernous sinus was

**Table 1** Summary of clinical characteristics of patients

Characteristics	Number (%)
Total no. of patients	141
Male/female	46 (32.6)/95 (67.4)
Mean age and standard deviation	55 ± 14.1
First symptoms	
Ocular/orbital symptoms	84 (59.6)
Cavernous sinus symptoms	15 (10.6)
Headache/dizziness	25 (17.7)
Tinnitus/intracranial murmur	16 (11.3)
Hemorrhage	1 (0.7)
Symptoms on admission	
Ocular/orbital symptoms	128 (90.8)
Cavernous sinus symptoms	50 (35.5)
Headache or dizziness	44 (31.2)
Tinnitus or intracranial murmur	36 (25.5)

**Table 2** Summary of angioarchitecture of CS-DAVF

Characteristics	Number (%)
The location of the lesion in the cavernous sinus	
Unilateral cavernous sinus	89 (63.1)
Unilateral cavernous sinus and intercavernous sinus	33 (23.4)
Bilateral cavernous sinus	7 (5.0)
Bilateral cavernous sinus and intercavernous sinus	12 (8.5)
Side of arterial feeders	
Unilateral	62 (44.0)
Bilateral	79 (56.0)
Barrow classification	
B	22 (15.6)
C	17 (12.1)
D	102 (72.3)
Venous drainage	
Intercavernous sinus	68 (48.2)
Basilar venous plexus	19 (13.5)
Inferior petrosal sinus	75 (53.2)
Superior ophthalmic vein	137 (97.2)
Sphenoparietal sinus/superficial middle cerebral vein	60 (42.6)
Pterygoid venous plexus	29 (20.6)
Superior petrosal sinus	29 (20.6)
Occlusive inferior petrosal sinus	76 (53.9)

most frequently involved location, with 89 (63.1%) CS-DAVFs. Most CS-DAVFs (56.0%) were fed by bilateral arteries, and the majority (72.3%) were fed by meningeal branches of both the internal and external carotid arteries. The superior ophthalmic vein (97.2%) was the most common drainage vein, followed by the inferior petrosal sinus (53.2%). Notably, 76 (53.9%) of the patients included in this study had occlusive inferior petrosal sinuses on at least one side.

Since there was only one patient with hemorrhage as first symptom, statistical analysis could not be performed. After excluding this patient, we analyzed the relationship between first symptoms and patients' clinical characteristics, as well as CS-DAVF angioarchitecture in Supplemental Table 1. Cavernous sinus symptoms as first symptom were more common in male patients ( $p = 0.038$ ). The proportion of patients with inferior petrosal sinus drainage was lower in patients with ocular/orbital symptoms as the first symptom ( $p = 0.020$ ). The proportion of patients with sphenoparietal sinus/superficial middle cerebral vein drainage was higher in patients with headache/dizziness and tinnitus/intracranial murmur as the first symptom ( $p = 0.011$ ). The proportion of patients with occlusive inferior petrosal sinus was lower in patients with cavernous sinus symptoms as the first symptom ( $p = 0.032$ ).

## Treatment

Table 3 provides a summary of the treatment modalities among the patients in this study. Out of the patients included, 10 (7.1%) opted for conservative treatment using IICAC, while the remaining 131 (92.9%) underwent endovascular embolization. Among those who underwent embolization, 114 (87.0%) CS-DAVFs were treated via transvenous embolization (Fig. 2), 11 (8.4%) CS-DAVFs were treated via transarterial embolization, and 6 (4.6%) CS-DAVFs did not achieve the desired outcome after transvenous embolization and then combined with transarterial embolization (Fig. 3). Of the patients treated via transvenous embolization, 106

(93.0%) underwent embolization through the inferior petrosal sinus approach, while the remaining patients underwent embolization through the facial or superficial temporal veins into the superior ophthalmic vein.

Regarding the choice of embolic materials, Onyx was the most commonly used, employed in 121 (92.4%) patients, followed by coils, which were used in 98 (74.8%) patients. All coils were utilized in transvenous embolization and all balloon assisted were performed in transarterial embolization. The most frequently employed embolization material strategy per patient was the combination of Onyx and coils, accounting for 93 (71.0%) cases. The second most utilized strategy involved using only Onyx, with 21 (16.0%) cases. Immediate post-embolization angiography revealed complete embolization in 121 (92.4%) cases, subtotal embolization in 8 (6.1%) cases, and incomplete embolization in 2 (1.5%) cases.

In Supplementary Table 2, we compared CS-DAVF angioarchitecture and endovascular embolization process among different groups according to approaches. The transvenous approach was more commonly employed for CS-DAVFs with bilateral arterial feeders ( $p < 0.001$ ). Conversely, the transarterial approach was less frequently utilized for CS-DAVF with Barrow classification type D ( $p = 0.041$ ). Moreover, the combined transvenous and transarterial approach was more frequently used for fistulas draining into sphenoparietal sinus/superficial middle cerebral vein ( $p = 0.034$ ). The proportion of Onyx and coils used in the transvenous approach was higher compared to other approaches ( $p < 0.001$  and  $p < 0.001$ ), while the proportion of nBCA/Glubran and balloon assisted used in the transarterial approach and the combined transvenous and transarterial approach was higher than that in the transvenous approach ( $p < 0.001$  and  $p < 0.001$ ). In terms of the degree of occlusion, the complete embolization rate was higher in the transvenous approach than in other approaches ( $p = 0.001$ ).

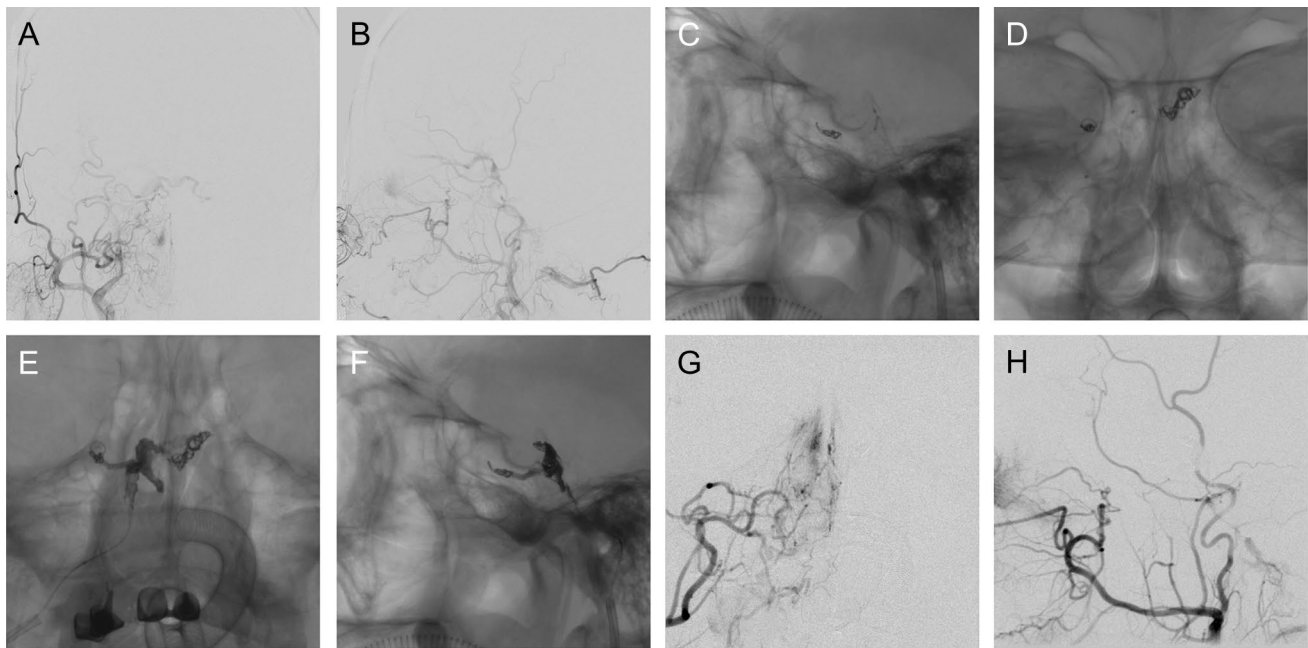
**Table 3** Summary of treatment process of CS-DAVF

Characteristics	Number (%)
Treatment methods	
Conservative treatment	10 (7.1)
Endovascular embolization,	131 (92.9)
Approach for embolization	
Transvenous	114 (87.0)
Inferior petrosal sinus	106 (93.0)
Facial vein	4 (3.5)
Superficial temporal vein	4 (3.5)
Transarterial	11 (8.4)
Transvenous + Transarterial	6 (4.6)
Inferior petrosal sinus	5 (83.3)
Facial vein	1 (16.7)
Embolic materials	
Onyx	121 (92.4)
nBCA/Glubran	14 (10.7)
PVA	1 (0.8)
Coils	98 (74.8)
Balloon-assisted	4 (3.1)
Embolic material strategy	
Onyx	21 (16.0)
nBCA/Glubran	6 (4.6)
Coils	1 (0.8)
Onyx + nBCA/Glubran	2 (1.5)
Onyx + Coils	93 (71.0)
Onyx + Balloon-assisted	1 (0.8)
nBCA/Glubran + PVA	1 (0.8)
nBCA/Glubran + Coils	2 (1.5)
Onyx + nBCA/Glubran + Coils	1 (0.8)
Onyx + nBCA/Glubran + Balloon-assisted	1 (0.8)
Onyx + Coils + Balloon-assisted	2 (1.5)
The degree of occlusion	
Complete occlusion	121 (92.4)
Subtotal occlusion	8 (6.1)
Incomplete embolization	2 (1.5)

nBCA n-butyl cyanoacrylate, PVA polyvinyl alcohol

## Outcome

As described in Supplemental Table 3, among 131 patients who underwent endovascular embolization, 17 (13.0%) patients experienced intraoperative or postoperative complications. Among these, 11 patients developed new abducens nerve palsy, 2 patients developed new oculomotor nerve palsy, 2 patients developed new trigeminal nerve palsy, and 2 patients suffered from intraoperative ectopic embolism resulting in cerebral infarction and subsequent death during the follow-up period. In one case, the embolic material entered the distal ICA through dangerous anastomoses during transarterial embolization; in the other case, the embolic material flowed back arterial feeders and entered the distal ICA through dangerous anastomoses during transvenous embolization. In contrast, among the



**Fig. 2** A CS-DAVF patient treated via transvenous embolization. This female CS-DAVF patient presented with blurred vision in her right eye. Initial right ECA angiography (A anteroposterior view, B lateral view) showed the shunt at intercavernous sinus with drainage into the superior ophthalmic vein and intercavernous sinus. The fistula was fed by right ECA meningeal branch (meningeal accessory artery, artery of foramen rotundum). The microcatheter entered the cavernous sinus through right inferior petrosal sinus, and coils were

placed at the opening of right superior ophthalmic vein (C). Then coils were placed at intercavernous sinus (D). Onyx-18 was injected transvenous, and the above figure showed the embolic materials after embolization (E anteroposterior view, F lateral view). Immediate post-embolization right ECA angiography (G anteroposterior view, H lateral view) showed complete occlusion. After long-term follow-up the patient's vision returned to normal

15 patients with new cranial nerve palsy, 11 (73.3%) fully recovered within 6 months of discharge, and 4 (26.7%) experienced significant symptom relief with only partial residual symptoms at the last follow-up. The overall clinical outcome of patients with cranial nerve palsy was better compared to those with ectopic embolism ( $p = 0.015$ ).

During the follow-up period, 112 (79.4%) were cured, 24 (17.0%) showed symptomatic improvement, 5 (3.5%) had no symptomatic improvement, and 2 of the 5 patients who showed no improvement died. There were no instances of recurrence in any of the patients after treatment. Additionally, 10 patients who received conservative treatment also achieved good clinical outcome with 8 patients (80.0%) being cured and 2 patients (20.0%) experiencing symptomatic improvement.

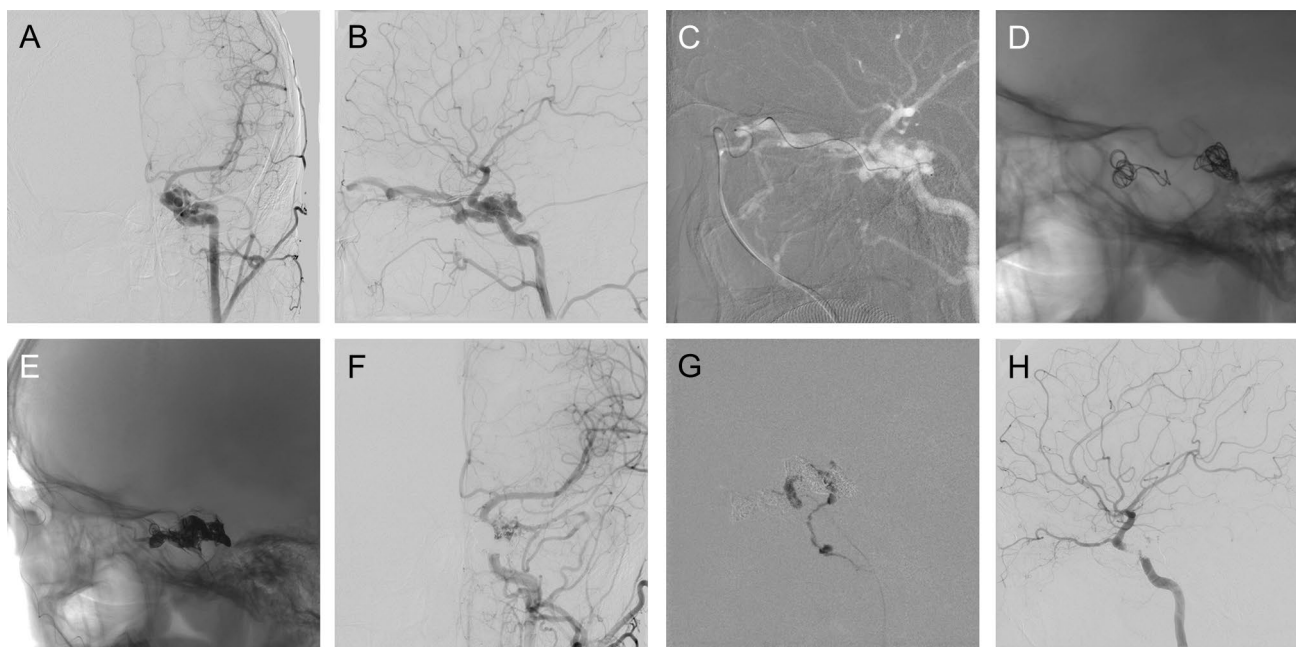
In Supplementary Table 4, we divided the treatment time into three groups to investigate the characteristics and outcomes of treatment at different time periods. Transvenous embolization became the prevailing approach after 2007 ( $p = 0.003$ ). Regarding the choice of embolic materials, Onyx and coils were more frequently employed ( $p < 0.001$  and  $p < 0.001$ ), while the use of nBCA/Glubran decreased after 2007 ( $p < 0.001$ ). Complete embolization

rates and clinical cure rates have improved over time ( $p < 0.001$  and  $p = 0.002$ ).

## Discussion

### Clinical characteristics and angioarchitecture

CS-DAVF typically occurs in middle-aged women [3, 5]. The clinical presentations of CS-DAVF patients are diverse. According to previous literature [4, 6, 7], CS-DAVF patients typically usually exhibit with such as bulbar conjunctival edema, conjunctival congestion, exophthalmos, blurred vision, intracranial murmurs, tinnitus, diplopia, headache, ptosis, ophthalmoplegia, and cerebral hemorrhage. In rare cases, CS-DAVF can also cause brainstem edema [8]. In this study, the clinical symptoms of patients with CS-DAVF were divided into first symptoms and symptoms on admission, with a focus on exploring the relationship between first symptoms and patients' clinical characteristics, as well as CS-DAVF angioarchitecture. Cavernous sinus symptoms were more frequently observed as the first symptom in male patients ( $p = 0.038$ ). Additionally, the most common



**Fig. 3** A CS-DAVF patient treated via transvenous and transarterial embolization. This male CS-DAVF patient presented with left exophthalmos and conjunctival congestion. Initial left ICA angiography (**A** anteroposterior view, **B** lateral view) showed the shunt at left cavernous sinus with drainage into the superior ophthalmic vein. The fistula was fed by left ICA meningeal branch (inferolateral trunk). Since we failed to enter cavernous sinus through the inferior petrosal sinus, the microcatheter entered the cavernous sinus through left facial vein and superior ophthalmic vein (**C**). Coils were placed at the opening of left

superior ophthalmic vein and distal cavernous sinus (**D**). Then Onyx-18 was injected transvenous, and the above figure showed the embolic materials after injection (**E** lateral view). Left ICA angiography (**F** anteroposterior view) showed that there was reflux of superficial middle cerebral vein. We used 33% Glubran 2 transarterial embolization (**G**). Immediate post-embolization left ICA angiography (**H** anteroposterior view) showed complete occlusion. After long-term follow-up the patient's ocular symptoms disappeared

first symptom among patients was ocular/orbital symptoms (59.6%). These findings were consistent with previous studies [3, 6, 9]. Patients presenting with symptoms such as conjunctival congestion and exophthalmos without obvious triggers should consider the possibility of CS-DAVF. Although cavernous sinus symptoms, headache/dizziness, and tinnitus/intracranial murmur were also common as first symptoms, patients often overlooked these symptoms and only sought medical consultation when experiencing severe ocular/orbital symptoms. Early detection and treatment of CS-DAVF are crucial.

CS-DAVFs were predominantly fed by the meningeal branches of both the internal and external carotid arteries, and the source and side of arterial feeders did not show significant correlation with symptoms [10, 11]. Within our CS-DAVF patient group, the superior ophthalmic vein was the most commonly observed drainage vein, accounting for 137 cases (97.2%), followed closely by the inferior petrosal sinus and intercavernous sinus, which aligns with previous studies [4].

Several studies have investigated the relationship between CS-DAVF venous drainage and clinical symptoms [6, 9, 12]. In the study of Dae Chul Suh et al. [9], orbital

symptoms were associated with lack of inferior petrosal sinus drainage and with superior ophthalmic vein drainage ( $p < 0.001$  and  $p = 0.026$ ), and cavernous sinus symptoms were associated with inferior petrosal sinus and posterior cranial fossa venous drainage ( $p = 0.046$  and  $p = 0.014$ ). Later, Thomas et al. [6] proposed a venous drainage-based classification system. Their results showed that posterior/inferior and anterior drainage was associated with ocular/orbital and cavernous sinus symptoms ( $p < 0.001$ ), anterior drainage only was associated with ocular/orbital symptoms ( $p < 0.010$ ), and retrograde drainage into cortical veins was associated with cortical symptoms with/without ocular/orbital and cavernous symptoms ( $p < 0.010$ ). In our study, there was no correlation between the location of the lesion in the cavernous sinus, side of arterial feeders, and the first symptoms. However, CS-DAVF with inferior petrosal sinus venous drainage indicated lower incidence of ocular/orbital symptoms ( $p = 0.020$ ). CS-DAVF with sphenoparietal sinus/superficial middle cerebral venous drainage predicted higher onset of headache/dizziness and tinnitus/intracranial murmur ( $p = 0.011$ ). Additionally, occlusion of inferior petrosal sinus also reduced the probability of developing cavernous sinus symptoms ( $p = 0.032$ ). We speculate that patients with

superior ophthalmic vein drainage but lacking inferior petrosal sinus drainage would experience higher venous pressure in the superior ophthalmic vein, thereby increasing the likelihood of ocular/orbital symptoms. Sphenoparietal sinus/superficial middle cerebral vein drainage would significantly raise cortical venous pressure, leading to an increased probability of experiencing headache/dizziness in patients [6, 9, 13].

## Treatment

In cases where patients exhibit mild clinical symptoms and have small fistulas confirmed by angiography, the rate of spontaneous remission can be as high as 43% [14]. For such patients, IICAC can be attempted. This treatment method promotes thrombosis within the cavernous sinus and embolizes the fistula [15]. In our study, 10 patients' original symptoms disappeared after 6 months of IICAC. This further supports the effectiveness of IICAC for the treatment of this type of CS-DAVF.

Currently, endovascular embolization is the most commonly used treatment method for CS-DAVF [3–5]. The cavernous sinus intersects with multiple intracranial veins, forming a complex venous network. The thin diameter of arterial feeder makes it challenging to selectively target. There are dangerous anastomoses between ECA and ICA in this area, and transarterial embolization through ECA carries a high risk of allowing embolic material to enter the distal ICA. Therefore, transvenous embolization has become the preferred treatment method [4]. Various access veins can be chosen, including inferior petrosal sinus, facial vein, superior ophthalmic vein, pterygoid venous plexus, and superficial temporal vein [7, 16–19]. Transorbital puncture embolization is a specialized transvenous access method [3, 20, 21].

In our study, transvenous embolization was the most commonly used approach (87.0%), with the inferior petrosal sinus being the preferred access vein (93.0%). For patients with occlusive inferior petrosal sinus, the 0.035-inch polymer jacketed guidewire could be used to reopen it. Although there is a risk of hemorrhage, reopening the inferior petrosal sinus is generally safe. Previous studies have shown that this method successfully reopened 50%–90% of occlusive inferior petrosal sinuses [7, 10]. If reopening of the inferior petrosal sinus fails, alternative access routes such as the contralateral inferior petrosal sinus, facial vein, superficial temporal vein, and transorbital puncture can be attempted to access the cavernous sinus [7, 22]. While three-dimensional computed tomography reconstruction and percutaneous ultrasound can provide a more accurate puncture insertion process [23, 24], there is a high risk of nerve injury and hemorrhage during the puncture process, and our center has not extensively used these techniques.

Once the cavernous sinus is accessed, cone beam computed tomography and three-dimensional rotational angiography can assist in locating the site of the fistula, enabling embolization with a minimal amount of embolic agent. This method helps preserve the original venous drainage function of cavernous sinus and reduces the risk of cranial nerve palsy [2]. In Alexander's study, the coil embolization was the preferred method for treating CS-DAVF. However, the shape of coils does not perfectly match the irregular shape of cavernous sinus, which can result in diversion of draining veins and the onset of new clinical symptoms [25]. Additionally, more coils are required to embolize CS-DAVF with multiple arterial feeders [26]. Increasing the volume of coils also increased the risk of cranial nerve palsy [27]. After Onyx became available, the immediate occlusion rate of CS-DAVF embolization with liquid embolic material alone was higher than that of using coil alone ( $p = 0.01$ ) [28]. Since 2007, our center has increasingly used Onyx and coils for embolization ( $p < 0.001$  and  $p < 0.001$ ). The choice between standalone Onyx embolization and combined Onyx with coils depends on the speed of venous drainage. If the drainage through the superior ophthalmic vein or sphenoparietal sinus/superficial middle cerebral vein is too rapid, coils can be placed at the opening of those veins of cavernous sinus to create a basket, thereby reducing the speed of venous drainage and prevent the Onyx from quickly entering the distal superior ophthalmic vein or cortical vein [11]. Subsequently, Onyx can be used to embolize the cavernous sinus compartments. Angiography should be performed if reflux of Onyx occurs to assess the degree of occlusion. Maintaining control over the tension within cavernous sinus is crucial to minimize the risk of cranial nerve palsy. The complete embolization rate achieved through the transvenous approach is higher than that of other approaches ( $p = 0.001$ ). In combination with previous studies, transvenous embolization has demonstrated high success rates and low complication rates, making it the preferred treatment method [4, 5].

In cases where transvenous embolization fails, the degree of occlusion is unsatisfactory, or when there are only a few arterial feeders, transarterial embolization can be attempted [29]. For transarterial embolization of the dural branches of ECA, Onyx is preferred, whereas for the dural branches of ICA, Glubran is preferred. In addition, balloon-assisted embolization can be used to prevent regurgitation of embolic material during the transarterial approach.

## Outcome

The overall complication rate ranged from 2.3 to 53.3%, with recent studies showing a decreasing trend in complication rates [4]. Alexander's study of 267 patients reported a complication rate of 3.6%, and only 0.51% of patients experienced permanent symptomatic complications during

long-term follow-up [10]. It is worth noting that cranial nerve palsy during the treatment of CS-DAVF can be easily recovered, and the present study did not find a long-term outcome associated with the occurrence of complications. Although our study found no association between the treatment approach or embolic materials and the occurrence of complications, we agree with previous reports that transarterial embolization has a higher risk of complications than transvenous embolization [7, 10]. However, it is important to highlight that the outcome after the occurrence of complications resulting from ectopic embolism was worse than that after the occurrence of cranial nerve palsy ( $p=0.015$ ). This suggests the need for utmost efforts to prevent the occurrence of such complications.

### Study limitations

The present study also has several limitations. Firstly, it was a retrospective single-center study, and the experiences from our center may not be directly applicable to other centers. Secondly, the study spanned a long period, and there were discrepancies between the statistical results and the actual results due to the loss of radiological data or the exclusion of follow-up data in some patients during the inclusion and exclusion process. Although we divided the treatment time into three groups for analysis, changes in treatment techniques and materials cannot be ignored. Thirdly, the angioarchitecture of CS-DAVF is complex, and despite our best efforts to gather extensive angioarchitecture information, there are still variables that were not included, such as the flow rate of the arteriovenous fistula, which may impact the results.

### Conclusion

CS-DAVF often occurred in middle-aged females. Ocular/orbital symptoms were the most common first symptom of CS-DAVF. The mode of venous drainage was an important factor affecting first symptoms, cortical veins drainage often led to headache/dizziness. Transvenous embolization was the primary treatment modality. The choice of embolic materials between standalone Onyx embolization and combined Onyx with coils depends on the speed of venous drainage. Endovascular treatment of CS-DAVF was safe and effective. Most CS-DAVF patients who had received endovascular treatment could recover. Proper control of the tension within the cavernous sinus was essential to prevent the occurrence of cranial nerve palsy. The majority of cases of cranial nerve palsy showed full recovery, and achieving better outcomes involves avoiding ectopic embolism.

**Supplementary Information** The online version contains supplementary material available at <https://doi.org/10.1007/s13760-023-02405-9>.

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**Author contributions** ZS and YM and contributed equally to this work and should be considered co-first authors. ZS, wrote the manuscript and arranged ideas. YM revised the manuscript and designed writing ideas. XS collected clinical and radiological data. YF followed up patients and did the statistics. HZ analyzed imaging data and ideas supervision. MY analyzed imaging data and ideas supervision. PZ analyzed imaging data and analyzed ideas supervision. All the authors made critical revisions of the manuscript and reviewed the final version.

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**Data availability** The data that support the findings of this study were available from the corresponding author upon reasonable request.

### Declarations

**Conflict of interest** The author declares no conflict of interest.

**Ethical approval** This study was approved by Ethics Committee of Xuanwu Hospital of Capital Medical University.

**Informed consent** Informed consent was obtained from all patients.

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