Middle cranial fossa non-cavernous sinus dural arteriovenous fistulas: 20 years of experience

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Abstract

Background

Non-cavernous sinus (CS) dural arteriovenous fistulas (DAVFs) involving the sphenoid bone are rare entities that are easily confused with one another due to the complex structure and high variability of the venous system around the middle cranial fossa.

Methods

We present a large retrospective study on middle cranial fossa non-CS DAVFs and review the literature on DAVF treatment in this location as well as relative anatomy.

Results

15 patients had DAVFs involving the lesser sphenoid wing and 11 patients had DAVFs involving the greater sphenoid wing. Six patients presented with intracranial hemorrhage or subarachnoid hemorrhage (23.1%, 6/26). The most common symptoms were eye symptoms (38.5%, 10/26). 19 patients were treated with trans-arterial embolization (TAE) using liquid embolic agents and two patients were treated with transvenous embolization (TVE) using Onyx or in combination with coils. Surgical disconnection of the drainage veins was performed in five patients, with three cases experiencing unsuccessful TAE. Anatomic cure was achieved in 92.3% of the patients (24/26). 12 patients had DSA and clinical follow-up from 3 months to 27 months. There was one recurrence (8.3%) of the fistula in the patient two months after the initial complete occlusion.

Conclusions

The majority of patients can be cured endovascularly. Laterocavernous sinus DAVFs may not be embolized by transvenous approach via the cavernous sinus because there is often no connection between them in most patients. A small percentage of patients may require surgical ligation to be cured.

INTRODUCTION

Intracranial dural arteriovenous fistulas (DAVFs) are abnormal shunts between the dural arteries or pial arteries and dural venous sinus or cortical veins. They account for approximately 10–15% of all intracranial vascular malformations.[1,2] DAVFs in the middle cranial fossa may involve structures such as the cavernous sinus (CS), laterocavernous sinus (LCS), sphenoparietal sinus (SPS), superficial middle cerebral vein (SMCV), paracavernous sinus (sphenobasal sinus and sphenopetrosal sinus).[3–10] Non-cavernous sinus DAVFs involving the sphenoid bone are rare entities that are easily confused with one another due to the complex structure and high variability of the venous system around the middle cranial fossa.[3,5,11–14] Trans-arterial (TAE) or transvenous embolization (TVE) is the primary treatment strategy for these lesions, and surgical disconnection may be necessary if endovascular treatment fails due to its malignant nature.[3,4,15]

According to Shi et al., they classified non-CS DAVFs involving the sphenoid wings and middle cranial fossa into greater sphenoid wing and lesser sphenoid wing types.[3] DAVFs in the greater sphenoid wing mostly contained fistulas in the sphenobasal sinus, sphenopetrosal sinus, and LCS.[3,7,9,10,16,17] DAVFs found around the lesser sphenoid wing mostly included fistulas affecting the SMCV and the SPS.[3–6,8,15] Shi et al. also concluded that greater sphenoid wing DAVFs had a higher frequency of varix of the drainage vein than lesser sphenoid wing DAVFs and were more likely to increase the risk of intracranial hemorrhage.[3]

Because non-cavernous DAVFs located around the middle cranial fossa is highly unusual and complicated, only a few case series have been published,[3,4,10,18] the most of which are limited to case reports.[6–9,16,17,19,20] Here, we present a relatively large cohort of middle cranial fossa non-CS DAVFs and review the literature on DAVF treatment in this location as well as relative anatomy.

METHODS

Study design

This was a retrospective study of a consecutive series of patients with middle cranial fossa non-CS DAVFs who had received treatment at a single institution. A total of 26 patients received treatment at our hospital between 2002 and 2022. The ethics committee of our hospital approved this study. The study followed the STROBE guidelines.[21]

Data collection and definition

Patients' clinical data, including medical records, operative reports, and angiographic data, were maintained. Age, gender, clinical presentation, angiographic findings, treatment techniques, angiographic and clinical outcomes, and complications were reviewed. Admission, outpatient, and telephone follow-up were all considered. Most patients were contacted by telephone to check on their status after treatment. Radiological follow-up included magnetic resonance angiography (MRA) and digital subtraction angiography (DSA). All patients were evaluated using the modified Rankin Scale (mRS) score during the preoperative, postoperative, and follow-up periods. Complete occlusion was defined as the obliteration of the fistulous zone, with embolized agents effectively reaching the venous side.

We categorize according to the previously mentioned classifications[3]: (1) Greater sphenoid wing type included sphenobasal sinus, sphenopetrosal sinus, and LCS DAVFs. (2) Lesser sphenoid wing type included SMCV and the SPS DAVFs.

Treatment options

Endovascular procedure

TAE is usually the first option for treatment if it is available. Balloon-assisted Onyx embolization may be used to improve the success rate of complete embolization. Coils can be detached into higher flow shunts in high-flow fistulas to better visualize and control flow before definitive transarterial occlusion with liquid embolic agents. If a transarterial embolization failed or was not feasible, retrograde transvenous embolization was used to obliterate the fistula and its recipient venous pouch with coils or Onyx.

A complete six-vessel catheter angiography before treatment (bilateral internal carotid artery, external carotid artery, and vertebral arteries) was performed to rule out the possibility of coexisting vascular malformations or multiple DAVFs. DAVF locations, feeding arteries, and venous drainage patterns were studied, and DAVFs were classified using the Borden classification.

The Magic (Balt, France) microcatheter with Glubran2 (Gem, Italy) as the embolic agent and the Marathon (Medtronic, USA) or Headway microcatheter catheter (Microvention, USA) with Onyx-18 (Medtronic, USA) were used. In some cases, a dual-lumen balloon catheter (Scepter-C, Microvention, Tustin, California) or a marathon microcatheter (Medtronic, USA) was placed near the fistula to await Onyx casting before placing an Echelon-10 microcatheter (Medtronic, USA) in the artery to perform coiling to ensure effective penetration and prevent Onyx reflux.

Surgical technique

Pterional and subtemporal approaches were used when embolization failed. Microsurgical techniques were used to expose and ligate the enlarged feeding artery, cortical vein, and variceal pouch. Any artery feeders that remained were coagulated and clipped. Intraoperative angiograms were used to ensure that the fistulas had been completely obliterated.

Statistical analysis

Continuous variables were expressed as mean and standard deviation, while categorical variables were expressed as frequency and percentages. Fisher's exact test was used for dichotomous data. All data were analyzed with IBM SPSS Statistics version 26.0 (International Business Machines Corporation).

Results

Patient and DAVF baseline characteristics

The average age of the patients was 40.7 ± 13.2 (range, 15–65) years, and 73.1% (19/26) were men. Six patients presented with intracranial hemorrhage or subarachnoid hemorrhage (23.1%, 6/26). The most common symptoms were eye symptoms (38.5%, 10/26), which included proptosis, chemosis, diplopia, visual deterioration, hemianopsia, and retro-orbital pain. Seven patients (26.9%, 7/26) had headaches, five (19.2%, 5/26) had tinnitus, one (3.8%, 1/26) had dizziness, and one (3.8%. 1/26) had seizures. Three patients (11.5%, 3/26) were diagnosed with DAVFs by chance. Five patients (19.2%, 5/26) had a significant history of head trauma or surgery. One patient (3.8%, 1/26) had multiple DAVFs. Three patients (11.5%, 3/26) had previously received unsuccessful endovascular treatment at another hospital. The median mRS score at presentation was 2 (IQR 1 to 2).

In our series of angiograms, 15 patients had DAVFs involving the lesser sphenoid wing and 11 patients had DAVFs involving the greater sphenoid wing. Most of DAVFs had multiple feeders (88.5%, 23/26). The middle meningeal artery (MMA) was the most common arterial feeder (88.5%, 23/26), followed by the ophthalmic artery (53.8%, 14/26), the artery of foramen rotundum (26.9%, 7/26), the meningohypophyseal trunk (23.1%, 6/26), the inferolateral trunk (15.4%, 4/26), the accessory meningeal artery (15.4%, 4/26), and the ascending pharyngeal artery (3.8%, 1/26).

In patients with lesser wing fistulas, eight patients had venous drainage into the SPS/lesser wing sinus, while seven patients had direct drainage into the SMCV (46.7%, 7/15) (Fig. 1). Five patients with SPS drainage emptied into the CS and superior ophthalmic vein (Fig. 2), two patients into the pterygoid plexus, and one patient into the cortical veins. The seven fistulas draining into the SMCV then drained into the vein of Labbe, transverse sinus, the vein of Trolard, superior sagittal sinus, CS, superior ophthalmic vein, pterygoid plexus, and cortical veins. In the 11 patients with greater wing fistulas, six had venous drainage through the sphenobasal sinus, which then emptied into the SMCV (Fig. 3; Fig. 4I-K) or CS (Fig. 4A-C). The other five patients had LCS opacification (Fig. 4F-H; Fig. 5), which led to reflux into the basal vein of Rosenthal, the vein of Galen, SMCV, the vein of Trolard and cortical veins.

A higher frequency of varix was observed in LCS DAVFs compared to other middle cranial fossa DAVFs (100% versus 19.0%, P = 0.002; Fisher exact test). The detailed baseline characteristics of the 26 patients with non-CS middle cranial fossa DAVFs who received treatment are summarized in Table 1.

Table 1
Baseline characteristics of 26 patients with dural arteriovenous fistulas of the middle cranial fossa

Variables	N(%)
Sex,n	26
Male/Female	19/7
Age,mean(SD,years)	40.7 ± 13.2
Presentation	26
Hemorrhage	6(23.1)
Eye symptoms	10(38.5)
Headache	7(26.9)
Tinnitus	5(19.2)
Incidental	3(11.5)
Dizziness	1(3.8)
Seizures	1(3.8)
Trauma or surgery history	5(19.2)
Previous treatment	3(11.5)
Treatment modalities	26
TAE alone	19(73.1)
TVE alone	2(7.7)
Surgery	5(19.2)
DAVF side	26
Left side	13(50.0)
Right side	13(50.0)
Number of feeders	26
One	3(11.5)
Multiple	23(88.5)
Arterial feeders	26
Middle meningeal artery	23(88.5)
Recurrent meningeal branch of OphA	14(53.8)

Variables	N(%)
Artery of foramen rotundum	7(26.9)
Meningohypophyseal trunk	6(23.1)
Inferolateral trunk	4(15.4)
Accessory meningeal artery	4(15.4)
Ascending pharyngeal artery	1(3.8)
Venous Drainage	26
Superficial sylvian vein	14(53.4)
Vein of Trolard	12(46.2)
Inferior temporal vein	9(34.6)
Basal vein of Rosenthal	4(15.4)
Cavernous sinus	3(11.5)
Superior petrosal sinus	2(7.7)
Pterygoid venous plexus	1(3.8)
Varix of drainage vein	9(34.6)
Greater sphenoid wing DAVFs	6(66.7)
Lesser sphenoid wing DAVFs	3(33.3)
mRS ≥ 2[1]	20
preoperative	10(50.0)
follow-up	0
Follow-up period(months,median,IQR) [1]	52.1(7.0-80.8)

DAVF, dural arteriovenous fistula; IQR, interquartile range. mRS, modified ranking scale. OphA, ophthalmic artery; SD, standard deviation. TAE, trans-arterial embolization. TVE, transvenous embolization.

1. A patient died in the hospital due to the severity of his condition. Based on 25 (20/25,80.0%) patients who were either clinically or telephoned for follow-up.

Endovascular and surgical treatment

22 patients with 22 middle cranial fossa fistulas were primarily treated with TAE using liquid embolic agents, coils and balloon. There were 26 embolization attempts. 15 fistulas (68.2%, 15/22) achieved anatomic endovascular cure in a single attempt. nBCA was used alone in three patients, Onyx alone in five, and Glubran2 alone in one patient. Six fistulas in six patients were completely embolized using Onyx

or nBCA in combination with coils, Glubran2, or a balloon. One fistulas in one patients were anatomically cured after two sessions of TAE, such as the first session via the OphA and the second session via the MMA. One fistula in one patient were anatomically cured after three sessions of TAE. TAE was failed in three patients and were cured by microsurgical ligation of the lesions. Two patients decided to take conservative treatment after TAE failed. The most common arterial route was MMA (73.1%).

The complete occlusion rate of TAE according to procedures was 78.8% (17/26). 17 patients cured by TAE.

Two fistulas were embolized transvenously with Onyx and coils. In both cases, the drainage vein was accessed retrogradely via the inferior petrosal sinus. All patients had anatomic cures on immediate postprocedural angiograms.

In five cases, surgery was necessary to completely close the fistula after unsuccessful attempts with TAE and TVE, either due to failure or the absence of a suitable approach. All patients had anatomic cures.

Immediate complete occlusion of the fistulas was achieved in 24 patients (92.3%).

Complications

We encountered a major complication when intracranial hemorrhage occurred after a TVE attempt and a successful TAE. We suspect that a venous pedicle was perforated when attempting to perform a transvenous approach through the CS to the SMCV. When the patient was followed up on 7 months after treatment, the patient was asymptomatic.

Follow-up

One patient died in the hospital due to the hemorrhage on presentation, but the treatment was successful. Among 25 patients, 20 (80.0%) were followed-up either as inpatient, outpatient, or by telephone. No patients reported worsening symptoms after complete embolization. 12 patients had DSA and clinical follow-up from 3 months to 27 months. There was one recurrence (8.3%) of the fistula in the patient two months after the initial complete occlusion. He had successful surgery, and there has been no recurrence of the fistula in the following 13 months.

The detailed characteristics and outcomes of treatment modalities on 26 non-CS middle cranial fossa DAVFs are summarized in Table 2.

Table 2
Results of treatment modalities

Variables	N(%)	
Fistulas	26	
Immediate complete occlusion	24(92.3)	
TAE alone	17(70.8)	
TVE alone	2(8.3)	
Surgery	5(20.8)	
Near-complete occlusion	2(7.7)	
TAE alone	2(100)	
Procedures	33	**Complete occlusion (according to procedures)[1]**
TAE	26(78.8)	17(65.4)
MMA	19(73.1)	17(89.5)
MHT	2(7.7)	1(50)
Recurrent meningeal branch of OphA	5(19.2)	3(60)
TVE	2(6.1)	2(100)
Surgery	5(15.2)	5(100)
DSA	12	
Follow-up period(months,median,IQR)	8.8(5.0–12.0)	
Recurrence[2]	1(8.3)	
Complications[3]	1(3.8)	

DSA, digital subtraction angiography. MMA, middle meningeal artery. MRA, magnetic resonance angiography. OphA, ophthalmic artery. PMA, posterior meningeal artery. TAE, trans-arterial embolization. TVE, transvenous embolization.

1. Based on 33 procedures.

2. Based on 12 patients with DSA follow-up.

3. Based on 26 patients who received treatment at our facility.

Discussion

Anatomic considerations

Sphenoparietal sinus and superficial middle cerebral vein

The SPS, which runs alongside the anterior-superior aspect of the middle cranial fossa in the dura just below the sphenoid ridge, is the largest of the meningeal channels coursing with the meningeal arteries.[4,5,22] The SPS may receive drainage from the SMCV and communicates with the CS and superior sagittal sinus via the middle meningeal veins. The deep sylvian veins that drain to the basal vein of Rosenthal and the pterygoid plexus may have bridging and emissary vein connections to the SPS.[4,22] Classically, the dural sinus located at the lesser wing is described as being capable of receiving inflow from the SMCV. This particular sinus is referred to as the SPS. However, the existence of the SPS has been questioned.[5] San Milla'n Ruz et al. believe there is no connection of the SMCV along the lesser wing and that there is only a small dural sinus, which they call the dural sinus of the lesser wing. They also claim that the SMCV can run close to this area but has a separate connection to the cavernous sinus. Therefore, a fistula in the lesser sphenoid wing could potentially connect and drain in two ways[6]: (1) It could directly connect to the lesser wing sinus and drain into the CS or pterygoid plexus, without having any direct cortical venous drainage. (2) Alternatively, it could directly connect to the SMCV and drain into the CS and around cortical veins. In our study, 15 patients had DAVFs of the lesser sphenoid wing, with eight of them having true SPS DAVFs. On angiography, a clear SPS could be seen, which drained into the cavernous sinus (Fig. 2). In some cases, the SPS does not connect to the SMCV. However, in some surgical cases, there is a clear connection between the SPS and the SMCV.[4,22] It would be premature to emphasize the disconnection between the SPS and the SMCV based solely on a small number of cases.[5]

Sphenobasal sinus and sphenopetrosal sinus

Classically, the variant in which the SPS exits the cranium by joining the sphenoidal emissary veins and the pterygoid plexus is known as the sphenobasal sinus. On the other hand, the variant in which the SPS continues posteriorly along the floor of the middle fossa and drains into the superior petrosal or lateral sinus is called the sphenopetrosal sinus.[22] Together, they are referred to as the paracavernous sinus.[3,5,9,13,23] Tanoue et al. evaluated the drainage patterns of the SMCV on MR imaging.[13] SMCVs had four variations in the drainage patterns. The SMCV has two variants related to the paracavernous sinus: the sphenobsal sinus or vein and the sphenopetrosal sinus or vein, which connect to the pterygoid plexus and the superior petrosal sinus or transverse sinus, respectively.[14,23] Whether it is a SPS variant or an SMCV variant, its presence in the sphenoid bone region can affect the drainage pattern in DAVFs. In this study, six patients with greater wing fistulas had venous drainage through the sphenobasal sinus, which then emptied into the SMCV or CS. We also observed the drainage pattern of SMCV to the sphenopetrosal sinus/vein and then to the transverse sinus in one of our LCS DAVFs patients (Fig. 4F-H).

Laterocavernous sinus

The LCS is a venous structure located between the two dural layers that form the lateral wall of the CS and is described as one of the main drainage pathways of the SMCV.[5,10–12] Gailloud et al. conducted a comprehensive evaluation of the drainage pathways of the SMCV and LCS based on 100 selective carotid angiograms obtained from 65 consecutive patients.[12] The basic drainage pathways were described as follows: (1) toward the ipsilateral transverse sinus via the superior petrosal sinus; (2) toward the pterygoid plexus via an opening in the floor of the middle cranial fossa; and (3) toward the posterior aspect of the CS. It is interesting to note that the drainage pathway toward the superior petrosal sinus and pterygoid plexus is similar to the outflow patterns described for the paracavernous sinus.[9,12] However, descriptions in many articles indicate that these venous structures are completely distinct from one another.[3,5,7,9–11,16,17] A complete absence of connection between the LCS and CS was observed in 63.5% of the patients.[12] It's not surprising that the majority of LCS DAVFs are treated via the arterial route, as a suitable venous route, such as through the CS, may be lacking.[10] San Millán Ruíz et al. reported a case where a LCS DAVF was successfully treated transvenously through the pterygoid plexus.[9] Shi et al. also reported a case where a LCS DAVF was treated transvenously through the vein of Galen.[3] These cases demonstrate the potential for treating LCS DAVFs via alternative venous routes, thereby expanding treatment options beyond the traditional arterial approach. However, it is important to note that in some cases, the availability and feasibility of these alternative routes may be limited. In our study, we treated five patients with LCS DAVFs with either TAE or surgery. Two of these patients were successfully cured through TAE, while the remaining three were cured through surgery.

Given the variability of venous anatomy and the complexity of the anatomic location in the middle cranial fossa, the variable nomenclature and descriptions are understandable because each individual difference can manifest in different venous drainage patterns.[3,5,6,14,22,24]

Treatment outcomes

In this study, 26 patients with non-CS middle cranial fossa DAVFs received treatment. TAE was usually the first option for treating this location of DAVFs. The MMA was the most common arterial route. TVE would be performed if TAE failed. Surgical disconnection was an alternative treatment option for those who could not be cured by endovascular therapy. 17 patients were finally cured by TAE and the complete occlusion rate of TAE was 89.5%. Two patients underwent TVE via the inferior petrosal sinus route and both were cured (100%). Five patients underwent surgery and were completely cured (100%). One major complication (3.8%) occurred. One fistula recurred (8.3%), but it was completely occluded again. Overall, 92.3% (24/26) of the patients achieved immediate complete occlusion of the fistulas.

Pakarinen et al. described the first case of SPS DAVFs with bruit that were cured by ligating the origin of the external carotid artery in 1965.[19] As embolic materials, microcatheters, and techniques improved, more DAVFs were cured endovascularly. Successful TAE and TVE have been well-described for the treatment of DAVFs involving the lesser[6,8] and greater sphenoid wing.[9,10,17] However, the majority of them are limited to case studies. Piippo et al. reported 20 cases of middle fossa DAVFs, with nine patients treated surgically and only one patient undergoing endovascular treatment but failing.[18] They concluded that the overall outcomes of patients with middle fossa DAVFs were poor, with only 65% achieving a good recovery. However, the study did not specify the exact location of the fistula and venous drainage. Shi et al. described 11 cases of DAVFs in the middle cranial fossa sphenoidal region treated endovascularly or with a combined endovascular and surgical approach.[3] They conducted a thorough study on middle fossa DAVFs, including detailed descriptions of each case and an anatomical literature review. Anatomic cure was achieved in all patients. Eight patients had angiographic and clinical follow-up, and none of their lesions recurred. Their study was the largest relevant research on endovascular treatment of middle fossa DAVFs prior to ours. However, it is important to note that the number of cases included in the study was still limited. Hartke et al. described 10 patients with SPS DAVFs who were treated with open surgery.[4] The surgery resulted in angiographically confirmed fistula obliteration in all ten patients. Clinical outcomes at the last follow-up were excellent in six patients and poor in one. However, in an era when endovascular therapy has dominated in the treatment of DAVFs, this study may not fully reflect the current state of treating DAVFs in that specific location. To the best of our knowledge, this is the largest single-center study of middle cranial fossa non-CS DAVFs with good treatment outcomes.

TVE is regarded as a safe and effective treatment option, particularly when the fistula sites are accessible via a suitable venous pathway, such as the inferior petrosal sinus, facial vein and the vein of Galen.[3,25] Venous access has also been reported through the external jugular vein, the pterygoid plexus, and an emissary vein of the foramen ovale.[9] In our study, two cases, one in the lesser sphenoid wing and one in the greater sphenoid wing (Fig. 3), were successfully treated with TVE using Onyx and coils via the inferior petrosal sinus. We believe that if a viable venous pathway exists, TVE should be prioritized over TAE, but there is a risk of venous perforation.

TAE can be a promising treatment option for middle fossa DAVFs when combined with the Onyx embolic agent. Shi et al. achieved anatomic cure in 4 patients by using trans-arterial Onyx embolization via the MMA.[3] Trans-arterial Onyx-based embolization involving the lesser and greater sphenoid wings, with or without balloon-assisted techniques via the MMA, has been well described in cases.[6,8,10,15,17] It should be noted that Onyx should be avoided from refluxing into the cavernous and petrosal branches, as well as MMA-orbital collaterals. The majority of patients in our study received TAE via the MMA using Onyx alone or in combination with Glubran2 or coils. TAE has an occlusion rate of 89.5% (17/19). 90.5% (19/21) of the patients had anatomic cures endovascularly. Therefore, endovascular treatment can handle the majority of non-CS middle cranial fossa DAVFs.

Surgical ligation becomes necessary when there is a lack of appropriate arterial or venous access for endovascular treatment (Fig. 5). A standard pterional approach, a subtemporal approach or an orbitozygomatic craniotomy are the main surgical approaches used to treat non-CS middle fossa DAVFs.[3,4,7] Ligation of the arterial supply and drainage vein are critical. Five patients were treated surgically in this study, and all had anatomic cure without complications. In total, 92.3% (24/26) of the patients had anatomic cure on immediate angiogram, and one major complication occurred in this study.

Study Limitations

As a single-center, retrospective study, this study has some limitations. Among these limitations are self-report bias and the absence of core laboratory adjudication. Furthermore, many embolizations were performed prior to the advent of advanced technology and liquid embolic agents. In addition, not all patients had a DSA-follow up, which may have underestimated the final complete occlusion and recurrence rate.

Conclusion

Dural arteriovenous fistulas involving the lesser and greater wings of the sphenoid bone are rare and their drainage patterns can be confused. The majority of them are non-benign lesions. Curative treatment can be achieved after careful identification of the feeders and drainage veins using transarterial embolization or a combination of transvenous embolization. Laterocavernous sinus dural arteriovenous fistulas may not be embolized by transvenous approach via the cavernous sinus because there is often no connection between them in most patients. A small percentage of patients may require surgical ligation to be cured.

Abbreviations

CS, cavernous sinus; DAVF, dural arteriovenous fistula; DSA, digital subtraction angiography; IQR, interquartile range; LCS, laterocavernous sinus; MMA, middle meningeal artery; MRA, magnetic resonance angiography; mRS, modified Ranking score; SMCV, superficial middle cerebral vein; SPS, sphenoparietal sinus; TAE, transarterial embolization; TVE, transvenous embolization;

Declarations

Ethical Approval

This retrospective study involved human participants and was approved by Ethics Committee of Xuanwu Hospital, Capital Medical University [2017; 010].

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Author Contribution

Conception and design: Xin Su, Peng Zhang. Acquisition of data: Xin Su, Zihao Song. Drafting the article: Xin Su. Critically revising the article: Yongjie Ma, Ming Ye, Peng Zhang, Hongqi Zhang. All of the authors have read and approved the final manuscript.

Availability of data and materials

Data are available upon reasonable request.

References

1. Cognard C, Gobin YP, Pierot L, et al. Cerebral dural arteriovenous fistulas: clinical and angiographic correlation with a revised classification of venous drainage. *Radiology*. Mar 1995;194(3):671-80. doi:10.1148/radiology.194.3.7862961
2. Borden JA, Wu JK, Shucart WA. A proposed classification for spinal and cranial dural arteriovenous fistulous malformations and implications for treatment. *Journal of neurosurgery*. Feb 1995;82(2):166-79. doi:10.3171/jns.1995.82.2.0166
3. Shi ZS, Ziegler J, Feng L, et al. Middle cranial fossa sphenoidal region dural arteriovenous fistulas: anatomic and treatment considerations. *AJNR Am J Neuroradiol*. Feb 2013;34(2):373-80. doi:10.3174/ajnr.A3193
4. Hartke JN, Srinivasan VM, Rahmani R, et al. Sphenoparietal Sinus Dural Arteriovenous Fistulas: A Series of 10 Patients. *Oper Neurosurg (Hagerstown)*. Aug 1 2022;23(2):139-147. doi:10.1227/ons.0000000000000269
5. San Millán Ruíz D, Fasel JH, Rüfenacht DA, Gailloud P. The sphenoparietal sinus of breschet: does it exist? An anatomic study. *AJNR Am J Neuroradiol*. Jan 2004;25(1):112-20.
6. Kandyba DV, Babichev KN, Stanishevskiy AV, Abramyan AA, Svistov DV. Dural arteriovenous fistula in the sphenoid bone lesser wing region: Endovascular adjuvant techniques of treatment and literature review. *Interv Neuroradiol*. Oct 2018;24(5):559-566. doi:10.1177/1591019918777233
7. Nomura S, Anegawa S, Nakagawa S, Tomokiyo M, Koga H, Hayashi T. Subarachnoid hemorrhage caused by dural arteriovenous fistula of the sphenobasal sinus--case report. *Neurol Med Chir (Tokyo)*. Jun 2002;42(6):255-8. doi:10.2176/nmc.42.255
8. Rezende MT, Piotin M, Mounayer C, Spelle L, Abud DG, Moret J. Dural arteriovenous fistula of the lesser sphenoid wing region treated with Onyx: technical note. *Neuroradiology*. Feb 2006;48(2):130-4. doi:10.1007/s00234-005-0020-9
9. San Millán Ruíz D, Oka M, Fasel JH, Clatterbuck R, Gailloud P, Murphy K. Transvenous embolization of a dural arteriovenous fistula of the laterocavernous sinus through the pterygoid plexus. *Neuroradiology*. Aug 2007;49(8):665-8. doi:10.1007/s00234-007-0245-x
10. Lv X, Jiang C, Li Y, Lv M, Wu Z. Endovascular treatment of dural fistulas with the venous outflow of laterocavernous sinus. *Eur J Radiol*. Aug 2010;75(2):e129-34. doi:10.1016/j.ejrad.2010.02.003
11. San Millán Ruiz D, Gailloud P, de Miquel Miquel MA, et al. Laterocavernous sinus. *Anat Rec*. Jan 1999;254(1):7-12. doi:10.1002/(sici)1097-0185(19990101)254:1<7::Aid-ar2>3.0.Co;2-y
12. Gailloud P, San Millán Ruíz D, Muster M, Murphy KJ, Fasel JH, Rüfenacht DA. Angiographic anatomy of the laterocavernous sinus. *AJNR Am J Neuroradiol*. Nov-Dec 2000;21(10):1923-9.
13. Tanoue S, Kiyosue H, Okahara M, et al. Para-cavernous sinus venous structures: anatomic variations and pathologic conditions evaluated on fat-suppressed 3D fast gradient-echo MR images. *AJNR Am*

J Neuroradiol. May 2006;27(5):1083-9.

14. Shibao S, Toda M, Orii M, Fujiwara H, Yoshida K. Various patterns of the middle cerebral vein and preservation of venous drainage during the anterior transpetrosal approach. *J Neurosurg*. Feb 2016;124(2):432-9. doi:10.3171/2015.1.Jns141854
15. Chen S, Ocak PE, Xia Y, Zhang H. Intra-Arterial Onyx-18 embolization of a dural arteriovenous fistula of the sphenoparietal sinus using scepter C balloon microcatheter: Case report. *Nigerian journal of clinical practice*. Jun 2020;23(6):879-882. doi:10.4103/njcp.njcp_620_18
16. Zhou LF, Chen L, Song DL, Gu YX, Leng B. Dural arteriovenous fistula of the sphenobasilar sinus with concomitant meningioma: case report and review of the literature. *Neurosurgical review*. Jul 2007;30(3):269-74; discussion 274. doi:10.1007/s10143-007-0071-y
17. Sahu CD, Bhargava N. Intra-arterial onyx embolisation of sphenobasilar sinus fistula using pressure cooker technique: case report and review of the literature. *Neuroradiol J*. Apr 2021;34(2):131-134. doi:10.1177/1971400920972512
18. Piippo A, Niemelä M, van Popta J, et al. Characteristics and long-term outcome of 251 patients with dural arteriovenous fistulas in a defined population. *J Neurosurg*. May 2013;118(5):923-34. doi:10.3171/2012.11.Jns111604
19. Pakarinen S. Arteriovenous fistula between the middle meningeal artery and the sphenoparietal sinus. A case report. *J Neurosurg*. Oct 1965;23(4):438-9. doi:10.3171/jns.1965.23.4.0438
20. Tsutsumi K, Shiokawa Y, Kubota M, Aoki N, Mizutani H. Postoperative arteriovenous fistula between the middle meningeal artery and the sphenoparietal sinus. *Neurosurgery*. May 1990;26(5):869-71. doi:10.1097/00006123-199005000-00023
21. von Elm E, Altman DG, Egger M, Pocock SJ, Gøtzsche PC, Vandenbroucke JP. Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) statement: guidelines for reporting observational studies. *Bmj*. Oct 20 2007;335(7624):806-8. doi:10.1136/bmj.39335.541782.AD
22. Rhoton AL, Jr. The cerebral veins. *Neurosurgery*. Oct 2002;51(4 Suppl):S159-205.
23. Suzuki Y, Matsumoto K. Variations of the superficial middle cerebral vein: classification using three-dimensional CT angiography. *AJNR Am J Neuroradiol*. May 2000;21(5):932-8.
24. Osbun JW, Kim LJ, Spetzler RF, McDougall CG. Aberrant venous drainage pattern in a medial sphenoid wing dural arteriovenous fistula: a case report and review of the literature. *World Neurosurg*. Dec 2013;80(6):e381-6. doi:10.1016/j.wneu.2013.02.022
25. Kim MJ, Shin YS, Ihn YK, et al. Transvenous Embolization of Cavernous and Paracavernous Dural Arteriovenous Fistula through the Facial Vein: Report of 12 Cases. *Neurointervention*. Feb 2013;8(1):15-22. doi:10.5469/neuroint.2013.8.1.15

Figures

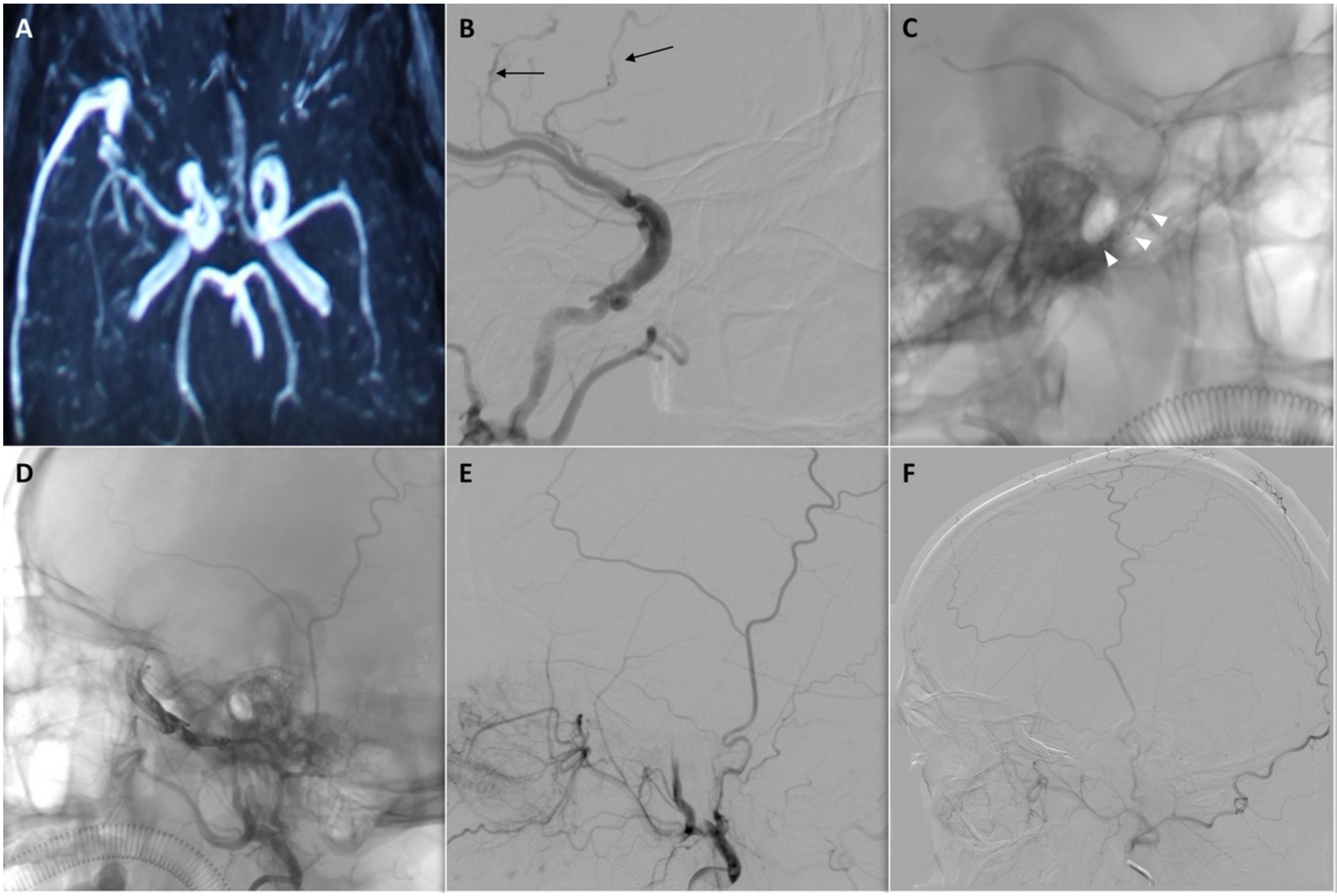

Figure 1

Lesser sphenoid wing type.

This patient in their 40s presented with seizure and intracranial bruit after head trauma. (A) MRA revealed dilation of the right sphenoparietal and superficial middle cerebral vein. (B-C) This dural arteriovenous fistula was supplied by the middle meningeal artery and drains into the sphenoparietal sinus, superficial middle cerebral vein, corticle veins (B, black arrows), and finally to the superior sagittal sinus (not shown). The Scepter C balloon catheter was used to inject Onyx-18 into the fistula via the middle meningeal artery (C, white arrow heads). (E-F) There was no recurrence of the fistula and no symptoms 6 months after the complete embolization.

Modified with permission from Chen and colleagues (2020)[15]

1. Chen S, Ocak PE, Xia Y, Zhang H. Intra-Arterial Onyx-18 embolization of a dural arteriovenous fistula of the sphenoparietal sinus using scepter C balloon microcatheter: Case report. *Niger J Clin Pract*. Jun 2020;23(6):879-882. doi:10.4103/njcp.njcp_620_18

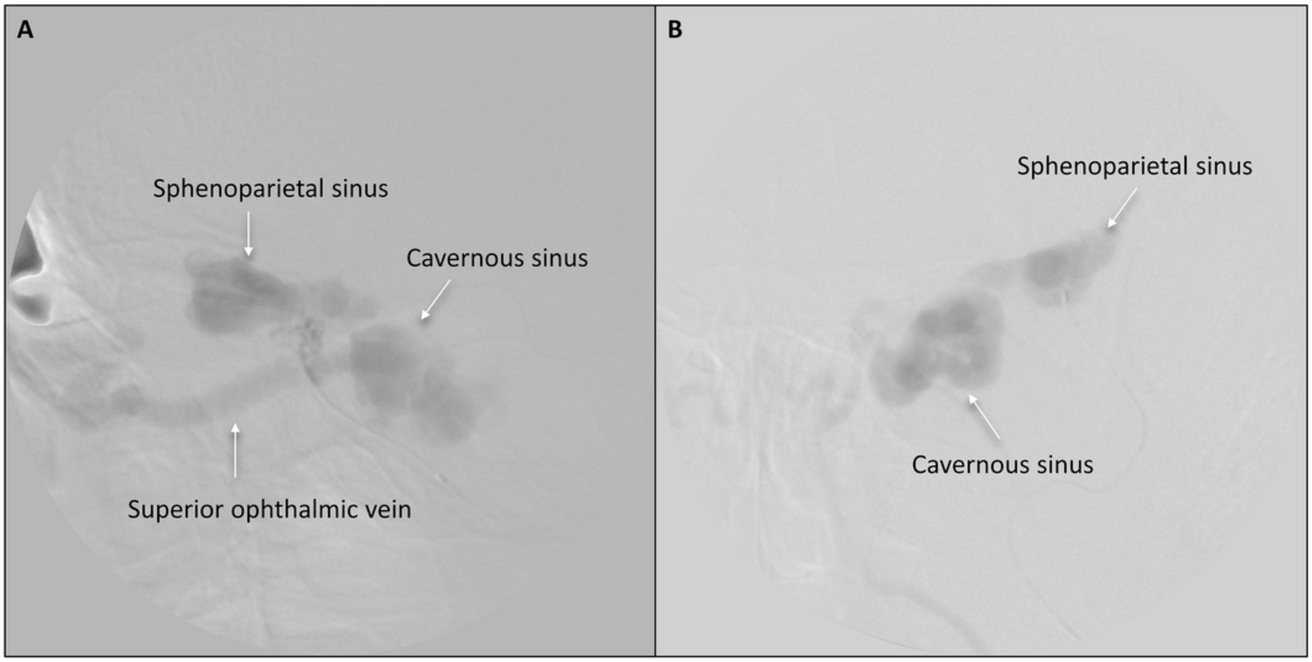

Figure 2

A case of sphenoparietal sinus dural arteriovenous fistulas.

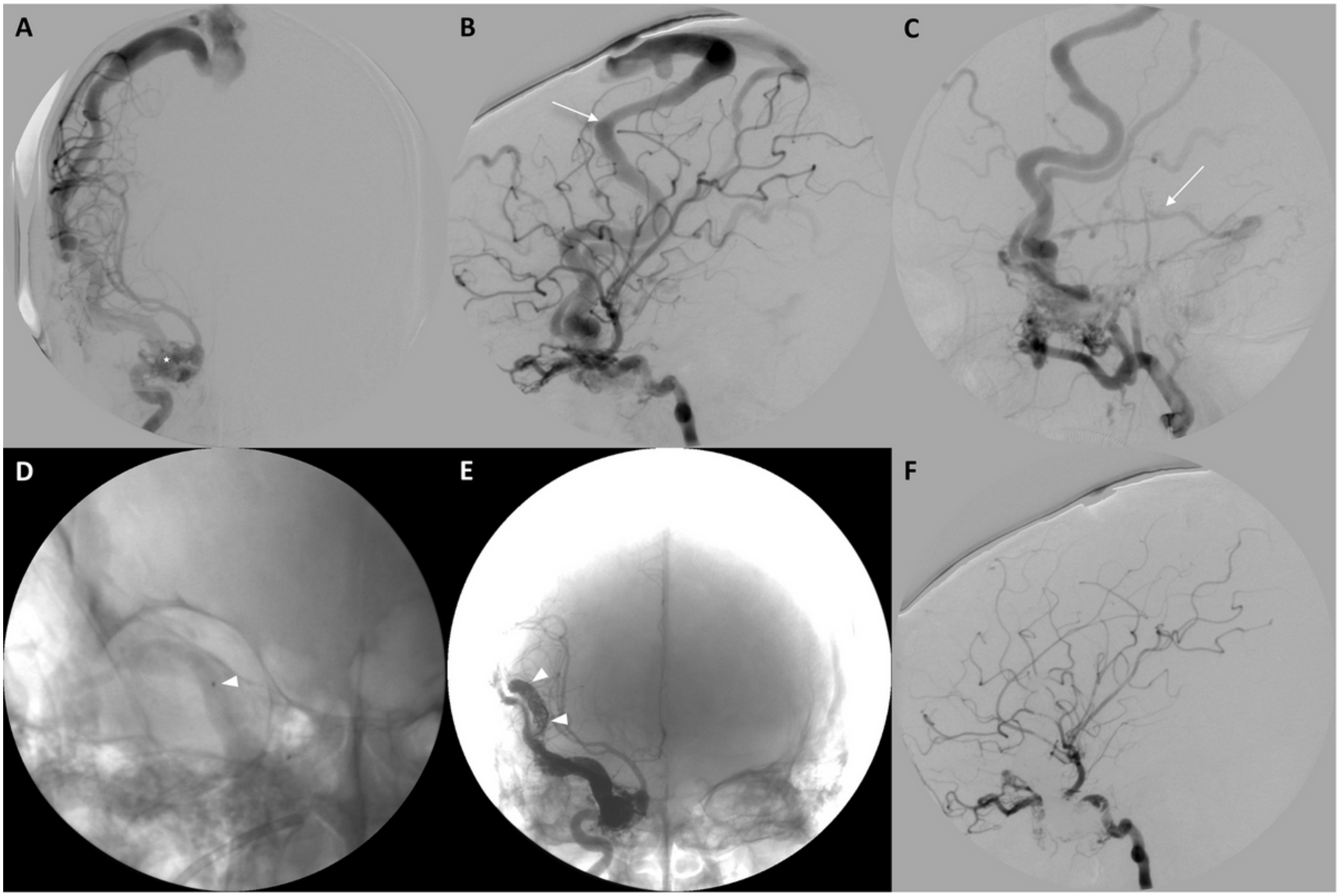

Figure 3

Paracavernous sinus/sphenobasal sinus type.

This patient in their 30s presented with right exophthalmos. (A-C) Anteroposterior and lateral angiography reveal a right dural arteriovenous fistula supplied by multiple branches from the ophthalmic artery, the middle meningeal artery, and the internal maxillary artery. The fistula is drained by the superficial middle cerebral vein, the Trolard vein (B, white arrow), and the temporal cortical vein (C, white arrow). It is important to note that there was no contrast agent filling in the cavernous sinus, and the fistula point (A, asterisk) was located outside of the cavernous sinus. (D-E) Transvenous embolization was performed via the right cavernous sinus to the superficial middle cerebral vein. The Echelon-10 microcatheter (D, white arrow) was initially used to insert coils into the distal side of the superficial middle cerebral vein, reducing blood flow (E, white arrow). Subsequently, Onyx-18 was injected into the drainage vein, resulting in complete occlusion of the fistula. (F) The fistula did not recur 27 months after embolization, and treatment for transverse sinus dural arteriovenous fistula was still ongoing (not shown).

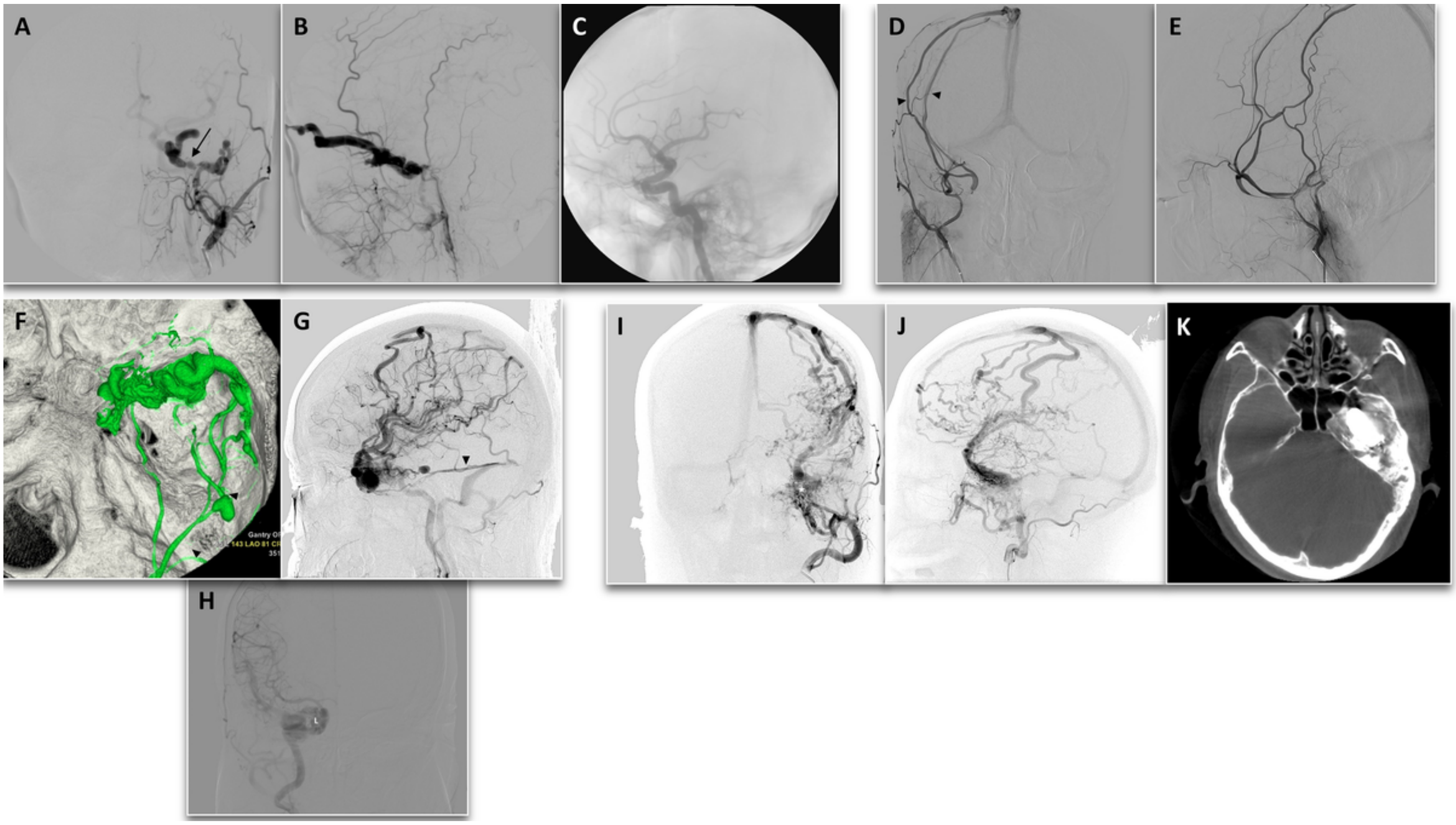

Figure 4

(A-C) This patient in their 20s presented with left exophthalmos. The angiograms revealed a left Cognard type I middle cranial fossa dural arteriovenous fistula located around the sphenobasal sinus (A, black arrow) supplied by the middle meningeal artery with sphenobasal sinus, cavernous sinus, superior ophthalmic vein and facial vein drainage. The fistula was completely occluded using nBCA via the middle meningeal artery. (D-E) This patient in their 40s presented with subarachnoid hemorrhage. The cerebral angiograms showed a right dural arteriovenous fistula along the lesser sphenoid wing, primarily fed by the right middle meningeal artery and draining into the corticle veins and superior sagittal sinus (D, black arrow heads). A subtemporal approach was used to ligate the supplying arteries and drainage vein. The patient was clinically asymptomatic 91 months after surgery. (F-H) This patient in their 50s presented with right eye pain and blurry vision. The lateral (G) and oblique (H) view of the angiography demonstrated a right dural arteriovenous fistula located laterocavernous sinus (H) fed by the middle meningeal artery, ophthalmic artery, inferior lateral trunk with dilated superficial cerebral vein, sphenopetrosal vein or sinus and superior petrosal sinus (F and G, black arrow heads), corticles veins drainage and finally to the superior sagittal sinus. After TAE failed, a subtemporal approach was used to ligate the drainage vein. The patient had no clinical symptoms three months after surgery, and there was no evidence of fistula recurrence with DSA follow-up. (I-K) This patient in their 50s presented with left temporal lobe hemorrhage. Anteroposterior and lateral angiograms of the left external carotid artery revealed a left sphenobasal fistula fed by multiple branches of the external and internal carotid arteries with superficial middle cerebral vein, the vein of Trolard, and superior sagittal sinus drainage (I, fistula point, asterisk). Trans-arterial embolization of the middle meningeal artery with coils and Onyx was successful, resulting in complete embolization. Note the Onyx deposition along the greater sphenoid wing (K). The patient had no clinical symptoms seven months after embolization, and there was no evidence of fistula recurrence with DSA follow-up.

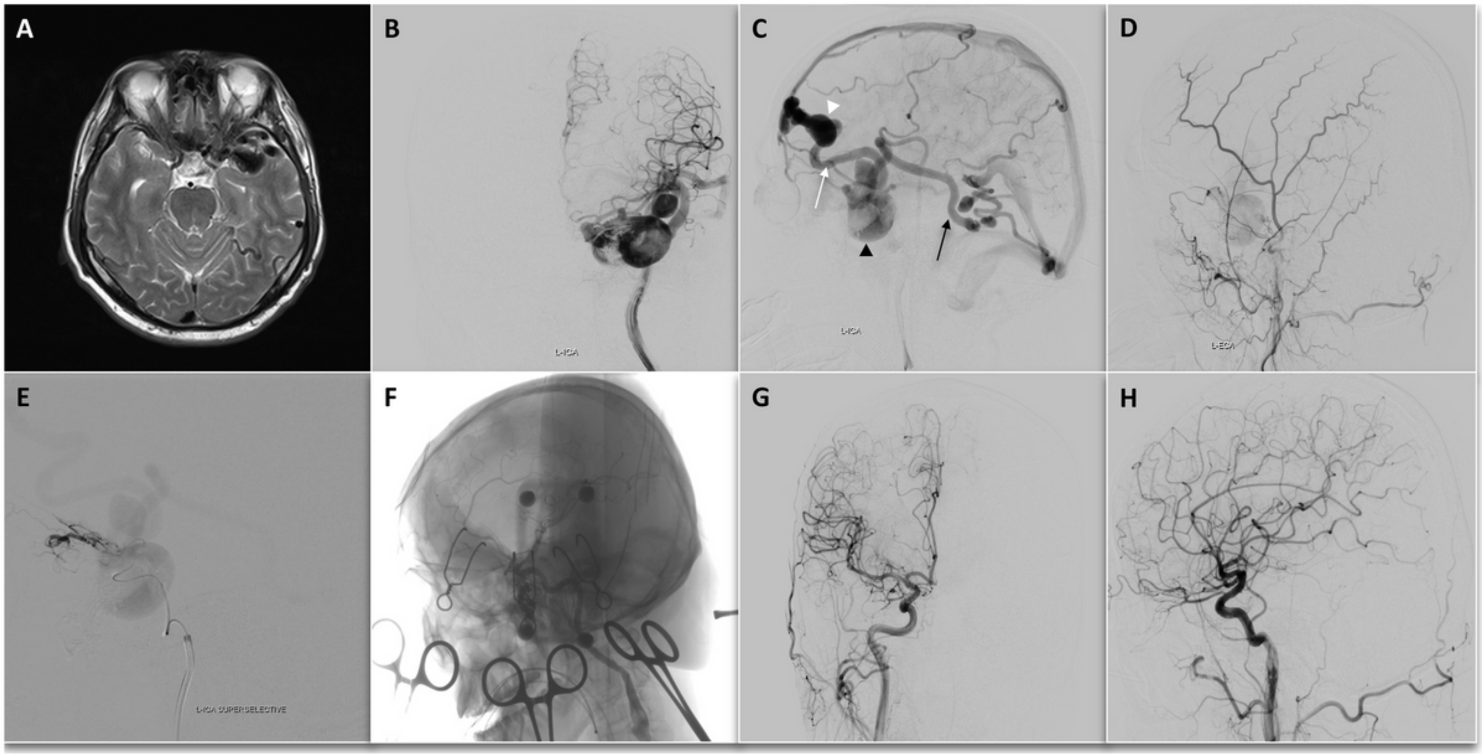

Figure 5

Laterocavernous sinus type.

This patient in their 50s presented with frontal lobe hemorrhage. (A) Axial T2 MRI revealed large abnormal flow void signals on the lateral side of the left cavernous sinus. (B-D) The angiograms revealed a right Cognard type IV dural arteriovenous fistula supplied by the left ophthalmic artery and branches of the internal maxillary artery, with drainage to the dilated superficial middle cerebral vein, fontal (C, white arrow), temporal cortical vein (C, black arrow), and finally to the vein of Galen, straight sinus, transverse sinus, and superior sagittal sinus. (E-F) The Magic microcatheter was carefully inserted into the recurrent branch of the ophthalmic artery, and Glubran2 was injected to reduce blood flow. A pterional approach was then used to ligate the lesion. (G-H) The fistula did not recur 12 months later with DSA-follow, and the patient was fully recovered.