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(Citation)
Neurosurgical Review,44(1):401-409

(Issue Date)
2021-02

(Resource Type)
journal article

(Version)
Accepted Manuscript

(URL)
https://hdl.handle.net/20.500.14094/90007889

Title

Impact of transvenous embolization via superior ophthalmic vein on reducing the total number of coils used for patients with cavernous sinus dural arteriovenous fistula

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Abstract

Although transvenous embolization (TVE) via the superior ophthalmic vein (SOV) is adopted in treating cavernous sinus dural arteriovenous fistula (CS DAVF), its effect on the coil volume is rarely understood. The purpose of the study was to investigate if there is a difference in the total number of coils used and in patient safety when comparing two access strategies. We retrospectively reviewed charts for patients with CS DAVF treated with TVE

between January 2008 and March 2018. The baseline patient characteristics, details of procedure, placed coils, and clinical results were compared. A total of 42 patients with CS DAVF were treated with the inferior petrosal sinus (IPS) (n = 32) or SOV (n = 10) approach. TVE via SOV showed a high success rate of 100% (10/10) by transfemoral access. The total number (23 versus 11; $P < 0.001$), length (159 versus 81 cm; $P = 0.003$), and volume of placed coils (111 versus 46 mm^3; $P = 0.005$) were significantly lower in patients treated via SOV. Patients treated via SOV had significantly higher initial intrasinus pressure (49 versus 59 mmHg; $P = 0.022$) obtained by microcatheters; however, no adverse events occurred related to elevated sinus pressure between both approaches. Procedural complications and cranial nerve palsy outcomes were not significantly different. In cases with a visualized pathway to the SOV, this approach should be preferred, in all other cases standard approach via the IPS should be used, even if it cannot be visualized.

Key words

Cavernous sinus, Dural arteriovenous fistula, Facial vein, Superior ophthalmic vein, Transvenous embolization

Acknowledgements

This report relied on the intensive perioperative management of neurosurgeons at our department. The authors would like to thank all other staff, neurosurgeons, and radiologists of our hospital.

Author contributions

All authors contributed to the study conception and design. Material preparation, data collection, and analysis were performed by A. Fujita, M. Kohta. The project was directed and supervised by T. Sasayama and E. Kohmura. The first draft of the manuscript was written by A. Fujita and all authors commented on previous versions of the manuscript. All authors read and approved the final manuscripts

Compliance with ethical standards

Funding

No funding was received for this study.

Conflict of Interest

The authors declare that they have no conflict of interest.

Ethical approval

All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. This study was approved by the Institutional Review Board of Kobe University Hospital (approval number 180258).

Informed consent

Informed consent was obtained from all individual participants included in the study.

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Introduction

Cavernous sinus (CS) dural arteriovenous fistula (DAVF) is recognized as a common subtype of intracranial DAVF, which is defined as an abnormal arteriovenous connection involving the dura mater within or near the wall of the CS [1]. Barrow et al [2] classified 4 types (Type A-D) of carotid-cavernous fistula. Type A were direct, high-flow fistula connecting the internal carotid artery (ICA) to the CS. In contrast to high-flow lesion, low-flow indirect lesion, often called CS DAVF was separated into Types B, C, and D with arterial supply arising from the ICA only, the external carotid artery (ECA) only, and both the ICA and ECA, respectively. Of these three types, Type D is by far the most common. When venous drainage is diverted anteriorly into the superior ophthalmic vein (SOV), it causes ocular symptoms of chemosis, proptosis, and ophthalmoplegia. Posterior drainage through the inferior petrosal sinus (IPS) may cause pulsatile tinnitus; additionally, venous infarction or hemorrhage may rarely result from cortical venous reflux through superficial sylvian, uncal, or petrosal veins [3-5]. Although the natural history of CS DAVF is relatively benign with the potential to spontaneously resolve by thrombosis, aggressive lesions involving venous reflux require treatment [3, 6].

The goal of CS DAVF treatment is to completely close the fistula while preserving the normal flow of blood through the ICA. Endovascular treatment, including transvenous and transarterial embolization, is widely used to achieve this goal. Transvenous embolization (TVE) is usually preferred and is performed by accessing the CS via the IPS or SOV. A transvenous route through the ipsilateral IPS is frequently selected as a first-line treatment route regardless of IPS occlusion because it provides a relatively straight and short course to the CS [7]. Standard TVE via the ipsilateral IPS consists of retrograde cannulation of the IPS, navigation through the CS to its junction with the SOV, and obliteration of the sinus by anterior-posterior packing. Because the ipsilateral IPS is occasionally occluded, access through the occluded sinus is not always possible, and access to the CS can be achieved through other venous approaches. Various approach routes have been reported in the literature including the transfacial-SOV, pterygoid plexus, the superior petrosal sinus, clival venous plexus, and contralateral IPS accessing to the affected CS through the circular sinus [8-10]. Access through the ipsilateral SOV via a transfemoral-facial vein approach is sometimes possible [11], and

platinum coils could be deployed, initially at the posterior part of the CS and then backward toward the junction with the SOV. Based on our anecdotal experience, we hypothesize that TVE via the SOV could reduce the total amount of coils by obliterating the fistula shunt at the early stage of the embolization. To date, there are no reports focusing on the relationship between approaches and coil volume used for the treatment of CS DAVF.

The objective of this study was to determine whether the contribution of the selection of approach routes of TVE for patients with CS DAVF would result in a reduction in the number of coils without compromising patient safety and efficacy.

Materials and Methods

Ethics statement

This study is in accordance with the Declaration of Helsinki and International Council for Harmonisation/Good Clinical Practice guidelines approved by the institutional review boards (No.180258), and informed written consent was obtained from all subjects. All patient information was anonymized and deidentified prior to the analysis.

Subjects

We performed a retrospective analysis of a prospectively collected patient database of consecutive patients with CS DAVF who were treated with endovascular treatment from January 2008 to March 2018 at our institution and affiliated hospitals. Patient demographics, clinical presentation, and clinical follow-up were recorded by a board-certified neurosurgeon. Ocular features such as chemosis, visual acuity, proptosis, and diplopia, including Hess charting evaluated and diagnosed by ophthalmologists, were extracted. Angiographic features of treated patients were extracted, including shunt location (according to our previous report [12]) and drainage pattern. Procedural parameters, such as the number of procedures, operation times (from the time a patient enters the angio suite until he or she leaves), and related complications were also extracted. Placed coils in the CS were documented regarding the total number, length, maximum diameter, and volume of coils. Cerebral digital subtraction angiography (DSA) was obtained using a biplane flat detector angiography unit (Artis Zee BA twin; Siemens, Erlangen, Germany). The system automatically stored accumulated exposure data, such as total fluoroscopic time and skin absorbed dose (SAD), at the interventional

reference point in patient examination protocols. At the end of the procedure, we extracted fluoroscopic time (minutes) and SAD (mGy) that were recorded separately for anterior-posterior and lateral views and combined for comparison.

Endovascular procedure

We intended to catheterize into fistulous points or fistula components to avoid total sinus packing with detachable coils through the following two venous accesses routes. In the early part of the study (involving first one-third of patients), we only used the ipsilateral IPS for the first-line approach route regardless of the opacification of SOV. During this period, we encountered two patients whom catheterization of the ipsilateral and contralateral IPS was not successful and the transfacial-SOV catheterization was attempted. After that, the ipsilateral SOV connecting angular and facial vein were found to be of enough size to cannulate 4Fr catheter on angiogram, SOV approach was chosen for a first-line access route. Endovascular procedures were performed by one operator (A.F.) under local anesthesia for all patients. A 5 French (Fr) diagnostic catheter was placed in the ECA related to the shunt. A 7Fr (Roadmaster; Aichi, Japan) and 4Fr (Cerulean G; Medikit, Tokyo, Japan) coaxial guiding system was placed in the IPS through the ipsilateral internal jugular vein. A microcatheter (Excelsior 1018; Stryker Neurovascular, Fremont, MN, USA) is advanced over a 0.016 inch microguidewire (GT wire 16; Terumo, Tokyo, Japan) into the CS. For the transfacial-SOV approach, a 7Fr guiding system (Roadmaster; Aichi, Japan) was placed in the internal/external jugular vein or facial vein, and a 4Fr coaxial catheter (Cerulean G; Medikit, Tokyo, Japan) was advanced into the angular vein. A microcatheter (Excelsior 1018; Stryker Neurovascular, Fremont, MN, USA) is advanced over a 0.016 inch microguidewire (GT wire 16; Terumo, Tokyo, Japan) into the CS. In patients with sharp tortuous angulation at the junction of the angular vein and SOV, we used a 0.016 inch double angled microguidewire (GT wire 16 double angled; Terumo, Tokyo, Japan) to pass through an abrupt angle. After a microcatheter was advanced into the CS, pressure measurements were performed prior to starting TVE. A microcatheter was connected to an arterial transducer of a monitoring system (RMC-4000 Cardio Master; Nihon Kohden, Tokyo, Japan). With repeatedly flushing the heparin saline, we kept the whole system being free of air bubbles. The waveform of the tip of microcatheter was demonstrated on the monitor and we repositioned a microcatheter when the waveform was insufficient quality, including blunted or

absence of pressure signal. When a monophasic arterial waveform was obtained, we recorded mean arterial pressure (mmHg) as the initial pressure in the CS. We also simultaneously recorded a mean arterial pressure (MAP) at the left arm. In cases in which shunting points or components could be identified clearly, selective occlusion of these targets was planned [13]. When shunt flow remained after selective occlusion or if the microcatheter could not be navigated to the shunt component, sinus packing associated with occlusion of dangerous drainages was added. In cases in which diffuse shunt points were present, simple sinus packing was conducted.

Clinical follow-up

Angiographical results were assessed at final angiograms immediately following the procedure. Clinical follow-up was routinely conducted with both three-tesla time-of-flight (TOF) magnetic resonance angiography (MRA) and consultation to a neuro-ophthalmologist at 3 and 6 months. Source images of three-dimensional TOF imaging were reviewed by both operators, and one experienced neuroradiologist and disagreements were resolved by consensus. The criteria of complete occlusion at 6 months on MRA included the absence of a high-intensity abnormal signal adjacent to the sinus wall or in the CS. If abnormal MRA signals were observed, diagnostic angiography was conducted to evaluate recurrence.

Statistical analysis

Descriptive statistics were presented as the median with interquartile range (IQR) and were compared using Welch's two-sample t-test for continuous variables showing normal distribution and Mann-Whitney U test for discrete variables. Categorical variables are compared using Fisher's exact test. Probability values of $P < .05$ were considered statistically significant. Statistical analysis was performed with free open-source software (R3.5.0; R Foundation for Statistical Computing; http://www.r-project.org). The datasets analyzed during the current study are available from the corresponding author on reasonable request.

Results

Of 44 patients with CS DAVF who were treated with endovascular embolization during the study periods, 42 patients were included in this study and analyzed. We excluded two patients treated with palliative transarterial embolization

alone. Of 42 patients, 32 patients were treated with TVE via ipsilateral IPS as the first-line treatment, and 8 patients were treated with the SOV approach as the first-line treatment. Two patients treated with the SOV approach had failed another approach prior to deciding to perform the SOV approach. We encountered these two patients before we had not mastered the technique of the SOV approach, however, we applied this technique as a first-line treatment in 8 patients after that. Thus, we analyzed a total of 42 CS DAVF patients who underwent TVE, including 32 patients treated via the IPS (IPS group) and 10 patients treated via the SOV (SOV group) approach. Table 1 summarizes the patient characteristics, and there was no significant difference between the two groups with respect to age, sex, symptoms at presentations, cranial palsies, locations of the shunt point, and drainage pattern based on the angiogram. The SOV group had more ocular signs and symptoms due to anterior drainage, which were not significant. Occlusion of the ipsilateral IPS was observed in 25/32 (78%) of the IPS group and 10/10 (100%) of the SOV group. Of 27 patients with ipsilateral IPS occlusion, 25 (93%) were successfully treated via the ipsilateral IPS route. In two patients with a failed ipsilateral IPS approach, we changed the approach route and successfully treated patients via the SOV in the same session, and these patients were included in the SOV group. A representative case of the SOV approach is shown in Fig. 1a-f and 2a-e. An 88-year-old woman presented with chemosis, proptosis, and abducens nerve palsy and was treated with a transfemoral facial vein-SOV approach. The total number, length, and volume of placed coils were 9, 48 cm, and 26.54 mm^3, respectively. Table 2 shows the results of treatment between the two groups. Of the 10 patients treated via the SOV approach, 2 patients had facial veins draining into the external jugular vein. In these cases, guiding catheters for venous approach side should be placed in external jugular veins. Among the SOV group, we were able to pass the tortuous superior (80%) and inferior roots (20%) of the SOV [11] to reach the CS. Patients with the SOV approach had significantly higher initial pressure (49 versus 59 mmHg; $P = 0.022$) in the CS (Fig. S1a), small number of placed coils (23 versus 11; $P < 0.001$, Fig. S1b), short total length of placed coils (159 versus 81 cm; $P = 0.003$, Fig. S1c), and a small volume of placed coils (111 versus 46 mm^3; $P = 0.005$, Fig. S1d). There were no differences in MAP at the time of CS pressure measurement (98 versus 101 mmHg; $P = 0.325$), maximum diameter of placed coils (4.0 versus 3.5mm; $P = 0.154$), the rate of angiographically complete occlusion in the final angiogram

(91 versus 90%; $P = 1.000$), and that at the six-month follow-up. The data in Table 2 also indicated that there were no differences in the radiation dose in SAD (2676 versus 1730 mGy; $P = 0.107$), total fluoroscopic time (126 versus 107 minutes; $P = 0.470$), operation time (360 versus 330 min; $P = 0.549$), and follow-up period (52 versus 36 months; $P = 0.738$) between the two groups. We had one procedure-related complication (newly appearing abducens nerve palsy) in the IPS group; however, there were no differences in postoperative abducens nerve palsy on the next day of TVE (47 versus 80%; $P = 0.083$) and at the six-month follow-up (13 versus 0%; $P = 0.557$). One patient in the IPS group experienced recurrence 15 months after the first treatment needed additional TVE.

Discussion

Key results

This study examined the effectiveness of the reduction in coils used in patients with CS DAVF, particularly in the selection of an approach to the CS. Four key findings were observed. First, TVE via the facial vein-SOV approach showed a high success rate of 100% (10/10) by transfemoral access. This finding confirms the results of previous reports focusing on the usefulness of TVE via the SOV approach [11]. Second, our study showed that in patients where SOV approach was possible less coils were used. The total number (23 versus 11; $P < 0.001$), length (159 versus 81 cm; $P = 0.003$), and volume of placed coils (111 versus 46 mm^3; $P = 0.005$) were significantly lower in patients treated via the SOV approach. Third, patients treated via the SOV approach had significantly higher initial intrasinus pressure (49 versus 59 mmHg; $P = 0.022$); however, no adverse events occurred related to this elevation of sinus pressure between the two approaches. Fourth, there was no significant difference regarding procedural complications and outcomes of cranial nerve palsy. This result extends the findings to the usefulness of the SOV approach, reducing the coils used in the procedure without compromising the efficacy or safety of the treatment.

Selection of approach to CS

Transvenous embolization is a widely accepted approach in most cases of CS DAVF, and the ipsilateral IPS is the most common and safe access route to the CS region [7]. However, when the ipsilateral IPS is occluded, the access to the CS becomes problematic with a success rate of approximately 50-80% [14]. In our study, occluded IPS occurred

in 35 of 42 patients (83.3%), which is higher than the rates in previous reports [7, 14]. As reported in the literature, we also selected the ipsilateral occluded IPS route as a first-line treatment, with a success rate of 93% (25/27), which is higher than that reported in the literature [7]. If the ipsilateral IPS is in an unacceptable access route, the SOV should be a reasonable alternative [11]. Because of the tortuosity and stenosis at the junction of the angular vein and SOV, various approaches have been reported, such as direct puncture of a surgically exposed SOV [15] or percutaneous preseptal puncture [16]. The major advantage of the facial vein-SOV approach over surgical SOV exposure is that the facial vein-SOV approach is less traumatic and cosmetically sufficient. Our transfemoral facial vein-SOV approach had a sufficiently high success rate using a triple coaxial system supporting a microcatheter [17].

Advantages and disadvantages of TVE via the SOV

For the TVE of CS DAVF, it is essential to obliterate the shunting point completely and avoid packing the CS completely. Complications involving the ipsilateral abducens nerve are thought to be associated with overpacking of the CS, especially with dense packing in the posterolateral component of the CS [18, 19]. We recently reported that the long-term outcome of the abducens nerve palsy had a strong correlation with the coil volume placed in the middle-lateral part of CS, and a volume of 27.9 mm^3 was the optimal cutoff in this part [12]. Standard TVE via the IPS consists of retrograde cannulation of the ipsilateral IPS, advancement through the CS to its junction with the SOV, and obliteration of the CS by anterior-to-posterior packing. However, as shown in our case in Table 1, many shunting points were located at the posterior part of CS; thus, we could not obliterate this part until the end of the embolization. Alternatively, TVE via the SOV approach had a major advantage as follows. Access via SOV enable easy navigation of the microcatheter at the posterior part of CS and embolization at the shunting point. If tightly occlusive packing at this starting point was completed and left the shunt intact, we could obliterate the CS with posterior-anterior packing. In this situation, there was no need to completely pack the CS from the posterior part of the CS to the junction of the SOV. This finding is supported by our results that TVE via the SOV approach significantly reduced the total number, length, and volume of placed coils. Moreover, our study showed that total fluoroscopic time and SAD in both approaches had no significant differences. The observed median SAD in TVE via the IPS and SOV were 2676 and

1730 mGy, respectively, which were within the range of published reports [20]. This result suggested that the use of the SOV for TVE did not result in a time-consuming procedure. Obviously, there was a learning curve for TVE via the SOV due to the anatomical venous variation in the extracranial portion. Both fluoroscopic time and SAD have a tendency toward a reduction in radiation exposure in patients with SOV, this may be explained by the fact that the SOV approach needed fewer coils, so we believe that further experiences with cases will be needed to describe this issue.

The disadvantages of SOV access are as follows. First, many cases have severe tortuosity or stenosis at the junction of the angular vein and SOV. Once a microcatheter enters the CS, drainage routes may be wedged by the inserted catheter. A major concern in this situation is critical elevation of intrasinus pressure before TVE. Our study adds new data demonstrating statistically significant elevation of sinus pressure (49 versus 59 mmHg; $P = 0.022$) after catheterization into the SOV; however, there were no differences in post-procedural neurological outcome compared with the IPS approach. A possible explanation of our results is as follows. Although the ipsilateral angular and facial veins were no longer opacified after the advancement of the microcatheter into the CS, newly opacified collateral veins, such as the ipsilateral supratrochlear, transverse supraorbital, and supraorbital veins, were observed in many cases. In our cases, a box plot diagram (Fig. S1a) showed that an outlier of sinus pressure reaching 91 mmHg was observed in a patient treated via the IPS. This outlier in an IPS case might be due to technical problems or reproducibility of measurement in bended microcatheters. Thus, we believe that variations in venous anatomy may contribute to the release of the critical elevation of sinus pressure. As the pressure in the CS is mainly dependent on the MAP, another explanation could be an increased arterial pressure, which might be due to discomfort or pain caused by the catheter manipulation in the access route. Although our MAP data in both group at the time of pressure measurement did not show any significant differences, further investigation under general anesthesia may resolve these findings. Second, there is a potential risk of procedural complications, such as venous injury or rupture. Unlike the IPS route, the facial vein-SOV route is surrounded by soft tissue and not supported by bony structures, and reopening of the unvisualized vein carries a greater risk of procedural complications. Thus, our indication of the SOV

approach was limited in cases with clearly visualized SOV on angiograms. None of the patients with our SOV group had a major complication. In 2 patients, a subtle preseptal hematoma developed during the procedure. However, these hematomas were asymptomatic and resolved within a week, thus requiring no additional management.

Limitations and generalizability

We acknowledge several limitations that need to be taken into account when interpreting our findings. This study has a retrospective design, and the studied group is relatively small. Referral biases of our institution and its treating physicians may affect the selection of subjects and approach to the CS. Many patients in our cohort had a prominent SOV, affecting the selection of approach route, and the studied population may not be representative. The fact that one-quarter of our patients (10/42) did not have SOV drainage should be considered before applying our results in general. As in most cases the shunt was located in the medial and dorsal part of the CS, only less than 10% of all cases (4/42) had a shunt in the anterior part of the CS in this study. More widespread use of our SOV approach may be corroborated by the fact that most fistulas are located in the posterior part of the cavernous sinus. Moreover, patients with TVE via SOV tended to have smaller shunts than those with IPS. Therefore, a complete obliteration of the shunt could be possible via the SOV approach with fewer and smaller coils, as the anterior CS can be spared in most cases. Thus, our results may depend not only on the approach used but more important on the anatomical feature of the fistula in the CS. To prove our results at a high evidence level, it is necessary to randomize patients with a clearly visualized access route to the SOV into two groups, SOV approach and IPS approach. Because fistulous disease is relatively rare and a large sample size may not be feasible, we believe that our retrospective cohort study was helpful in the treatment planning of CS DAVF. Indeed, further investigation is warranted to confirm the generalization of our findings as accurate. There are also other limitations that should be discussed. The choice of TOF-MRA for following up patients with CS DAVF would be problematic. DSA provides high temporal and spatial resolution that cannot be matched by current other imaging modalities for the evaluation of complex and potentially subtle fistulae. Thus, DSA still remains the gold standard for the both diagnosis and follow-up of CS DAVF [21].

Conclusions

According to our findings, our treatment strategy for patients with CS DAVF is as follows. In cases with a visualized pathway from the SOV through the facial vein to the internal/external jugular vein SOV approach should be preferred, in all other cases standard approach via the IPS should be used, even if it cannot be visualized. Because TVE via the SOV would be possible to obliterate the shunting point located at the posterior part of the CS at the early stage of the procedure, which would result in a significant reduction in the total number of coils.

Compliance with ethical standards

Conflict of interest

The authors declare that they have no conflicts of interest.

Ethical approval

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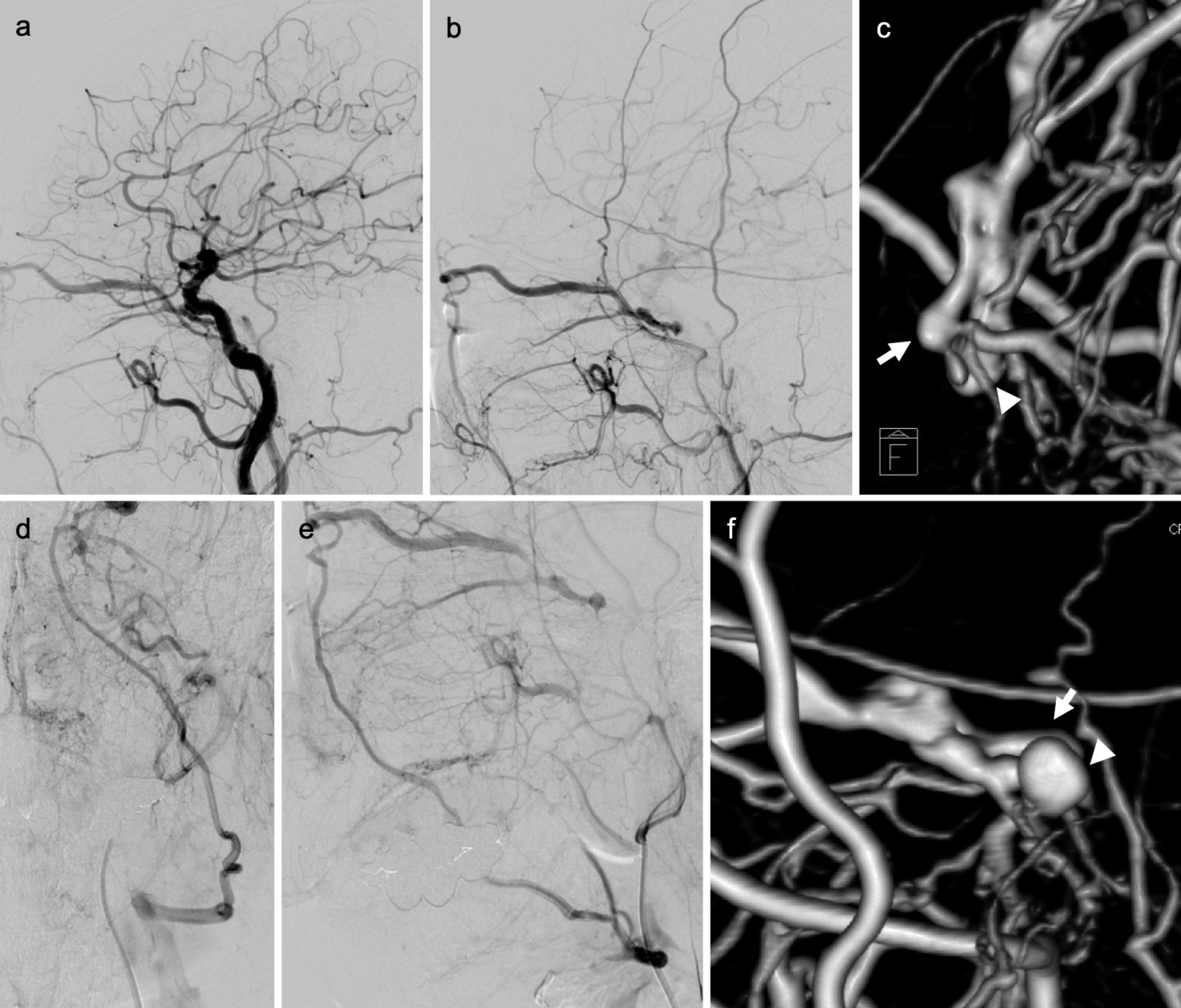
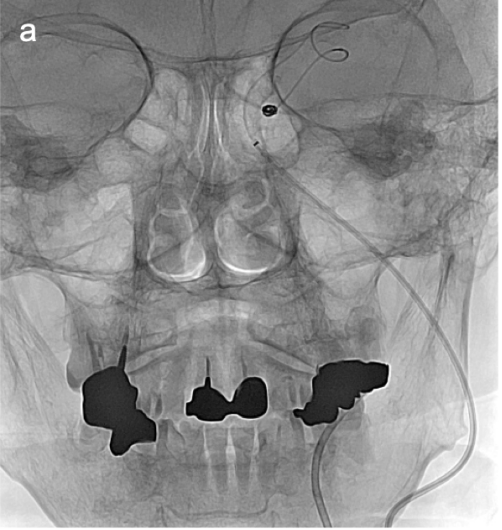
Figure Captions

Fig. 1 Representative case of a left cavernous sinus dural arteriovenous fistula treated with transvenous embolization through the transfacial-superior ophthalmic vein approach. Lateral views of left common (a) and external (b) carotid angiograms show early opacification of both the cavernous sinus and superior ophthalmic vein. Caudal (c) and lateral (f) views of three-dimensional digital subtraction angiograms show two shunting components at the dorsal part of the cavernous sinus. Arrows and arrow heads show shunting components of the medial and lateral part of cavernous sinus, respectively. Anterior-posterior (d) and lateral (e) views of left external carotid angiograms show clear opacification of the transfacial-superior ophthalmic vein approach root. Note the facial vein draining into the ipsilateral internal jugular vein.

Fig. 2 Anterior-posterior (a) and lateral (b) views of nonsubtracted craniograms obtained just after placement of a first coil in the cavernous sinus. A microcatheter is advanced into the lateral part of the shunting component supported by a 4-French distal access catheter placed in the angular vein. Anterior-posterior (c) and lateral (d) views of nonsubtracted left external carotid angiograms show the placed coils in the cavernous sinus. A total of 9 coils are placed in two shunting components with preservation of the middle and anterior part of the cavernous sinus. A lateral view of the left external carotid angiogram (e) obtained at the end of the session shows the complete obliteration of the cavernous sinus dural arteriovenous fistula.

Fig. S1 Boxplots of differences in the initial pressure in the cavernous sinus (a) and total number (b), length (c), and volume (d) of placed coils according to two approach routes. The initial pressure in the cavernous sinus is significantly higher, and the total number, length, and volume of placed coils are significantly lower in subjects with the transfacial-superior ophthalmic vein approach ($P < 0.05$). The boxplots follow Tukey's convention; the maximum whiskers are 1.55 x interquartile ranges, and outliers are marked with circles.


a
b
c
d
e
f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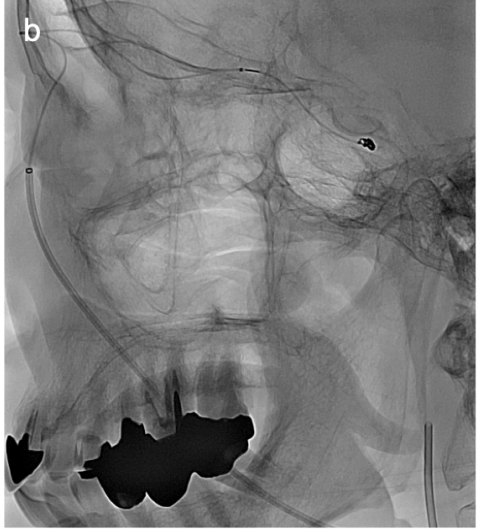
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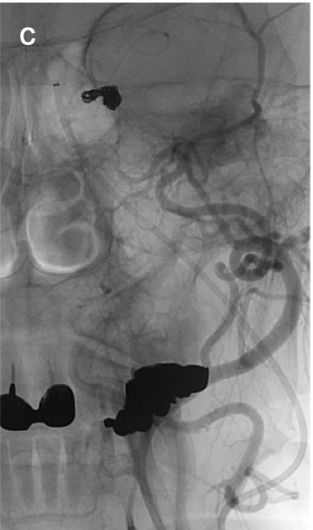
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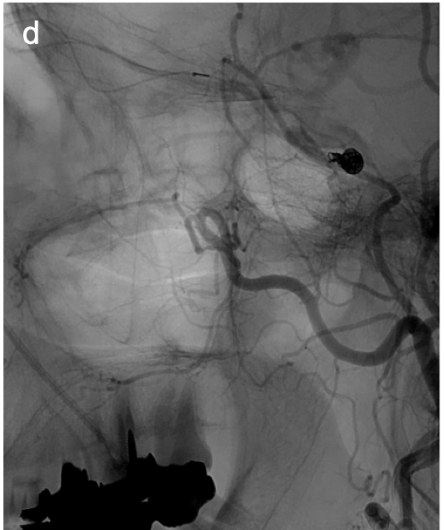
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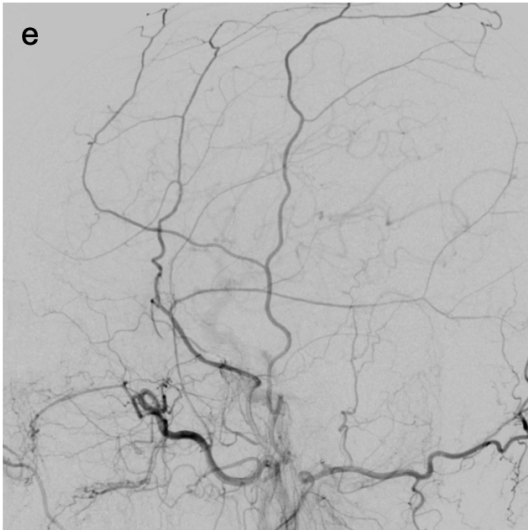
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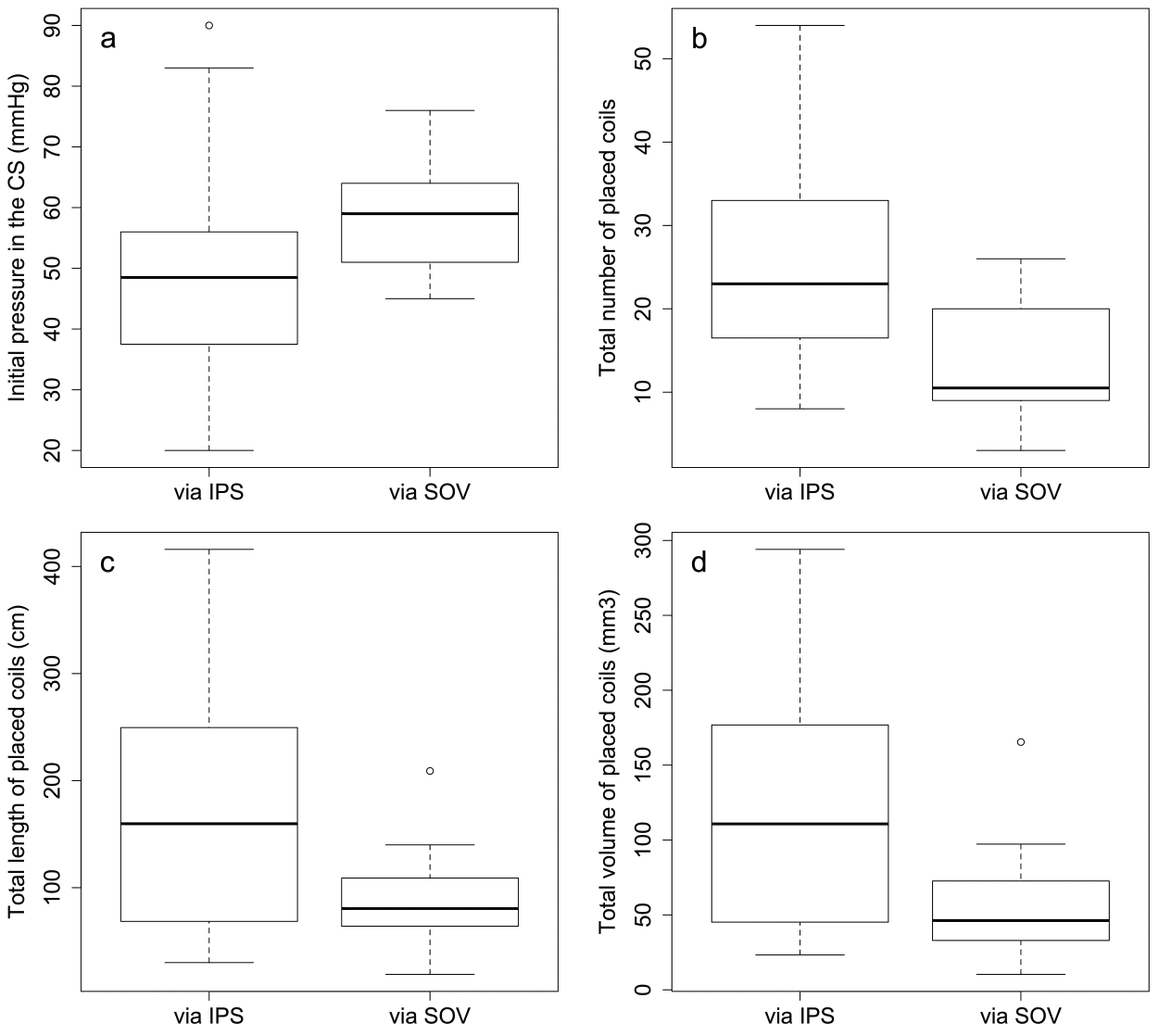
a
Initial pressure in the CS (mmHg)
20
30
40
50
60
70
80
90
via IPS
via SOV
b
Total number of placed coils
10
20
30
40
50
via IPS
via SOV
c
Total length of placed coils (cm)
100
200
300
400
via IPS
via SOV
d
Total volume of placed coils (mm3)
0
50
100
150
200
250
300
via IPS
via SOV

Table 1 Baseline characteristics of the study patients stratified by approach

Characteristics	via IPS (n = 32)	via SOV (n = 10)	P value
Age (IQR), years	72 (65-78)	66 (51-74)	0.234
Female sex, no. (%)	26 (81)	9 (90)	1.000
Clinical presentations, no. (%)			
Chemosis	27 (84)	10 (100)	0.315
Proptosis	13 (41)	8 (80)	0.670
Diplopia	23 (71)	9 (90)	0.404
Decreased visual acuity	3 (9)	3 (30)	0.139
Cranial nerve palsy, no. (%)			
Oculomotor (III)	3 (9)	3 (30)	0.139
Trochlear (IV)	2 (6)	2 (20)	0.236
Abducens (VI)	18 (56)	8 (80)	0.270
Location of shunt, no. (%)			
Anterior	4 (13)	0 (0)	0.557
Middle	12 (38)	2 (20)	0.451
Posterior	30 (94)	10 (100)	1.000
Drainage vein, no. (%)			
SOV	22 (69)	10 (100)	0.084
SMCV	21 (66)	4 (40)	0.268
Uncal vein	9 (28)	4 (40)	0.697
IPS	7 (22)	0 (0)	0.168

Values are presented as the median with interquartile range (IQR) for continuous variables and counts (percentage) for categorical variables

IPS inferior petrosal sinus, *SOV* superior ophthalmic vein, *IQR* interquartile range, *SMCV* superficial middle cerebral vein

1

Table 2 Comparison of treatment results between TVE via the IPS and SOV

	via IPS (n = 32)	via SOV (n = 10)	P value
Failed other approach, no. (%)	0 (0)	2 (20)	0.053
FV drain into ext. jugular vein, no. (%)	-	2 (20)	-
Via superior root of SOV, no. (%)	-	8 (80)	-
Initial pressure in the CS (IQR), mmHg	49 (38-56)	59 (51-64)	0.022*
Mean arterial pressure (IQR), mmHg	98 (90-111)	101 (96-104)	0.325
Placed coils in the CS			
Total number of coils (IQR), no.	23 (17-33)	11 (9-18)	<0.001*
Total length of coils (IQR), cm	159 (69-249)	81 (64-91)	0.003*
Total volume of coils (IQR), mm^3	111 (47-177)	46 (35-72)	0.005*
Maximum diameter of coils (IQR), mm	4.0 (3.5-5.0)	3.5 (3.25-4.5)	0.154
Angiographically complete occlusion			
At final angiogram, no. (%)	29 (91)	9 (90)	1.000
At six months follow-up, no. (%)	32 (100)	10 (100)	-
Operation time (IQR), min	360 (300-453)	330 (270-450)	0.549
Fluoroscopic time (IQR), min	126(101-151)	107(67-141)	0.470
SAD (IQR), mGy	2676(1848-3236)	1730(1404-1968)	0.107
Complications, no. (%)	1 (3)	0 (0)	1.000
Cranial nerve VI palsy, no. (%)			
At the next day of TVE	15 (47)	8 (80)	0.083
At six months follow-up	4 (13)	0 (0)	0.557
Recurrence, no. (%)	1 (3)	0 (0)	1.000
Follow-up period (IQR), months	52 (24-80)	36 (18-53)	0.738

Values are presented as the median with interquartile range (IQR) for continuous variables and counts (percentage) for categorical variables

TVE transvenous embolization, *IPS* inferior petrosal sinus, *SOV* superior ophthalmic vein, *CS* cavernous sinus, *IQR,* interquartile range; *SAD,* skin absorbed dose

*statistically significant

1