Endovascular Treatment of Borden Type III Transverse-sigmoid Sinus Dural Arteriovenous Fistulas: a Single-center 12-year Experience

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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.

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The authors have no personal, financial, or institutional interest in any of the drugs, materials, and devices described in this article.

Conflict of interest

A. Fujita, M. Kohta, T. Sasayama, and E. Kohmura declare that they have no competing interests.

Title of article

Endovascular treatment of Borden type III transverse–sigmoid sinus dural arteriovenous fistulas: A single-center 12-year experience

Abstract

Purpose The objective of this study was to evaluate our 12-year experience in treating Borden type III transverse–sigmoid sinus (TSS) dural arteriovenous fistulas (DAVFs) and discuss the technical aspects of ipsi- and contralateral transvenous embolization (TVE) approaches.

Methods We retrospectively reviewed charts of consecutive patients with TSS DAVF treated with multimodal treatment between April 2008 and March 2020. The baseline patient characteristics, imaging data, details of procedure, data sets of sinus pressure monitoring, and clinical results were systematically collected.

Results Of 44 patients with TSS DAVF who were treated during study periods, 23 patients of Borden type III were extracted. Among the 23 patients, 18 with transfemoral TVE were included for analysis. TVE was performed using an ipsilateral approach in eight patients and a contralateral approach in 10. Pressure monitoring data revealed that initial mean sinus pressure (43.5 mm Hg vs. 29.5 mm Hg; $P = 0.033$), maximum sinus pressure during the procedure (69.0 mm Hg vs. 40.5 mm Hg; $P = 0.011$), and sinus pressure gradient (22.5 mm Hg vs. 5.5 mm Hg; $P = 0.021$) were significantly higher in the ipsilateral approach group. The complete obliteration rate by primary embolization was 94% in our cohort with the recurrence rate of 5.6% with median follow-up periods of 57 months.

Conclusion Our study showed the durability of TVE for patients with Borden type III TSS DAVF. TVE performed via the contralateral approach might prevent a potentially dangerous increase in intraprocedural sinus pressure and cortical venous reflux.

Key words

Dural arteriovenous fistula, isolated sinus, sigmoid sinus, transvenous embolization, transverse sinus

Abbreviations

DAVF dural arteriovenous fistula

CVR cortical venous reflux

MRA magnetic resonance angiography

MSP mean sinus pressure

SAD skin absorbed dose

SPG sinus pressure gradient

TAE transarterial embolization

TSS transverse-sigmoid sinus

TVE transvenous embolization

Introduction

Dural arteriovenous fistulas (DAVFs) account for 10%–15% of intracranial vascular pathologies. Annual incidence rates reportedly range between 0.16 and 0.51 per 100,000 persons [1]. The prognosis of DAVF depends on the findings of cortical venous reflux (CVR) and fistulas with CVR are aggressive and have been found to have an annual mortality of 10.4% with an annual hemorrhage risk of 8.1% and a non-hemorrhagic neurological deficit risk of 6.9% [2]. Therefore, aggressive treatment is recommended for patients with severe clinical presentation or CVR.

Most intracranial DAVFs involve the transverse–sigmoid sinus (TSS) [1] and 71% of TSS DAVFs are high-grade lesions and classify as Borden type II or III [3]. The pathogenesis of most DAVFs probably involves a cycle of sinus thrombosis and recruitment of dural collateral arterioles; recanalization of the occluded segment determines the clinical course [4]. In Borden type III TSS DAVFs (isolated type), sinus occlusion results in venous drainage flowing directly into cortical veins [5].

During the past two decades, endovascular treatment has become the first-line treatment for TSS DAVF including transarterial embolization (TAE), transvenous embolization (TVE), or both combined [6]. TVE of TSS DAVFs using coils is currently recognized as an effective treatment with long-term durability [6, 7]. In patients with Borden type III TSS DAVFs, the occluded sinuses are permeated by small channels and the isolated sinus is frequently difficult to reach via the ipsilateral jugular vein. In these cases, a contralateral approach may be feasible [8]. Based on our experience, we hypothesize that TVE via the contralateral side reduces the risk of intraprocedural sinus pressure elevation by obliterating the fistula early in the procedure. To the best of our knowledge, the relationship between TVE approach and change in venous sinus pressure during treatment of Borden type III TSS DAVFs has not been previously examined. The objective of this study was to evaluate our 12-year experience in treating Borden type III TSS DAVFs. We also discuss the technical aspects of both the ipsilateral and contralateral TVE approaches.

Methods

Ethics statement

This study was conducted in accordance with the Declaration of Helsinki and the Good Clinical Practice guidelines of the International Council for Harmonisation. Institutional review board approval was obtained (No. B190293). All patients provided written informed consent. Patient data was anonymized and deidentified prior to analysis.

Subjects

We retrospectively reviewed a database of consecutive TSS DAVF patients treated in our institution from April 2008 to March 2020. Patient data including age, clinical presentation, treatment modalities, complications, recurrences, and clinical follow-up were recorded. Angiographic data included feeding arteries, fistulous portions (according to a previously published classification system [9]), opacified sinuses, and varix–draining vein association. Procedural details including number of sessions, approach, operation time (total time in the angiography suite), and intraoperative pressure monitoring were also recorded. Cerebral digital subtraction angiography (DSA) was obtained using a biplane flat detector angiography unit (Artis Zee BA twin; Siemens, Erlangen, Germany). The system automatically stores accumulated exposure data such as total fluoroscopic time and skin absorbed dose (SAD), which were recorded at the end of treatment sessions.

Endovascular procedure

Endovascular procedures were performed by one author (A.F.). Local anesthesia was used in transfemoral TVE procedures; general anesthesia was used for TAE and direct sinus packing. Transfemoral TVE was used as the first-line treatment approach for Borden type III TSS DAVFs. In patients undergoing emergent craniotomy for evacuation of intracranial hematoma, direct sinus packing was performed. After the Onyx liquid embolic system (ev3, Irvine, California, USA) was approved in our country for embolization of intracranial DAVFs in September 2018, we modified our treatment strategy: transarterial Onyx was used preferentially in patients with a straight middle meningeal artery in which a dual-lumen balloon catheter could be advanced near the fistula. Onyx was only used in transarterial approaches. In patients who underwent transfemoral TVE, the ipsilateral approach was preferred except for patients with a transverse sinus groove on preoperative computed tomography angiography (CTA); the contralateral approach was preferred in these patients. In patients with Borden type III TSS DAVFs, the transverse sinus between the torcular herophili and the sigmoid sinus is completely occluded and is not opacified on CTA. Thin-slice CT images were reconstructed in a 3-dimentional (3D) volume-rendering skull by imaging editor. Only a 3D skull base with affected TSS was left and convexity skull was removed. We evaluated the presence of the transverse sinus groove of the affected side on the internal surface of the skull base. During the penetrating procedure of the occluded sinuses, we used the shape of this groove as an anatomical landmark. A 5 Fr diagnostic catheter was placed in the external carotid artery on the affected side. A 7 Fr (Roadmaster; Goodman, Aichi, Japan) and 4 Fr (Cerulean G; Medikit, Tokyo, Japan) coaxial guiding system was placed in the internal jugular vein. The tip of the 4 Fr catheter was advanced into the occluded sinus using a 0.035-inch guidewire (Radifocus; Terumo, Tokyo, Japan). A microcatheter (Excelsior 1018) was advanced over a 0.016 inch microguidewire (GT wire 16; Terumo, Tokyo, Japan) into the affected sinus and connected to an arterial transducer (RMC-4000 Cardio Master; Nihon Kohden, Tokyo, Japan) to record mean sinus pressures (MSPs) in arterialized sinuses. The initial MSP in the sinus was defined as the pressure obtained from a microcatheter placed in the center of the affected sinus prior TVE and MSPs were measured intermittently throughout the procedure. The highest reading was recorded as maximum MSPs and the difference between the initial and maximum values was defined as sinus pressure gradient (SPG). We also simultaneously recorded mean arterial pressure as a reference in the left arm. Our treatment strategy of transfemoral TVE for Borden type III TSS DAVF was as follows. In ipsilateral approach cases, standard TVE was performed from the distal portion of the transverse sinus to the proximal sigmoid sinus. In contralateral approach cases, the microcatheter was navigated into the sigmoid–jugular junction through the distal portion of the occluded transverse sinus and TVE was performed from the proximal portion of the sigmoid sinus to the distal portion of the transverse sinus. If angiography showed residual opacification along the sinus with CVR despite complete sinus packing, additional TAE via the middle meningeal artery was performed in the same session using low-concentration N-butyl-2-cyanoacrylate.

Clinical follow-up

At the end of treatment, angiographic occlusion was classified as follows: complete occlusion, no residual shunt; near-complete occlusion, minimal residual shunt without cortical reflux; and incomplete occlusion, residual shunt with cortical reflux. Clinical and 3 T time-of-flight magnetic resonance angiography (MRA) follow-up were performed 6 and 12 months after treatment and annually thereafter. Imaging studies were reviewed by two experienced neuroradiologists. Absence of high-intensity abnormal signal adjacent to the sinus wall on MRA indicated complete occlusion. If abnormal MRA signal was observed, diagnostic angiography was performed for further evaluation.

Statistical analysis

Statistical analyses were performed using open source R software version 3.5.1 (R Foundation for Statistical Computing; http://www.r-project.org). Statistical analysis was performed in two groups, TVE using ipsilateral and contralateral approaches. Data are presented as medians with interquartile range (IQR) or numbers with percentage. Continuous variables with a normal distribution were compared using Welch's two-sample t-test; those with a non-normal distribution were compared using the Mann–Whitney U test. Categorical variables were compared using Fisher's exact test. P <0.05 was considered significant. The datasets from the study are available from the corresponding author on reasonable request.

Results

Our indication of curable treatment of TSS DAVF was Borden type II or more, we had no cases of Borden type I treated in our institution during study periods. From April 2008 to March 2020, 44 patients with TSS DAVF underwent endovascular embolization in our institution and affiliated hospitals. A study flow chart is shown in Figure 1. Among the 44 patients, 21 patients with a Borden type II DAVF were excluded. Among the 23 patients with Borden type III DAVF, two patients were treated with Onyx TAE as first-line treatment. Three patients with intracranial hemorrhage underwent emergent craniotomy at presentation; these patients were treated by hematoma removal followed by direct sinus packing. Therefore, 18 patients with Borden type III DAVF underwent transfemoral TVE were included for analysis. TVE approach was decided based on CTA findings. The contralateral approach was used for patients with the transverse sinus groove; otherwise, the ipsilateral approach was used. The ipsilateral and contralateral approaches were initially used in nine patients each. However, ipsilateral TVE failed in one, which required switching to the contralateral approach. Therefore, eight patients underwent ipsilateral TVE and 10 underwent contralateral. A representative contralateral TVE case is shown in Figure 2. A 64-year-old man presented with right temporal lobe hemorrhage and the angiogram showed the right Borden type III TSS DAVF (Fig. 2 a). A reconstructed bone image of CTA showed a transverse sinus groove on the occluded right transverse sinus. We performed TVE from contralateral approach and obtained complete occlusion (Fig. 2 c-e).

Patient characteristics are summarized in Table 1. Median age was 65 years. Eight patients were men and 10 were women. The most frequent clinical presentation was intracranial hemorrhage (50.0%). All patients demonstrated feeding arteries from the middle meningeal artery and the transosseous branch of the occipital artery. The fistulous portion of the DAVF involved the transverse–sigmoid junction in 14 patients (77.8%), the horizontal portion of the sigmoid sinus in 8 (44.4%), and the junction with the vein of Labbé in 8 (44.4%). A varix of drainage vein was most frequently observed in the vein of Labbé (11.1%). Median follow-up was 57 months (IQR, 30–77).

Treatment results between two approaches are shown in Table 2. Among the 18 TVE patients, complete occlusion was achieved in all eight of the ipsilateral approach patients and nine of the 10 contralateral approach patients. Overall, the rate of complete occlusion after primary embolization was 94%. Number of sessions, additional TAE, opacified sinuses, mean arterial pressure in the arm, operation and fluoroscopy times, SAD, and complications did not significantly differ between the ipsilateral and contralateral TVE groups. Although the transeverse groove on reconstructed CT was not observed in patients treated by ipsilateral approach, we could find transverse sinus groove in 70% of patient with contralateral approach and this was statistically significant (P = 0.004). Initial MSPs (43.5 mm Hg vs. 29.5 mm Hg; $P = 0.033$; Fig. 4a), maximum MSPs during the procedure (69.0 mm Hg vs. 40.5 mm Hg; $P = 0.011$; Fig. 4b), and SPG (22.5 mm Hg vs. 5.5 mm Hg; $P = 0.021$; Fig. 4c) were significantly higher in the ipsilateral approach group. Rate of complete occlusion did not significantly differ between the ipsilateral and contralateral approach TVE groups on final intraprocedural angiography (100% vs. 90%) or

6-month follow-up angiography. Recurrence rate (zero vs. 10%) and clinical outcomes did not significantly differ either. One patient in the contralateral TVE group experienced recurrence associated with cortical reflux 1 year after embolization. This patient underwent glue embolization that resulted in complete occlusion without recurrence over a 35-month follow-up period. Overall, this was the only patient who experienced recurrence. Fifteen of 18 patients (83.3%) experienced no change in clinical symptoms after embolization, while three (16.7%) experienced an improvement. None of patients experienced worsening of symptoms.

A representative case of TVE using contralateral approach is shown in Fig. 3. A 55-year-old woman presented with pulsatile tinnitus and headache was diagnosed with Borden type III TSS DAVF (Fig. 3a-c) and was treated with a transfemoral TVE through the occluded left transverse sinus (Fig. 3d-h). With this approach, the tip of the microcatheter could be inserted into complex each parallel channel easily and coil deposition was started from sigmoid-jugular junction. Because the shunt points were obliterated at the early stage of embolization, it was possible to avoid a risk of inappropriate MSPs elevation during the procedure. The initial MSP of the sinus was measured at 39mmHg and the maximum MSP and SPG were measured at 42 and 3 mmHg, respectively.

Discussion

This study investigated long-term outcome of Borden type III TSS DAVF treatment in our institution. Two key findings were observed. First, at a mean follow-up of 57 months, transfemoral TVE achieved favorable and durable clinical outcomes using either the ipsi- or contralateral approach. The overall complete occlusion rate after primary embolization was 94% in our cohort. At the last follow-up, same was obtained in all patients and worse functional outcome was not observed. The overall rate of TSS DAVF recurrence after initial treatment was 5.6%. Our results are consistent with previous reports [10, 11]. Second, our study shows that TVE of TSS DAVF using the contralateral approach is safe and effective. Among the patients who underwent TVE, the intraprocedural change in sinus pressure was significantly lower in the contralateral approach group (22.5 mm Hg vs. 5.5 mm Hg; $P = 0.021$), demonstrating that this approach can avoid inadequate elevation of sinus pressure. Furthermore, procedural complications and angiographic and clinical results did not significantly differ between the groups.

Current treatments for TSS DAVFs include endovascular embolization, microsurgical disconnection, and stereotactic radiosurgery. Among these, endovascular embolization has been the first line modality for decades [12, 13], TAE using Onyx has become an alternative. However, this approach is associated with reported recurrence rates ranging between 0% and 14% [14, 15]. At present, we believe that Onyx TAE cannot readily replace TVE as an alternative treatment for TSS DAVFs. Standard TVE via the ipsilateral approach consists of retrograde cannulation of the ipsilateral SS, advancement through the occluded sigmoid sinus to the transverse sinus, and occlusion of the transverse sinus by packing it distally to proximally. However, as shown in our case in Table 1, many shunting points were located along the horizontal portion of the sigmoid sinus; therefore, we could not occlude this portion until the end of the procedure. The "turn-back embolization technique," in which a microcatheter is turned back into the pathological sinus and introduced into the shunting point located more proximally can overcome this issue [16]. The technique is ideal in that coils can be placed preferentially into the shunting point at an early stage of the procedure, which minimizes the risk of pressure increase in the residual sinus and CVR during the procedure. However, thrombosis in the TSS may prevent navigation of the catheter to the proper shunting point when using this technique. Alternatively, our TVE via the contralateral approach had a major advantage as follows. Navigation of the microcatheter through the occluded transverse sinus is easy with TVE via the contralateral approach because the sinus is anatomically straight. In our series, 70% of patients who underwent the contralateral approach had the transverse groove on CTA on the affected side. The contralateral approach was successful in all who had this finding.

The important thing in our approach is that anatomical variations of the torcular herophili clearly impact treatment strategy. An anatomical study has reported that approximately half of individuals have symmetric drainage of the superior sagittal sinus into both transverse sinuses and most of the other half have a right-dominant transverse sinus. The same study also reported that 11.3% of right-dominant transverse sinuses and 3.5% of left-dominant transverse sinuses do not communicate with the contralateral sinus [17]. This means that approximately 15% of patients do not have an anatomical connection between the left and right transverse sinuses. Another advantage of contralateral TVE is that it avoids causing pressure elevation of both intra-sinus and CVR during embolization. Patients who underwent ipsilateral TVE had significantly higher initial and maximum MSPs during the procedure. Change in sinus pressure during the procedure was also significantly higher in the ipsilateral TVE group. These findings are explained by the fact that contralateral TVE enables us to close shunting points around the sigmoid–jugular junction at the early stage of the procedure. Our intra-sinus pressure monitoring showed that the major advantage of contralateral TVE is the ability to limit elevation of sinus pressure during the procedure. Why the initial sinus pressure was higher in the ipsilateral TVE group is unclear but may be related to the approach and further investigation is warranted.

Total fluoroscopy time and SAD did not significantly differ between the ipsi- and contralateral approaches in our study. Median SAD in the ipsilateral and contralateral TVE approaches was 3300 and 2887 mGy, respectively, which are similar to previous reports [18]. Contralateral TVE does not appear to be more time consuming. Although one patient in the contralateral TVE group experienced recurrence associated with CVR 1 year after embolization, retreatment with glue embolization resulted in complete occlusion that was maintained over 35 months of follow-up. In this patient, the contralateral approach was able to occlude the shunt early during embolization, so we used selective shunt occlusion, as we do in cavernous sinus DAVFs [19]. However, unlike cavernous sinus DAVFs, the pathological sinus should be completely occluded with coils in TSS DAVFs because iatrogenic cranial nerve palsy is less of a concern.

This study has several limitations. It was retrospective in design and the sample size was small. The main limitation that needed to be taken account when interpreting our findings is achieving reproducibility of the results, which is a basic foundation of credibility. Because all of the interventional procedures in this study were performed by a single surgeon, selection bias affecting the reproducibility of the study may have been introduced. The results of our study showed that there are statistical differences in intraoperative sinus dynamic pressure changes between two approaches. However, there is no clear proof that it is directly connected to the fact associated with perioperative intracranial hemorrhagic complications. Since there are few cases of hemorrhagic complications during the perioperative period, it is difficult to prove the relationship between increased sinus pressure reading dangerous elevation of CVR resulting bleeding complications during procedure. Borden type III TSS DAVFs are relatively rare, therefore, a large-scale study in a single institution may not be feasible. For the purpose of standardizing the procedure, it is necessary to conduct a multicenter study in the future. Our experience with Onyx TAE was quite limited during the study period. As Onyx TAE is being increasingly performed to treat TSS DAVFs, its long-term clinical outcomes and durability should be compared with TVE in future studies.

Conclusions

The overall complete occlusion rate with primary embolization in our cohort of patients with Borden type III TSS DAVFs was 94%. The rate of recurrence was 5.6%. Among patients treated with TVE, intraprocedural sinus pressure elevation was significantly lower in the contralateral approach group. We recommend TVE via the contralateral approach when treating patients with Borden type III TSS DAVFs to avoid a potentially dangerous increase in sinus pressure and CVR.

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Figure captions

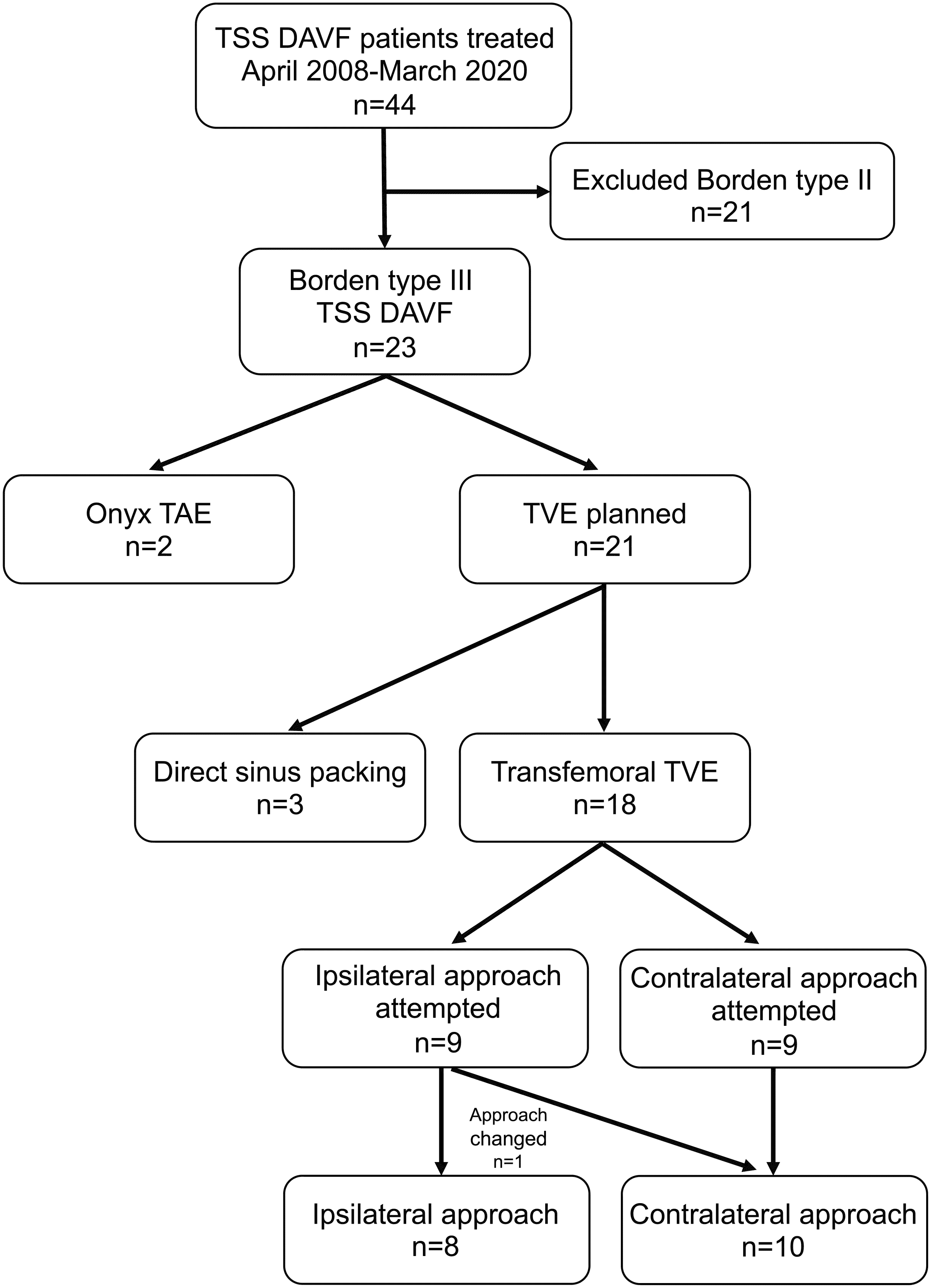
Fig. 1 Flow diagram highlighting the selection for multimodal treatments for patients with transverse-sigmoid sinus dural arteriovenous fistula (TSS DAVF). TAE transarterial embolization, TVE transvenous embolization

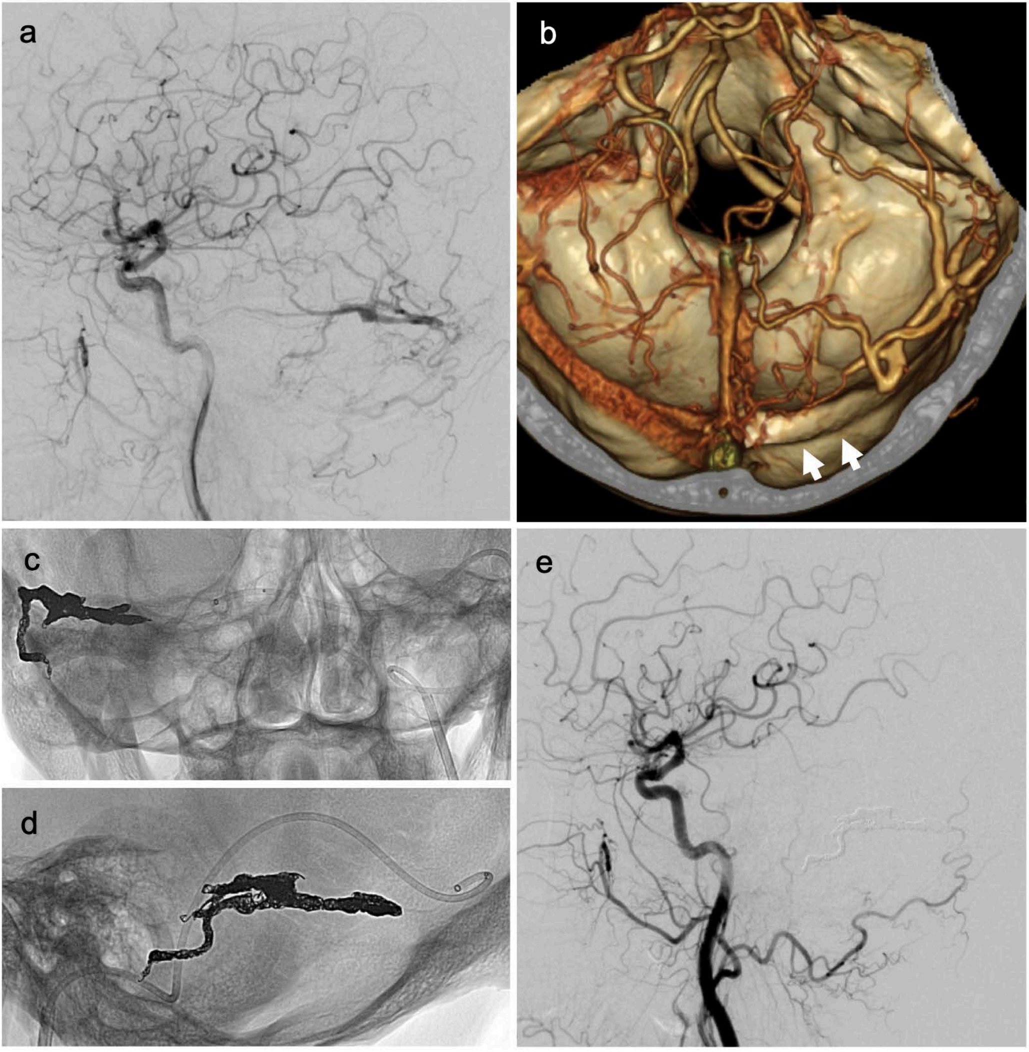
Fig. 2 (a) Lateral view of right common carotid angiography shows a Borden type III transverse–sigmoid sinus dural arteriovenous fistula (TSS DAVF). (b) A superior view of three-dimensional computed tomography angiography reconstruction shows a right TSS DAVF associated with retrograde cortical reflux. The right transverse sinus groove (white arrows) is clearly seen without opacification of the sinus. Intraprocedural anterior–posterior (c) and lateral (d) fluoroscopic views show coils within the transverse sinus, which were placed via the contralateral approach. (e) A lateral view of right common carotid angiography obtained at the end of the procedure shows complete occlusion of the DAVF.

Fig. 3 (a) Lateral view of left common carotid angiography shows a complex Borden type III transverse–sigmoid sinus dural arteriovenous fistula (TSS DAVF). (b) Left oblique view of three-dimensional rotational angiography (3D-RA) shows the shunting point is located at the sigmoid–jugular junction (white arrow); spiral parallel channels (arrow heads) are shown connecting to the transverse–sigmoid junction. (c) Another 3D-RA view shows a shunting point at the transverse–sigmoid junction fed by the middle meningeal artery. TVE was performed via the contralateral approach. Anterior–posterior (d) and lateral (e) fluoroscopic views during the procedure show coils in the sigmoid–jugular junction. Final coil configuration is shown in other anterior–posterior (f) and lateral (g) views. h) Lateral view of left common carotid angiography performed at the end of the procedure shows complete occlusion of the DAVF.

Fig. 4 Boxplots of differences in the mean sinus pressures (MSPs) in the initial measurement (a) and maximum measurement during procedure (b) according to two approaches. Sinus pressure gradient (SPG) (c) were calculated as the differences of initial and maximum pressure measurements in the sinus. Initial and maximum MSPs and SPG were significantly higher in the ipsilateral approach group ($P < 0.05$). The boxplots follow Tukey's convention: the maximum whiskers are 1.55 × interquartile range and outliers are marked with circles.

iTVE, transvenous embolization via the ipsilateral approach; *cTVE*, transvenous embolization via the contralateral approach


TSS DAVF patients treated April 2008-March 2020 n=44
Excluded Borden type II n=21
Borden type III TSS DAVF n=23
Onyx TAE n=2
TVE planned n=21
Direct sinus packing n=3
Transfemoral TVE n=18
Ipsilateral approach attempted n=9
Contralateral approach attempted n=9
Approach changed n=1
Ipsilateral approach n=8
Contralateral approach n=10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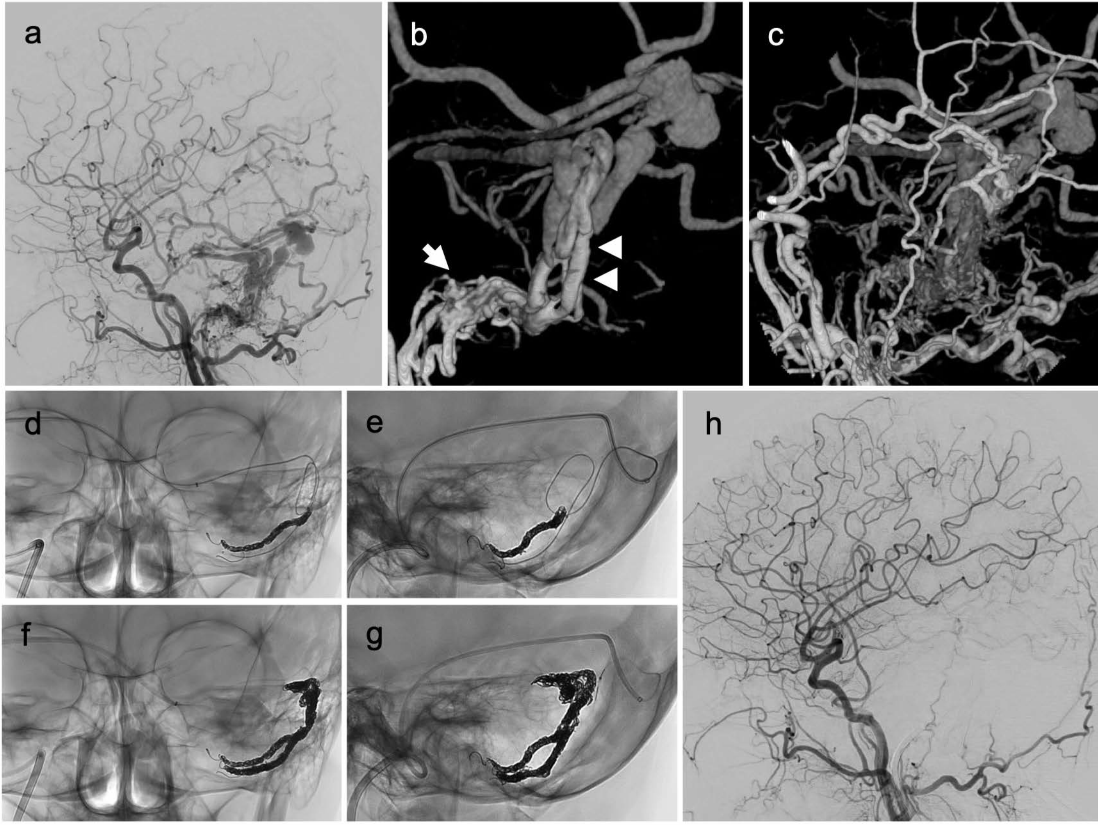
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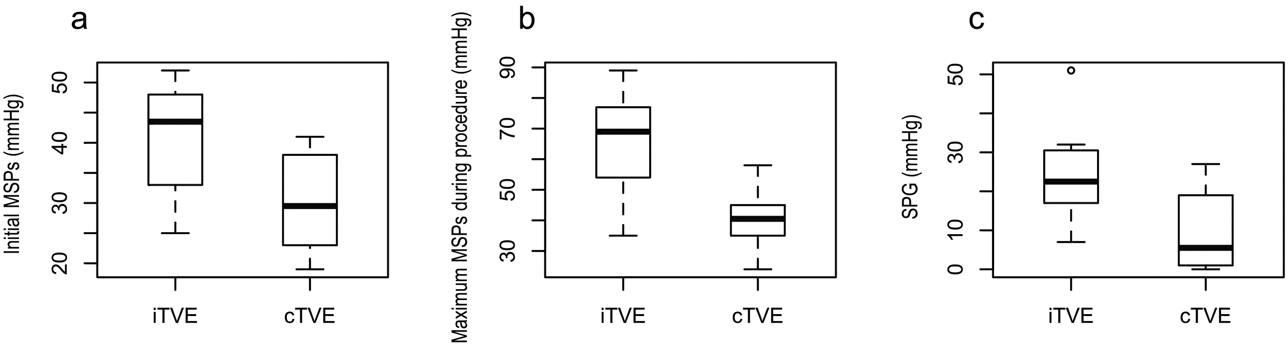
a
Initial MSPs (mmHg)
20
30
40
50
iTVE
cTVE
b
Maximum MSPs during procedure (mmHg)
30
50
70
90
iTVE
cTVE
c
SPG (mmHg)
0
10
30
50
iTVE
cTVE

Table 1 Baseline characteristics of the study patients (n = 18)

Characteristics	
Age (IQR) - yr	65 (56-72)
Male sex - no. (%)	8 (44.4)
Clinical presentations - no. (%)	
Intracranial hemorrhage	9 (50.0)
Seizure	5 (27.8)
Headache	8 (44.4)
Dementia	3 (16.7)
Pulsatile tinnitus	3 (16.7)
Incidental	1 (2.2)
Feeding arteries - no. (%)	
Middle meningeal artery	18 (100)
Ascending pharyngeal artery	14 (77.8)
Transosseous branch of OA	18 (100)
Tentorial branch of ICA	14 (77.8)
Posterior menigeal artery	4 (22.2)
Fistulous portions - no. (%)	
Sigmoid-jugular junction	4 (22.2)
Horizontal portion of SS	8 (44.4)
Transverse-sigmoid junction	14 (77.8)
Junction of vein of Labbé	8 (44.4)
Distal portion of TS	4 (22.2)
Varix of drainage vein - no. (%)	
Vein of Labbé	2 (11.1)
Petrosal vein	1 (5.6)
Temporal vein	1 (5.6)
Follow up period (IQR) -months	57 (30-77)

Values are presented as the median with interquartile range (IQR) for continuous variables and counts (percentage) for categorical variables *TVE* transvenous embolization, *OA* occipital artery, *ICA* internal carotid artery, S*S* sigmoid sinus, *TS* transverse sinus

Table 2 Comparison of treatment results between ipsi- and contralateral TVE approaches

	Ipsilateral TVE (n = 8)	Contralateral TVE (n = 10)	*P* -value
Multiple sessions - no. (%)	0	1 (10)	1.000
Additional TAE - no. (%)	1 (13)	2 (20)	1.000
TS groove on reconstructed CT - no. (%)	0	7 (70)	0.004*
Opacified sinuses - no. (%)			
Simoid-jugular junction	0	2 (20)	0.477
Horizontal portion of SS	5 (63)	6 (60)	1.000
Transverse-sigmoid junction	5 (63)	8 (80)	0.451
Junction of vein of Labbé	7 (88)	10 (100)	0.512
Distal portion of TS	1 (13)	3 (30)	0.567
Sinus pressure (IQR) - mmHg			
Initial MSPs	43.5 (35.5-48.0)	29.5 (24.0-37.3)	0.033*
Maximum MSPs	69.0 (59.5-77.0)	40.5 (35.8-44.3)	0.011*
SPG	22.5 (17.5-29.5)	5.5 (2.0-18.7)	0.021*
MAP of the arm (IQR), mmHg	91 (79-97)	90 (85-96)	0.929
Operation time (IQR) - min	340 (322-420)	367 (315-442)	0.789
Fluoroscopic time (IQR) - min	155 (131-188)	161 (146-181)	0.824
SAD (IQR) - mGy	3300(2815-3895)	2887 (2850-3937)	0.824
Complications - no. (%)			
Cranial nerve palsy	0	0	-
Hemorrhage	1(13)	0	1.000
Initial angiographical results - no. (%)			
Complete occlusion	8 (100)	9 (90)	1.000
Near-complete occlusion	0	1 (10)	1.000
Incomplete occlusion	0	0	-
Follow up radiological results - no. (%)			
Complete occlusion	8 (100)	10 (100)	1.000
Near-complete occlusion	0	0	-
Incomplete occlusion	0	0	-
Recurence - no. (%)	0	1 (10)	1.000
Clinical outcome - no. (%)			
No change	7 (88)	8 (100)	1.000
Improvement	1 (13)	2 (20)	1.000
Deteriorate or new symptoms	0	0	-

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

TAE transarterial embolization, *TVE* transvenous embolization, *TS* transverse sinus, *CT* conputed comography scan, *SS* sigmoid sinus, *IQR* interquartile range, *MSPs* mean sinus pressures, *SPG* sinus pressure gradient.