An Experience of Endovascular Therapy for Transverse-Sigmoid Dural Arteriovenous Fistulas: A Simplified Strategy of Approach

Kajan Ranabhat[1], MD; Thaweesak Aurboonyawat[2], MD; Ekawut Chankaew[2], MD; Pattarawit Withayasuk[2], MD; Boonrerk Sangpetngam[2], MD; Anchalee Churojana[2], MD

[1]B&B Hospital, Gwarko, Lalitpur, Nepal

[2]Siriraj Center of Interventional Radiology, Faculty of Medicine, Siriraj Hospital, Mahidol University, Thailand

Address of Correspondence:

Dr. Kajan Ranabhat, MBBS, MD

B&B Hospital, Gwarko, Lalitpur, Nepal

Email: kajanranabhat@gmail.com

Phone: +977-9851210364

Dural arteriovenous fistulas (DAVFs) account for 10–15% of intracranial shunts, with the transverse-sigmoid sinus being a common site. Their clinical severity and treatment depend on venous drainage patterns. Endovascular therapy is the preferred first-line approach for aggressive lesions, aiming to occlude the fistula or at least eliminate retrograde venous reflux. This study aims to determine the outcome of sinus sacrifice as the strategy of treatment for aggressive TS-DAVFs. A retrospective analysis included patients with aggressive single TS-DAVFs who underwent endovascular treatment at Siriraj Hospital between 2005 and 2019. Demographic and clinical profiles were recorded. The treatment outcome was evaluated from the last control angiographic pattern. There were 158/565 DAVFs (28%) involving TSS, out of which 77/158 TSS-DAVFs (48.7%) were included in the study. Their venous drainage patterns were both sinus and cortical reflux 47(61%), only retrograded sinus drainage 17 (22.1%), and isolated sinus 13(16.9%). Sacrificing sinus as a treatment approach was successfully achieved in 61(79.2%), with subsequent angiographic cure in 44(72.1%) and benign residual shunt in 17(27.8%). Inability of target venous site access occurred in 4 patients (5%) due to sinus thrombosis and septations. Treatment of aggressive TS-DAVFs to sacrifice the sinus by transvenous coiling is a potential technique to achieve a high cure rate. Major concerns are the appropriate evaluation of venous drainage from both shunt disease and normal parenchyma, as well as the proper choice of access and embolic material for embolization.

Keywords: dural AVFs, endovascular treatment, transvenous approach, transverse-sigmoid dural AVFs.

A dural arteriovenous fistula (DAVF) is an arteriovenous shunt located in the dural wall of the venous sinus or expanded layer of the dura mater into the meningeal or cortical vein.[1,2] DAVF comprises 10-15% of all intracranial AVF, and the commonest location is the Transverse-Sigmoid Sinus (TSS)[3,4] keeping the cavernous sinus apart. The severity and neurological symptoms of DAVF and hence its various classifications are based on its venous drainage according to Borden et al.[5] and Cognard et al.[6]

Patients with TS-dural arteriovenous fistulas (TS-DAVFs) most commonly present with pulsatile tinnitus, followed by headaches and intracranial hemorrhage.[3] In patients with no cortical venous reflux (CVR), conservative treatment or symptom palliation should be considered because these DAVFs carry a low risk of intracerebral hemorrhage (<1% risk annually).[7] However, TSDAVFs with CVR have a greater risk of hemorrhage, reported up to 14%. The annual mortality rate in these patients was 10.4%.[8] Therefore, urgent treatment is required for patients with cortical reflux, life-threatening brain edema, venous infarction, and neurological deficit.

In the last two decades, embolization has become the first-line treatment for DAVFs due to the addition of new devices and novel embolic agents into the armamentarium. Temporarily inflating a large-lumen compliant balloon in the sinus compartment harboring a shunt during the injection of Onyx into an arterial feeder is a sinus-preserving embolization approach supposed to preserve the natural venous drainage and allow a better penetration of the fistula network by the liquid embolic agent.[9–11] Transvenous embolization (TVE) is performed by retrograde catheterization of the involved dural sinus or cortical vein and deposition of coils and/or liquid embolic agents adjacent to the shunt. The occlusion of a dural sinus, however, may carry a risk of venous infarction or hemorrhage in already compromised normal parenchymal venous drainage, which limits this therapeutic approach. The challenge is to obtain a controlled, gradual DAVF obliteration without any diversion of arterialized blood to the cortical veins.[12,13]

Coil occlusion of an intracranial sinus via a transvenous approach is usually well tolerated and highly effective if the affected sinus does not participate in normal venous return.[14] The combination of both techniques by occlusion of the draining sinus compartment from the venous side and embolization of the arterial feeders was supposed to offer a higher rate of definite occlusion.[15] However, potential complications resulting from a compromise of the natural intracranial venous drainage pathways remain the same as with TVE.[11]

The treatment of DAVF is done either to relieve the symptoms, like intractable tinnitus in benign cases, or to downgrade an aggressive fistula into a benign one.[16] But whatsoever, if a decision is made to treat a DAVF, regardless of the type of procedure, the goal of treatment needs to be the complete interruption of the arteriovenous shunt. Otherwise, recruitment of collateral flow and continued risk of hemorrhage are likely. Response of DAVF to any of these treatment modalities is unpredictable. Some DAVFs show spontaneous resolution, whereas some get cured by single or multiple attempts of interventions, and yet some are quite resilient to treatment of any kind.[17–19]

This study aims to determine the immediate and long-term outcomes of sinus-preserving and sinus-sacrificing endovascular treatment approaches in aggressive TS-DAVF.

Materials & Methods

Study design and population

A retrospective cohort of patients with transverse sigmoid sinus region DAVF was extracted and analyzed from all the consecutive patients who were diagnosed with DAVFs by conventional cerebral DSA at the Siriraj Hospital, from January 2005 to August 2019. Patients with concomitant DAVF at other locations were excluded, and so were patients with incomplete data of clinical recordings and follow-up catheter angiography. We obtained approval for this study from the Siriraj Institutional Review Board (SIRB Protocol No: 229/2563).

565 patients were diagnosed with DAVF by catheter angiography from 2005 to 2019. Out of them, 270 patients had dural CCF and were excluded. Out of the remaining 295 DAVF patients, involvement of the transverse–sigmoid sinus region was seen in 158 patients. Involvement of the TSS region alone was seen in 98 patients. 13 patients had benign DAVF. 8 patients had no follow-up angiographic evaluation and were excluded from the study. So, 77 patients were finally selected for the analysis.

Radiographic Evaluation

Catheter angiographies of all patients were done by transfemoral access. The Digital Subtraction Angiography (DSA) findings were described for the precise location of the shunt, all the involved ipsilateral and contralateral feeders, venous drainage via antegrade and or retrograde flow, mechanical or functional obstruction of the venous sinuses, cortical venous reflux, pattern of normal brain parenchyma drainage, and presence of venous congestion and strain. Using these angiographic characteristics, a shunt was primarily categorized into a benign or aggressive type. DAVF in which the shunt was draining anterograde without causing functional obstruction and strain to normal parenchyma is described as a benign DAVF. DAVF using retrograde dural sinus drainage with or without anterograde flow is considered an aggressive DAVF even without cortical venous reflux since this shunt always has the potential of causing strain to the normal parenchymal venous drainage. DAVF with cortical venous reflux, causing obvious strain, is considered malignant DAVF. An isolated DAVF would be defined as a shunt with mechanical thrombosis at sinuses both proximal and distal to the shunt location, and thereby shunt draining only to cortical veins.

Immediate post-endovascular control angiographic outcome is defined for total obliteration of the shunt as no residual shunt or no early venous drainage seen post-procedure, and residual shunt if there is still angiographic evidence of shunt persistence. At last follow-up angiography, outcome was defined as cured for shunt remaining totally obliterated, residual benign if some shunt persists from immediate post-treatment with anterograde drainage only, and aggressive residual if residual shunt has aggressive features described above. If, after initial total obliteration, immediate post-treatment, the shunt shows up at the same location on subsequent follow-up angiograms, it is considered a recurrence. If any shunt appears on subsequent follow-up angiograms at a new dural sinus location, it is considered de novo.

Diagnosis of transverse sigmoid sinus region DAVF was established by attending neuro-interventionists (AC, TA, EC, PW, BS) who have more than 5 years of experience in neurointervention.

Clinical evaluation

Clinical characteristics for gender, age, presenting symptoms and/or signs, duration, angiographic findings, mode of treatment, embolization material, angiographic and clinical outcome, and complications, if any, were extracted from the clinical data sheet. The clinical outcome endpoint was rendering the patient free of symptoms. The cerebral DSA was performed during follow up either if there was residual disease from the last treatment. An additional period of follow-up was considered if the clinical condition was changing, especially recurrence or persistence of tinnitus or headache, or neurological deficits. The non-invasive imaging or cerebral DSA will be needed for re-evaluation of progression or recurrence of disease.

Therapeutic strategy

Indications of endovascular treatment for TS-DAVF patients in our institute were 1) intractable tinnitus and /or headache or any increasing symptoms attributable to DAVF, and/or 2) aggressive venous drainage demonstrated by the first cerebral DSA at presentation.

For aggressive disease, the primary goal of treatment would be to completely obliterate the shunt. Preservation of the sinus would be considered in aggressive DAVFs where normal parenchymal venous drainage was still using the involved sinus. Trans arterial embolization of the shunt using liquid embolic agents (Onyx™ 18, Medtronic) either alone or under simultaneous transvenous balloon protection (mostly Copernic^rc^, Balt) was aimed at involved sinus preservation. Transvenous coil (mostly embolization was used primarily when sacrificing the involved sinus was considered, either due to distal/proximal mechanical or functional obstruction, or the extensive nature of the shunt. When a sinus-preserving procedure resulted in aggressive residual or recurrence, sacrificing the sinus with transvenous coils was considered.

The strategy of treatment was fistula obliteration with preservation of the cortical veins involved. The choice of the material for embolization depended on the approach, the goal of treatment, and the size of the fistula. After transvenous access from the femoral vein, further access to the shunt was done preferably from the ipsilateral jugular vein, and if it failed, was attempted from the contralateral jugular vein across the Torcula. Coil embolization was complemented with liquid embolic agent either into the coil mesh or obliterating the feeder arteries if coiling alone failed to obliterate the shunt totally.

Statistical analysis

All results were measured and analyzed for mean±standard deviation, median, or percentages. The demographic data, clinical presentation, angiographic findings, treatment strategies, and treatment outcome were analyzed. We used Pearson's chi-square test and correlation coefficient to find factors associated with clinical outcomes. For all statistical analyses, $P<0.05$ was considered significant.

Results

The mean age of the 77 patients with TS sinus region DAVF was 56.8 years, and the median age was 58. There was a slight female predominance with 40(51.94%), with the majority of females (70.00%) having DAVF with sinus and cortical

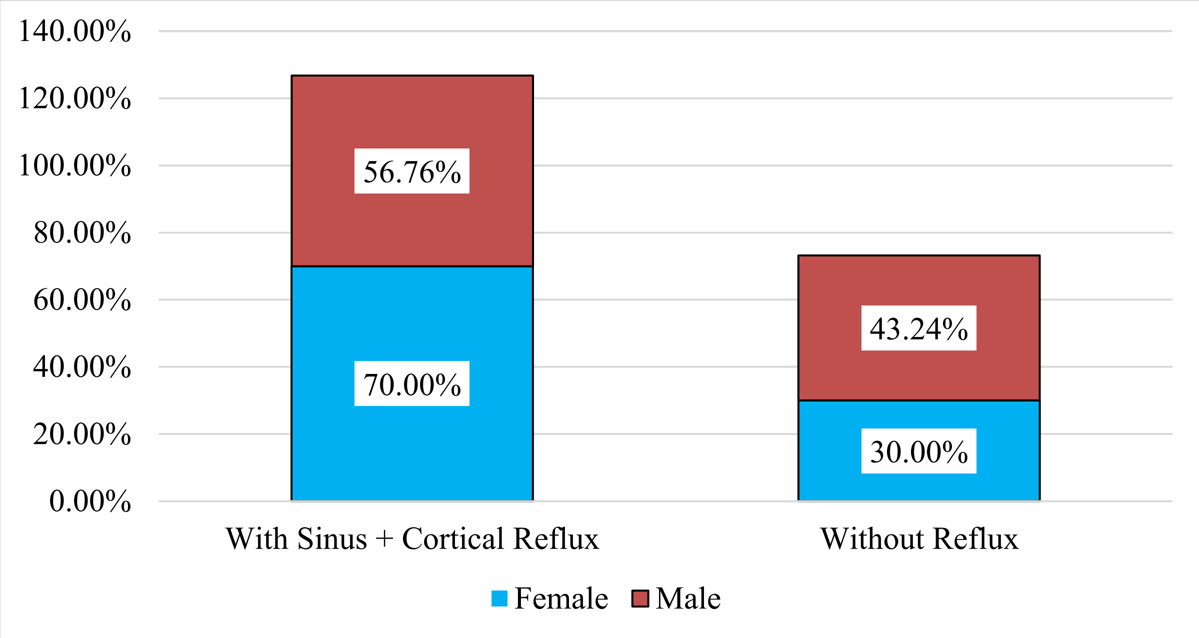

Figure 2: Distribution of Sinus and Cortical Reflux in Relation to Gender (n=77)

venous reflux compared to males (56.76%). The mean duration of presenting symptoms at the time of diagnosis was 5 months, with a median duration of 2 months.

Table 1 illustrates that the commonest primary symptom was headache (30; 39%), followed by pulsatile tinnitus (29; 37.70%). Cranial nerve deficits were present in 5(6.49%) patients. Focal neurological deficit was presenting problem in 13(16.88%) patients in the form of varying degree of motor weakness 6(7.79%), aphasia 3(3.90%), ataxia 3(3.90%) and dysarthria in 1(1.30%) patient. Other CNS presentations were alteration of consciousness 9(11.70%), cognitive impairment 5(6.49%), dizziness 4(5.19%). Seizure was present in 5(6.49%) patients. Intracranial bleed was present in 7(9.09%) patients. Ocular symptoms were present as congested sclera in 8(10.40%) patients, 5(6.49%) of whom had proptosis as well.

Table 2 illustrates that the majority of DAVFs in the transverse sigmoid sinus region were located at a single region (71.43%), followed by two locations (19.48%). Most of the fistulae in this region were located at the junction of the transverse and sigmoid sinus (59.74%), followed by the transverse sinus alone (12.99%). About 15.58% had both in the transverse sinus and the sigmoid sinus. About 42.86% fistulae were on the right, and slightly more than half, 53.25% were on the left.

Common arterial feeders in decreasing order of frequency were Occipital artery 72;93.51%, Middle meningeal artery 69(89.61%), Meningo-hypophyseal Trunk 43;55.84%, Vertebral artery (posterior meningeal artery and/or artery of Falx cerebelli) 39;50.65%, Ascending Pharyngeal artery 32(41.56%), Posterior Auricular artery 30(38.96%) and

Table 1: Clinical Presentations of Patients with Dural Arteriovenous Fistulas (DAVFs) (n=77)

Clinical Presentation	**n (%)**
Primary Symptoms	
Headache	30 (39%)
Pulsatile tinnitus	29 (37.70%)
Cranial nerve deficits	5 (6.49%)
Focal Neurological Deficit	13 (16.88%)
Motor weakness	6 (7.79%)
Aphasia	3 (3.90%)
Ataxia	3 (3.90%)
Dysarthria	1 (1.30%)
Other CNS Presentations	
Altered consciousness	9 (11.70%)
Cognitive impairment	5 (6.49%)
Dizziness	4 (5.19%)
Seizure	5 (6.49%)
Intracranial bleed	7 (9.09%)
Ocular Symptoms	
Congested sclera	8 (10.40%)
Proptosis (subset of congested sclera)	5 (6.49%)

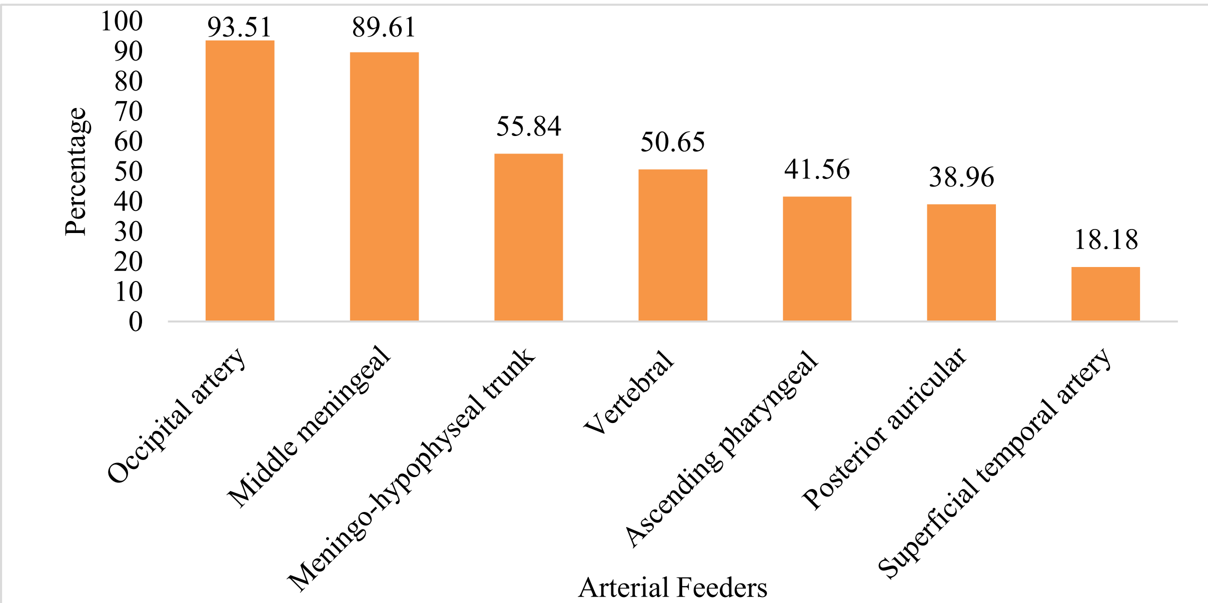

Figure 2: Percentage Distribution of Arterial Feeders in TS Sinus Region DAVF (n=77)

Table 2: Lesion Characteristics of Transverse–Sigmoid Sinus Region Dural Arteriovenous Fistulas (DAVFs)(n=77)

Characteristic	n (%)
Number of fistula locations	
Single region	55 (71.43)
2 locations	15 (19.48)
>2 locations	7 (9.09)
Location of fistula	
Transverse-sigmoid junction	46 (59.74)
Transverse sinus only	10 (12.99)
Sigmoid sinus only	9 (11.69)
Transverse + sigmoid sinus	12 (15.58)
Laterality	
Right	33 (42.86)
Left	41 (53.25)
Bilateral	3 (3.90)

Superficial Temporal artery 14(18.18%). The shunt had only ipsilateral feeders in 45(58.44%) and bilateral feeders in 32(41.56%) patients, as shown in **Figure 2**. **Table 3** shows that the baseline characteristics were largely comparable between the vessel-preserving and vessel-sacrificing groups. The mean age and sex distribution showed no significant difference (p=0.343 and p = 0.785, respectively). Clinical symptoms showed no statistical significance, but the vessel-sacrifice strategy demonstrated higher proportions across most symptoms in comparison to the vessel-preserving group. Tinnitus/bruit was more frequent in the sacrifice group (58.62% vs. 41.38%), as were headache (53.33% vs. 46.67%), cranial nerve deficits (80% vs. 20%), congested sclera (50% vs. 50%), and focal neurological deficits (69.23% vs. 30.77%). The majority of patients, 49(63.3%), had venous sinus reflux with corticovenous reflux, whereas 16(20.80%) patients had venous sinus reflux without cortical venous reflux. Isolated sinus type DAVF was present in 12 (15.5%) patients, and all of them had cortical venous reflux as the only drainage. When cortical venous reflux was present, the most common cortical vein involved was the Labbe vein, 37(77%), either alone or in combination with other veins. Other cortical veins used were the Temporal vein, Parietal vein or Occipital veins, posterior fossa veins, Frontal vein, and vein of Trolard in decreasing order of

Table 3: Comparison of sinus-preserving and sinus-sacrificing treatment strategies (n=77)

Variable	**Total** n (%)	**Strategy n(%)**		**p-value**
		Preserve	**Sacrifice**	
Age (mean±SD)		54.9±11.7	58.09±15.6	0.343
Sex				
Male	37(48.05)	15(40.54)	22(59.46)	
Female	40(51.94)	15(37.50)	25(62.50)	0.785
Clinical symptoms				
Tinnitus /Bruit	29(37.70%)	12(41.38%)	17(58.62%)	0.735
Headache	30(38.96%)	14(46.67%)	16(53.33%)	0.268
Cranial nerve deficits	5(6.49%)	1(20.00%)	4(80.00%)	0.369
Congested sclera	8(10.40%)	4(50.00%)	4(50.00%)	0.499
Focal neurological deficits	13(16.88%)	4(30.77%)	9(69.23%)	0.506
Duration of symptoms (in months) (mean±SD)	5.16±7.8	3.84±5.28	5.99±9.1	0.246
Angiographic Characters				
Thrombosis	44(57.10%)	17(38.64%)	27(61.36%)	0.579
Parenchymal congestion	59(76.60%)	21(35.59%)	38(64.41%)	0.273
Isolated sinus	12(15.50%)	0(0.00%)	12(100.00%)	
Types of DAVF				
Sinus venous reflux only	16(20.80%)	7(43.75%)	9(56.25%)	0.659
Cortical venous reflux#	61(79.20%)	23(37.70%)	38(62.30%)	
Immediate angiographic outcome				
Total obliteration	33(42.90%)	7(23.33%)	26(55.32%)	
Partial obliteration	44(57.10%)	23(53.33%)	21(47.73%)	0.006*
Follow-up (in months) (mean±SD)	16.47±21.37	15.37±13.78	17.17±25.1	0.721
Number of procedures (mean±SD)		1.8±1.03	1.68±0.91	0.597
Final Angiographic (after follow-up)*		(n=16)	(n=61)	
Total obliteration (Cured)	53(68.80%)	9(16.98%)	44(83.01%)	0.222
Partial obliteration (Residual)	24(31.20%)	7(29.17%)	17(70.83%)	

*14 cases initially treated with "preserve strategy" were further treated with "sacrifice strategy"

frequency. Parenchymal venous congestion was present in 59(76.6%) patients, represented by a pseudophlebitic pattern alone in 31(40.3%) or dilated veins in 25(32.6%).

Associated sinus thrombosis was present in

44(57.10%) patients. Immediate post-procedure control angiogram after trans arterial embolization resulted in complete obliteration of the shunt in 7(23.33%) and partial obliteration in 23(37.70%). However, 14/30, 46.67% of these patients with aggressive residual shunt were subsequently treated with sinus sacrifice procedures. Final angiogram in the last follow-up of these patients showed cure in 17 (56.66%) patients and residual benign fistula in 13(43.33%) of patients.

47(61,04%) patients were primarily treated with sinus-sacrificing procedures. This included 8/12 of the isolated sinus type DAVFs sacrificed by transvenous coiling from either ipsilateral or contralateral access. Transvenous coiling alone was done in 28;59.6% patients, and combined transvenous coiling and trans arterial embolization (glue or onyx) was done in 15(32%) patients. In 4(8.4%) of the isolated sinus type AVF in which the venous sinus couldn't be accessed due to stenosis and thrombosis, transarterial filling of the sinus was done to sacrifice the sinuses. Immediate post-procedure control angiogram showed total obliteration in 26(55.32%) patients and partial obliteration in 21(47.73%) patients. However, final angiographic follow-up showed cure in 36(76.6%).

Overall, the sinus-sacrificing strategy (including aggressive residual shunts of the sinus preserved patients who eventually underwent transvenous coiling) was eventually attempted in 61(79.2%) patients, with angiographic cure at final follow-up achieved in 44/61(72.1%) and residual benign shunt in 17/61(27.9%) of the total patients. Cure rate for sinus preserving procedure alone is 9/16, 56.3%. However, 32(41.5%) of patients needed some form of combined treatment during the course of their treatment until rendering them symptom-free. Mean total number of endovascular treatments was 1.8±1.0 in the sinus preservation group, whereas 1.68±0.9 in the sinus sacrifice group, with no statistical significance (p=0.597). Likewise, the median duration of follow-up until the patient was asymptomatic was 11.5 months in the sinus preservation group and 12 months in the sinus sacrifice group. One patient with TS-DAVF with retrograde drainage and sigmoid sinus stenosis was treated with balloon angioplasty followed by and carotid wall stent. There was complete obliteration in the immediate control angiogram with a cured fistula in long-term follow-up.

One major and 7 minor complications (n=8,10.40%) without mortality and permanent morbidity occurred. These complications were intracranial hemorrhage (n=1) without permanent neurological deficit, Onyx migration to ICA via MHT (n=2) with missing precentral cortical branch in 1, retained sonic catheter in feeding artery during detachment (n=1), retrograde glue cast in cortical vein (n=1), inadvertent vessel injury (MMA in 2 and OA in 1 patient) which resulted in minor epidural bleed.

Discussion

Immediate shunt obliteration rate was significantly high for sinus sacrificing procedure with transvenous coiling 26/47;55.3% vs sinus preservation by trans arterial embolization 7/30;23.3% (p=0.006). Likewise, sinus-preserving strategy by trans arterial embolization of feeding arteries showed a trend towards favourable cure rate 9/16(56.3%) vs sinus-sacrificing strategy with transvenous obliteration of the sinus 44/61;72.1% (p=0.222). 32(41.5%) of patients needed some form of combined treatment during the course of their treatment until rendering them symptom-free.

A large proportion of DAVFs had residual shunts immediately after TAE in our series. TVE performed in 14/30 of the patients treated initially by TAE shows that this may not be the strategy of choice for aggressive TS-DAVF. TAE alone can be useful in non-aggressive type DAVF for alleviating symptoms by decreasing the shunt load. It can also downgrade the fistula by decreasing the functional obstruction caused by the shunt to the normal venous drainage. However, TAE can be most useful as an adjunctive treatment to TVE, surgical treatment, or radiosurgery in complex DAVF or in cases where the dural sinus cannot be accessed for TVE. Gaining access and embolizing all arterial feeders is not always possible, and hence, fistulae somehow recruit collateral supply, resulting in incomplete treatment or recurrence of the fistula.[20]

In a strained parenchyma still significantly draining via the involved sinuses, the primary aim can still be to preserve the sinus. In these cases, an attempt should be made to decrease the shunt load by transarterial embolization of maximum feeders and downgrade the shunt, thereby alleviating the functional obstruction caused by the shunt to the normal parenchymal drainage. Venous sinus protection by inflating a balloon and simultaneous transarterial embolization of LEA has been a well-documented treatment option in preserving sinuses in such aggressive DAVFs. Our experience of transarterial embolization with transvenous balloon protection in 7 patients was very good, with excellent outcomes in preserving sinuses. By optimally inflating the Copernic balloon (BALT Extrusion, France) over an adequate length of the involved sinus and cortical vein, liquid embolic agents can be filled along the wall of the shunted as well as prevent reflux to the cortical veins. Precise localization of the anatomy where most of the shunts are converging is important prior to placement of the balloon. A 3D angiogram is useful in this regard. In our experience, gaining access to venous sinuses was possible despite thrombosis and stenosis in the majority of cases. Gaining access to the sinus was possible in all but 4 patients with an isolated sinus. In one patient with proximal jugular vein thrombosis, direct jugular vein access distal to the thrombosis allowed access to the venous sinus. When sacrificing isolated sinuses using LEA, reflux of agent into the major cortical vein, like the vein of Labbe, should be carefully prevented. However, minimal reflux of the embolic material into the proximal root of the cortical vein can be acceptable.

In 2 of our patients, all the feeder shunts were located in separate channels, and these channels could be separately sacrificed without obliterating the separate channel used by the normal parenchymal venous drainage. In this regard, transvenous coiling of the shunt is very preferable.

TVE for TSS DAVFs is currently recognized as one of the most effective treatments.[21,22] In this series, a significant proportion of complete obliteration of the shunt was seen immediately after transvenous coiling (p=0.006). In addition, the final angiographic outcome showed a trend towards a better cure rate for the sinus-sacrificing strategy. Mean total number of treatments was less for the sinus sacrifice strategy compared to the sinus preservation strategy, though statistically not significant (1.68±0.91 vs 1.8±1.03; p= 0.597). After EVT, the venous drainage can become slow and lead to stasis, which can cause venous thrombosis.[11] Therefore, treatment with low molecular weight heparin for three days followed by aspirin is necessary.[23]

The majority of TS-DAVF patients in our series (n=43, 61%) needed a combination of transarterial and transvenous procedures, many of which needed one or more transarterial procedures preceding or following the transvenous access. Better transvenous access due to improved microcatheters and better embolization due to newer coils (e.g., interlocking Nylon-fibered coils), thus we have modified our therapeutic strategy towards using the transvenous approach more as the primary therapy and transarterial embolization as an additional option for residual arterial feeders.

There has been a recent growing interest in using self-expanding stents in the treatment of TS-DAVFs in a small number of patients.[24] Transient balloon dilatation and the persistent radial force of an oversized stent may mechanically compress the arterio-venous shunts within the sinus wall and restore antegrade flow even in chronically occluded sinuses. We share one DAVF with long-term cure post balloon angioplasty and stenting. This indeed is a limited experience to comment on this perspective.

Literature series of endovascular procedures treating DAVFs reported complication rates between 10% and 42%.[25] Our overall complication rate was 10.3% (n=8), including 1 major complication and 7 minor complications; however, without mortality and significant morbidity. A large average number of procedures and a longer duration of follow-up until clinical cure are challenges in treating TS DAVFs. Associated thrombosis and stenosis prolonging the procedures due to difficult venous access is one of the limiting factors and a major risk factor.

Limitations

Our study has some limitations. First, it is a retrospective review with a small cohort of patients included. Second, the angiographic follow-up period was widely varied among patients, though comparable between the two treatment strategy groups. Third, we had a limited number of patients who had undergone transarterial embolization alone. Larger case series with long-term angiographic follow-up examinations are preferred to compare the efficacy and durability of the two treatment strategies.

Conclusion

TS-DAVF comprises a major proportion of intracranial DAVF. Aggressive DAVF presents with headache, tinnitus, ocular symptoms, and various neurological symptoms. Intracranial hemorrhage poses a large threat to mortality and morbidity. Sacrificing sinus with transvenous coiling seems a preferable and safe approach to primary treatment, with a significant immediate shunt obliteration rate and good long-term cure rate. Transarterial embolization is an adjunctive therapy to all other treatment options.

Conflict of Interest: None.

References

1. Hamada Y, Goto K, Inoue T, Iwaki T, Matsuno H, Suzuki S, et al. Histopathological aspects of dural arteriovenous fistulas in the transverse-sigmoid sinus region in nine patients. Neurosurgery. 1997 Mar;40(3):452–8. DOI: 10.1097/00006123-199703000-00005
2. Newton TH, Cronqvist S. Involvement of dural arteries in intracranial arteriovenous malformations. Radiology. 1969 Nov;93(5):1071–8. DOI: 10.1148/93.5.1071
3. Kirsch M, Liebig T, Kühne D, Henkes H. Endovascular management of dural arteriovenous fistulas of the transverse and sigmoid sinus in 150 patients. Neuroradiology. 2009 Jul;51(7):477–83. DOI: 10.1007/s00234-009-0524-9
4. Piippo A, Laakso A, Seppä K, Rinne J, Jääskeläinen JE, Hernesniemi J, et al. Early and long-term excess mortality in 227 patients with intracranial dural arteriovenous fistulas. J Neurosurg. 2013 Jul;119(1):164–71. DOI: 10.3171/2013.3.JNS121547

5. Borden JA, Wu JK, Shucart WA. A proposed classification for spinal and cranial dural arteriovenous fistulous malformations and implications for treatment. J Neurosurg. 1995 Feb;82(2):166–79.DOI: 10.3171/jns.1995.82.2.0166
6. Cognard C, Gobin YP, Pierot L, Bailly AL, Houdart E, Casasco A, et al. Cerebral dural arteriovenous fistulas: clinical and angiographic correlation with a revised classification of venous drainage. Radiology. 1995 Mar;194(3):671–80. DOI: 10.1148/radiology.194.3.7862961
7. Satomi J, van Dijk JMC, Terbrugge KG, Willinsky RA, Wallace MC. Benign cranial dural arteriovenous fistulas: outcome of conservative management based on the natural history of the lesion. J Neurosurg. 2002 Oct;97(4):767–70. DOI: 10.3171/jns.2002.97.4.0767
8. van Dijk JMC, terBrugge KG, Willinsky RA, Wallace MC. Clinical course of cranial dural arteriovenous fistulas with long-term persistent cortical venous reflux. Stroke. 2002 May;33(5):1233–6.DOI: 10.1161/01.str.0000014772.02908.44
9. Cognard C, Januel AC, Silva NAJ, Tall P. Endovascular treatment of intracranial dural arteriovenous fistulas with cortical venous drainage: new management using Onyx. AJNR Am J Neuroradiol. 2008 Feb;29(2):235–41.DOI: 10.3174/ajnr.A0817
10. Nogueira RG, Dabus G, Rabinov JD, Eskey CJ, Ogilvy CS, Hirsch JA, et al. Preliminary experience with onyx embolization for the treatment of intracranial dural arteriovenous fistulas. AJNR Am J Neuroradiol. 2008 Jan;29(1):91–7. DOI: 10.3174/ajnr.A0768
11. Ertl L, Brückmann H, Kunz M, Crispin A, Fesl G. Endovascular therapy of low- and intermediate-grade intracranial lateral dural arteriovenous fistulas: a detailed analysis of primary success rates, complication rates, and long-term follow-up of different technical approaches. J Neurosurg. 2017 Feb;126(2):360–7. DOI: 10.3171/2016.2.JNS152081
12. Carlson AP, Alaraj A, Amin-Hanjani S, Charbel FT, Aletich V. Endovascular approach and technique for treatment of transverse-sigmoid dural arteriovenous fistula with cortical reflux: the importance of venous sinus sacrifice. J Neurointerv Surg.

2013 Nov;5(6):566–72. DOI: 10.1136/neurintsurg-2012-010497

13. Roy D, Raymond J. The role of transvenous embolization in the treatment of intracranial dural arteriovenous fistulas. Neurosurgery. 1997 Jun;40(6):1133–4. DOI: 10.1097/00006123-199706000-00004
14. Dawson RC 3rd, Joseph GJ, Owens DS, Barrow DL. Transvenous embolization as the primary therapy for arteriovenous fistulas of the lateral and sigmoid sinuses. AJNR Am J Neuroradiol. 1998 Mar;19(3):571–6. PMCID: PMC8338260
15. Algharib A, Koning GG. Reviewing Endovascular and Conventional Angioplasty: Challenges in Modern Patient-Centered Care. Vol. 40, Vascular specialist international. Korea (South); 2024. p. 16. DOI: 10.5758/vsi.240004
16. Babici D, Johansen P, Snelling B. Surgical Treatment of Dural Arteriovenous Fistula: A Case Report and Literature Review. Cureus. 2021 Oct;13(10):e18995. DOI: 10.7759/cureus.18995
17. Ishiguro T, Satow T, Hamano E, Ikeda G, Chikuie H, Hashimura N, et al. Outcome of Endovascular Therapy Aiming for Single-session Obliteration of Intracranial Dural Arteriovenous Fistulas. Neurol Med Chir (Tokyo). 2021 Oct;61(10):563–9. DOI: 10.2176/nmc.oa.2021-0059
18. Gross BA. Cerebral Dural Arteriovenous Fistulas. Stroke Vasc Interv Neurol [Internet]. 2022 Jul 1;2(4):e000532. Available from: https://doi.org/10.1161/SVIN.122.000532
19. Baharvahdat H, Ooi YC, Kim WJ, Mowla A, Coon AL, Colby GP. Updates in the management of cranial dural arteriovenous fistula. Stroke Vasc Neurol [Internet]. 2020 Mar 30;5(1). Available from: https://doi.org/10.1136/svn-2019-000269
20. Kawaguchi S, Sakaki T, Morimoto T, Hoshida T, Nakase H. Surgery for dural arteriovenous fistula in superior sagittal sinus and transverse sigmoid sinus. J Clin Neurosci Off J Neurosurg Soc Australas. 2000 Sep;7 Suppl 1:47–9. DOI: 10.1054/jocn.2000.0711
21. Ghobrial GM, Marchan E, Nair AK, Dumont AS, Tjoumakaris SI, Gonzalez LF, et al. Dural arteriovenous fistulas: a review of the literature and a presentation of a single institution's experience. World Neurosurg. 2013;80(1–2):94–

102. DOI: 10.1016/j.wneu.2012.01.053

22. Xu K, Yang X, Li C, Yu J. Current status of endovascular treatment for dural arteriovenous fistula of the transverse-sigmoid sinus: A literature review. Int J Med Sci. 2018;15(14):1600–10. DOI: 10.7150/ijms.27683

23. Wong GKC, Poon WS, Yu SCH, Zhu CXL. Transvenous embolization for dural transverse sinus fistulas with occluded sigmoid sinus. Acta Neurochir (Wien). 2007;149(9):926–9. DOI: 10.1007/s00701-007-1264-4

24. Liebig T, Henkes H, Brew S, Miloslavski E, Kirsch M, Kühne D. Reconstructive treatment of dural arteriovenous fistulas of the transverse and sigmoid sinus: transvenous angioplasty and stent deployment. Neuroradiology. 2005 Jul;47(7):543–51. DOI: 10.1007/s00234-005-1377-5

25. Lv X, Jiang C, Li Y, Yang X, Wu Z. Intraarterial and intravenous treatment of transverse/sigmoid sinus dural arteriovenous fistulas. Interv Neuroradiol J peritherapeutic Neuroradiol Surg Proced Relat Neurosci. 2009 Sep;15(3):291–300. DOI: 10.1177/159101990901500306