Original Research

Intraluminal Magnetic Resonance (MR) Findings of Dural Sinuses: Evaluation in Patients having Dural Arteriovenous Fistulas with Sinus Occlusion for Implications of Transvenous Embolization

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Abstract

Purpose

Transcatheter angiography is the gold standard for evaluating the condition and anatomy of the dural sinuses in patients with arteriovenous fistulas (AVFs); however, the patency and intraluminal condition of the dural sinuses can also be evaluated on magnetic resonance imaging (MRI). The purpose of this study was to evaluate the usefulness of MRI for the diagnosis of sinus occlusion.

Materials and Methods

Thirty-one patients (19 males, 12 females; age range, 52-81 years) were diagnosed with dural arteriovenous fistulas (DAVFs) and surrounding dural sinus occlusion on transcatheter angiography. Twenty-three patients with transverse-sigmoid DAVFs showed ipsilateral transverse and/or sigmoid sinus occlusion, and eight patients with cavernous sinus DAVFs showed ipsilateral inferior petrosal sinus occlusion. The MR images were retrospectively evaluated, focusing on the signal intensity and contrast enhancement of the occluded sinuses. The accessibility of transvenous embolization through the occluded sinuses was also assessed.

Results

The occluded sinuses showed isointensity in 24 patients and hypointensity in six on T1-weighted imaging (T1WI); furthermore, they showed isointensity in seven patients, hyperintensity in 17, and heterogeneous hypo- and hyperintensity in seven on T2-weighted imaging (T2WI). All occluded sinuses showed marked enhancement in the 14 patients in whom contrast-enhanced three-dimensional (3D)-T1WI was performed. Transvenous embolization was performed in 27 patients. An approach through the occluded sinuses was successful in 18 of these 20 patients.

Conclusion

The occluded sinuses showed various signal intensities on T1WI and T2WI, while all of the occluded sinuses showed homogeneous enhancement on contrast-enhanced T1WI.

Key words: Dural arteriovenous fistula, Transvenous embolization, MRI

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Introduction

Transvenous embolization of a dural arteriovenous fistula (DAVF) is a well-established curative, minimally invasive treatment method. For effective embolization, embolic agents must be placed at the shunting points after navigation of a microcatheter within the affected dural sinus. However, navigation of the microcatheter to the affected dural sinus is difficult in some cases because of occlusion of the drainage routes[1]-[3]. Investigators have recently reported successful transvenous embolization in such cases after the navigation of microcatheters into the recipient venous pouches through the occluded sinuses[4]-[6]. Although there is a risk of sinus perforation, this technique is effective and minimally invasive. Successful navigation of a catheter through the occluded sinus can also depend on the degree of mural thickening and/or the organization of the thrombus in the sinus. Previous reports have shown that time-dependent changes in dural sinus thrombosis can be detected on magnetic resonance imaging (MRI)[7]. In the present study, the MR signals of occluded dural sinuses in patients with DAVFs were retrospectively evaluated. The relationships between the MR signals of the occluded sinus and the success rates of transvenous embolization were also assessed.

Materials and Methods

Patients

This study included 31 patients (19 men, 12 women; age range, 52-81 years; mean age, 67 years) who were diagnosed with DAVFs and occlusion of the surrounding dural sinuses on transcatheter angiography between January 2004 and March 2014. Twenty-three patients had transverse-sigmoid sinus DAVFs and eight had cavernous sinus DAVFs. The DAVFs were classified with the Borden grading system as type II in 20 patients and type III in 11 patients. Among the 20 patients with transverse-sigmoid sinus DAVFs, the occluded dural sinuses were the ipsilateral sigmoid sinus in 14 patients and the ipsilateral distal part of the transverse sinus and sigmoid sinus, forming an "isolated sinus," in 13 patients. Among the eight patients with cavernous sinus DAVFs, the occluded dural sinuses were the ipsilateral inferior petrosal sinus in five patients, the contralateral inferior petrosal sinus in one patient, and bilateral inferior and superior petrosal sinuses in two patients. Patient characteristics are shown in **Table 1**.

Table 1. DAVF locations, DAVF types, and occluded sinuses

Cases	Age	Sex	Location	Borden's classificati	Occluded sinus
1	79	F	lt CS	III	bil IPS, SPS
2	81	F	lt CS	II	lt IPS
3	64	F	lt CS	II	lt IPS
4	58	F	rt CS	II	lt IPS
5	78	F	rt CS	III	bil IPS, SPS
6	57	F	lt CS	II	lt IPS
7	79	F	lt CS	II	lt IPS
8	62	F	lt CS	II	lt IPS
		F			
9	76	M	rt TSS	II	rt SS
10	60	M	lt TSS	II	lt SS
11	71	M	lt TSS	II	lt SS
12	75	M	lt TSS	II	lt SS
13	67	M	lt TSS	III	lt SS, TS
14	57	M	lt TSS	III	lt SS, TS
15	71	M	rt TSS	III	rt SS, TS
16	76	M	lt TSS	III	lt SS, TS
17	75	M	lt TSS	II	lt SS
18	68	M	lt TSS	II	lt SS
19	52	F	lt TSS	II	lt SS
20	66	F	lt TSS	II	lt SS
21	71	M	rt TSS	II	rt SS
22	70	F	rt TSS	II	rt SS
23	76	M	rt TSS	II	rt SS
24	53	M	lt TSS	III	lt SS, TS
25	52	M	lt TSS	III	lt SS, TS
26	65	M	lt TSS	III	lt SS, TS
27	78	M	lt TSS	II	lt SS
28	79	M	lt TSS	III	lt SS, TS
29	48	M	bil TSS	III	bil TS, SS
30	68	F	lt TSS	III	lt SS
31	46	F	lt TSS	II	lt SS

CS, cavernous sinus; IPS, inferior petrosal sinus; SPS, superior petrosal sinus; TSS, transverse-sigmoid sinus; SS, sigmoid sinus; TS, transverse sinus

MRI techniques

All patients were examined before treatment using a 1.5T MRI system within about one week of diagnostic angiography. All of the examinations included at least spin-echo T1-weighted imaging (T1WI) (repetition time [TR]/echo time [TE] = 450/15 ms), spin-echo T2-weighted imaging (T2WI) (3500/90 ms), and fluid-attenuated inversion recovery (FLAIR) (TR/TE/inversion time [TI] = 6500/105/2200 ms). Three-dimensional contrast-enhanced T1WI was performed in 12 patients with the following parameters: TR/TE = 14.0/5.5 ms, flip angle = 25° , matrix size = matrix size, 224 × 256, section thickness = 1 mm, fat suppression, and intravenous injection of 0.1 mmol/kg of gadopentetate dimeglumine.

Embolization techniques

Twenty-seven patients were treated by transvenous embolization, while the remaining patients were treated by stereotactic radiosurgery (two patients), open surgery (one patient), or conservative therapy (one patient). All transvenous embolizations were performed under local anesthesia. A 5F guiding sheath/coaxial catheter guiding system was advanced into the ipsilateral and/or contralateral jugular vein, and a microcatheter (Excelsior 1018 or Excelsior SL-10; Striker Japan, Tokyo, Japan) was then advanced into the affected transverse-sigmoid sinus or cavernous sinus using a microguidewire (Radifocus Guide Wire GT 0.014"; Terumo, Tokyo, Japan, or CHIKAI 14; Asahi Intecc, Nagoya, Aichi, Japan) through the sigmoid sinus or inferior petrosal sinus with or without sinus occlusion. Detachable microcoils were placed via the advanced microcatheters.

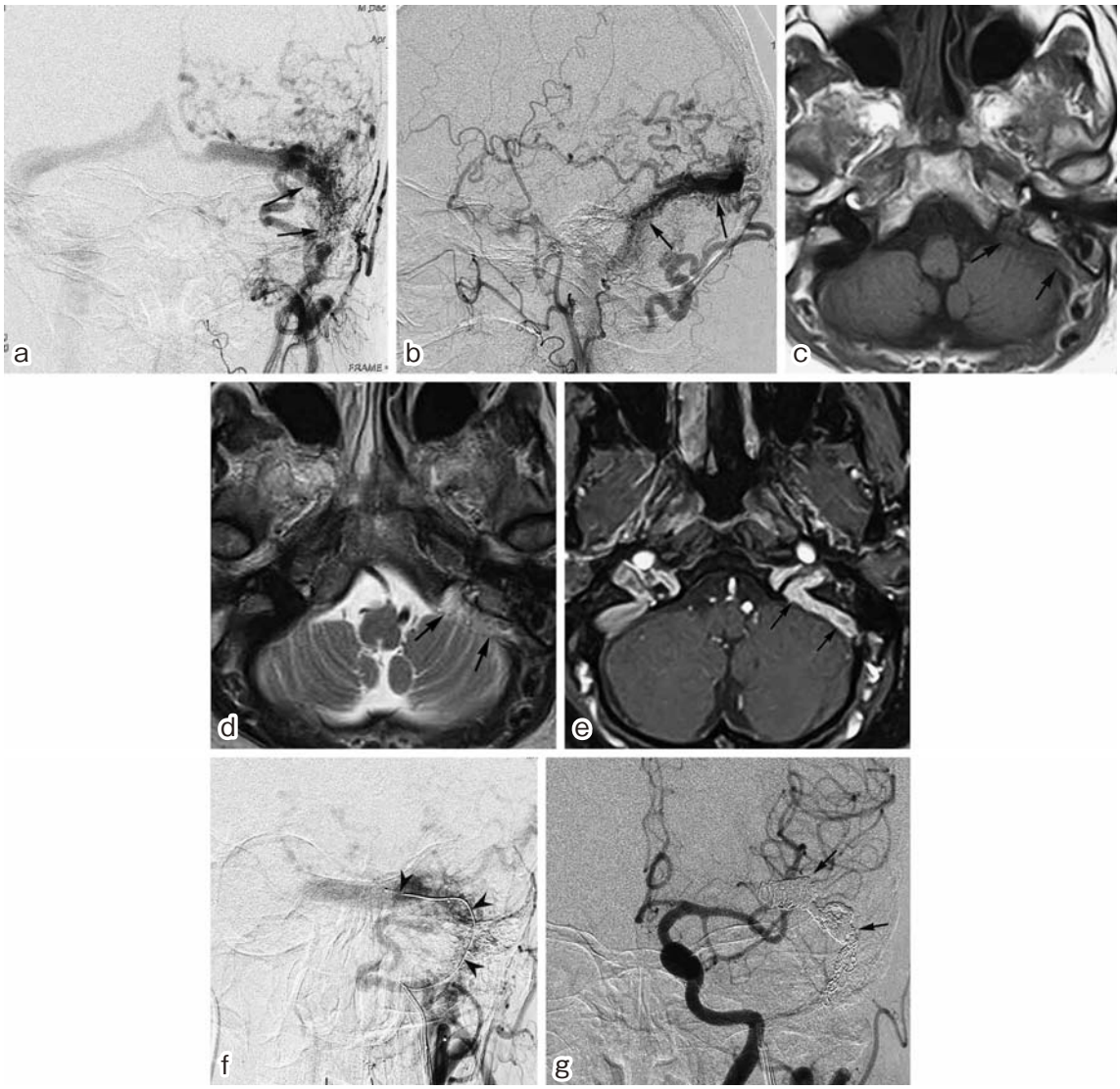

Figure 1. A 71-year-old man with a left transverse-sigmoid sinus dural arteriovenous fistula (Case 11). (a, b) Left external carotid arteriogram (a, frontal view; b, lateral view) demonstrates a left transverse-sigmoid sinus dural arteriovenous fistula (arrows) with occlusion of the left sigmoid sinus. (c, d, e) Occluded sigmoid sinus shows isointensity on T1WI (c, arrows), hyperintensity with spotty low intensity on T2WI (d, arrows), and homogeneous enhancement on the source image of postcontrast T1WI (e, arrows). (f) The microcatheter was successfully navigated into the transverse-sigmoid sinus through the occluded sinus (arrowheads). (g) Left common carotid arteriogram after coil packing shows complete disappearance of the transverse-sigmoid sinus dural arteriovenous fistula. Arrows indicate placed coil mass.

Evaluation

The detectability and signal intensity of the occluded dural sinuses on T1WI and T2WI were retrospectively evaluated and compared with the signal intensity of normal cerebral gray matter. The enhancement effect within the occluded sinus was also assessed in patients who underwent contrast-enhanced T1WI. Non-contrast time-of-flight MR angiography was excluded from the analysis set due to low contrast resolution for occluded sinus lumina. The enhancement effects within the occluded sinus on axial reconstruction images from three-dimensional digital subtraction angiography (DSA) (if applicable) and their relationship with MR signals were evaluated. The relationship between the accessibility of the occluded sinuses through transvenous embolization and the MR signals was also evaluated.

Results

In all patients, the occluded dural sinuses could be depicted as occluded by means of mixed low-high, iso-high, or high signal intensity on T2WI, despite the normal sinuses showing flow voids. Meanwhile, the normal sinuses in 20 patients displayed iso- or hyperintensity on T1WI, which was deemed due to flow-related enhancement. The occluded sinuses on T2WI corresponded to the occlusion sites on

Table 2. Results of MR signals and treatments

Cases	MRI signals			Treatments	Access through occluded sinus
	T1WI	T2WI	3D CE-T1WI		
1	iso	high	Enhanced	TVE	Successful
2	low	iso	Enhanced	SRS	NT
3	iso	iso	Enhanced	TVE	Failed
4	iso	high	Enhanced	TVE	NT
5	iso	iso	NA	Observation	NT
6	low	high	NA	TVE	Successful
7	iso	high	NA	TVE	NT
8	iso	high	NA	TVE	Successful
9	iso	high	Enhanced	TVE	NT
10	iso	low	Enhanced	TVE	NT
11	iso	low-high	Enhanced	TVE	Successful
12	iso	iso	Enhanced	Operation	NT
13	iso	high	Enhanced	TVE	Successful
14	low	low-high	Enhanced	TVE	Failed
15	low	iso	Enhanced	TVE	Successful
16	iso	high	Enhanced	SRS	NT
17	low	iso	NA	TVE	NT
18	iso	iso	NA	TVE	Successful
19	iso	high	NA	TVE	Successful
20	low	high	NA	TVE	NT
21	iso	high	NA	TVE	Successful
22	iso	high	NA	TVE	Successful
23	iso	high	NA	TVE	Successful
24	iso	high	NA	TVE	Successful
25	iso	high	NA	TVE	Successful
26	iso	high	NA	TVE	NT
27	iso	high	Enhanced	TVE	successful
28	iso	low-high	NA	TVE	successful
29	iso	low-high	NA	TVE	successful
30	iso-high	low-high	NA	TVE	successful
31	iso	low-high	Enhanced	TVE	successful

3D CE-T1WI, three-dimensional contrast-enhanced T1WI; TVE, transvernous embolization; SRS, stereotactic radiosurgery; NA, not assessed; NT, not tried

transcatheter angiography.

The occluded dural sinuses showed isointensity in 24 patients (75%) and hypointensity in six patients (23%) on T1 WI. On T2WI, the occluded sinuses showed isointensity in seven patients (27%), hyperintensity in 17 patients (62%), and mixed hyper- and hypointensity in seven patients (11%). Marked enhancement was observed in the occluded dural sinuses in all 14 patients examined by contrast-enhanced T1 WI (**Table 2**).

Axial reconstruction images from three-dimensional DSA were applicable in 12 patients. Among them, six patients showed partial enhancement of the occluded sinus, which corresponded to an area of low or isointensity on T2WI.

Transvenous embolization was performed in 27 patients. We tried to advance a microcatheter into the shunting venous pouch through the occluded dural sinus in 20 of these 27 patients. The approach through the occluded sinus was successful in 18 of these cases. MR signals of the occluded dural sinuses in the successful cases showed isointensity in 15 patients and low intensity in three patients on T1WI; they also showed isointensity in two patients, high intensity in 11 patients, and mixed low and high intensity in five patients on T2WI.

Discussion

MRI is a noninvasive examination for the diagnosis of dural sinus patency. No previous reports have discussed MR signals of occluded sinuses in patients with DAVFs, whereas MR signals in patients with dural sinus thrombosis have been described[7]-[11]. The MR signals in patients with spontaneous dural sinus thrombosis depend on the interval between the onset and examination; the signals shift with changes in the amount of water and the susceptibility effect of hemoglobin[7]. Dural sinus thrombosis in the acute phase tends to show isointensity on T1WI and iso- or hyperintensity on T2WI,[7] while the signal intensity of thrombi in the chronic stage can vary but is typically isointense on T1WI and iso- or hyperintense on T2WI[7]-[11]. In our series, most of the occluded sinuses with DAVFs showed isointensity on T1WI and hyperintensity on T2WI, whereby the signals corresponded with the findings of chronic dural sinus thrombosis. It is possible that the slow and progressive process of sinus stenosis or occlusion in patients with DAVFs can form an organized thrombus such as a chronic dural sinus thrombosis.

In a previous MRI study, spontaneous dural sinus thrombosis showed homogeneous enhancement on T1WI after

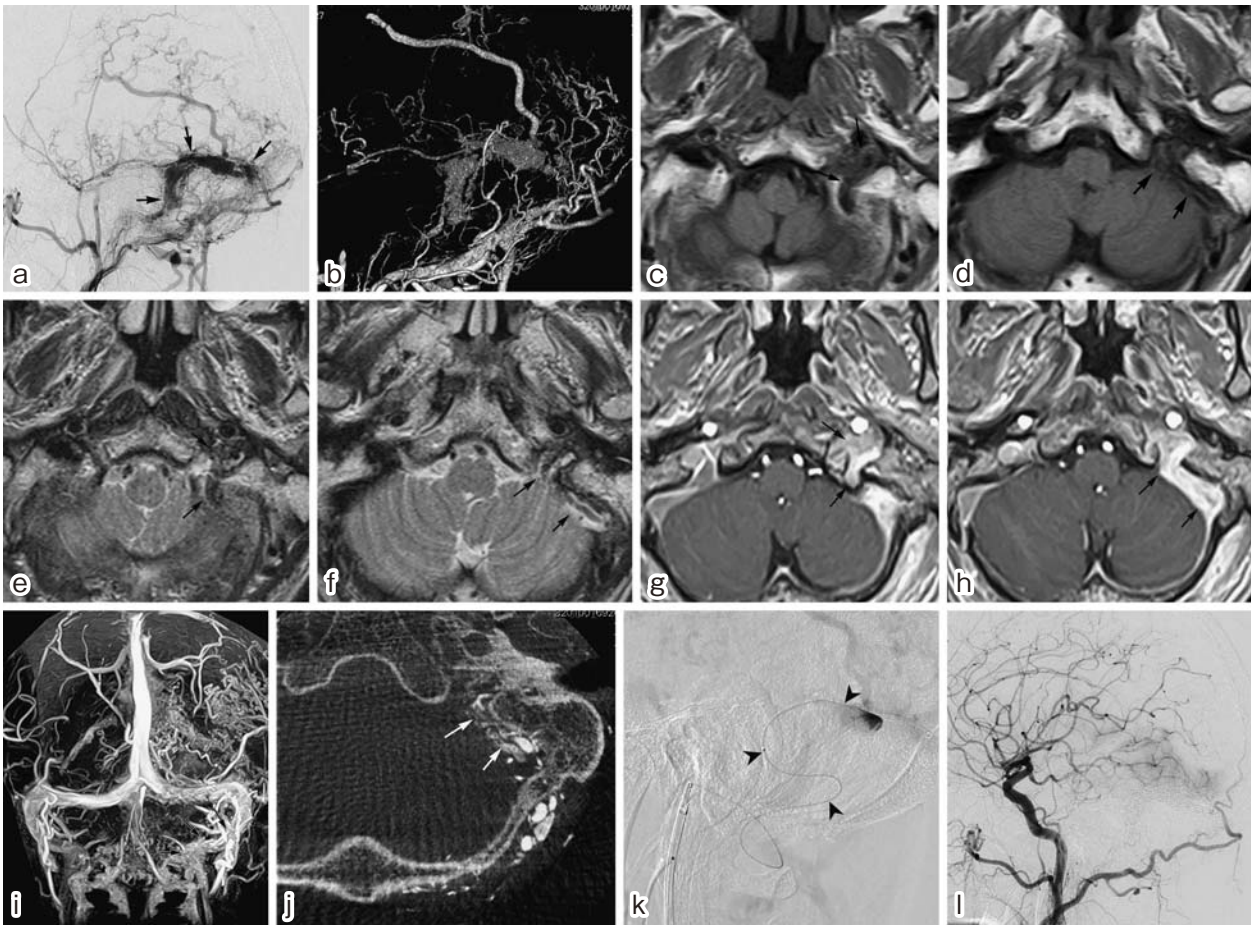

Figure 2. A 54-year-old man with a left transverse-sigmoid sinus dural arteriovenous fistula (Case 14). (a, b) Left external carotid arteriogram (a, lateral view; b, volume rendering) demonstrates left transverse-sigmoid sinus dural arteriovenous fistula (arrows) with occlusion of the left sigmoid and transverse sinuses. (c-i) Occluded sigmoid sinus shows hypointensity on T1WI (c, d, arrows), mixed hypo- and hyperintensity on T2WI (e, f, arrows), and homogeneous enhancement on the source image of postcontrast T1WI (g, h: source image, i: coronal projection of MIP, arrows). (j) Axial reconstruction image of rotational angiography shows vascular channels within the occluded sinus, which corresponds to hypointensity (flow voids) on T2WI. (k) Although a microguidewire could be navigated into the shunting transverse-sigmoid sinus through the occluded sinus, a microcatheter could not be advanced over the microguidewire. Finally, the microcatheter was advanced into the isolated sinus via the mastoid emissary vein (arrowheads). (l) Left common carotid arteriogram (lateral view) demonstrates complete disappearance of fistula.

gadolinium injection in the chronic stage; the enhancement was due to intrathrombotic organization and neovascular formation[12]. In our series, occluded dural sinuses with DAVFs showed homogeneous and marked enhancement in all cases, as in the aforementioned report. Uranishi et al.[13] previously reported that, following surgery, an occluded dural sinus showed inflammatory and proliferative changes, including inflammatory cell infiltration, fibrosis, proliferation of arterioles in the thickened sinus wall, and marked expression of vascular endothelial growth factor in the endothelium and basic fibroblast growth factor in the subendothelial tissue. Chronic venous endothelial injury and sinus wall thickening due to secondary fibrotic and vascular proliferation has been believed to affect sinus occlusion[14]. Additionally, hypointense areas on T2WI indicate the existence of not only fibrotic tissue but also flow void from normal dural flow and shunt flow, as shown in **Figure 2**. Therefore, enhancement of the occluded dural sinus is thought to be due to complex sinus wall thickening, organized thrombosis, and vascular channels.

Transvenous embolization through the occluded sinuses was successful in all but two patients in the present study. It is speculated that the more thrombotic organization and sinus wall thickening is present in the occluded sinus, the more interference is encountered while advancing the catheter. Our study showed no statistical significance between the success rate of transvenous embolization and MR signals. The success rate is probably related not only to the conditions in the occluded sinus but also to various factors including the extension of the occluded area, the tortuosity of

the sinus, and differences in techniques and devices. Matsuzaki et al.[15] reported that pseudo-occlusion of the sinuses was proven by retrograde transcatheter venography in patients with DAVFs, which showed sinus occlusion on cerebral arteriography. Moreover, a previous histopathological study involving nine patients with DAVFs revealed only three cases of sinus thrombosis among six patients with angiographic sinus occlusions[16]. These previous reports and the enhancement effect in our patients support the existence of loose vascular channels within the angiographically occluded sinuses. This speculation also provides an explanation for the large number of cases in which a transvenous approach through the occluded sinuses was possible.

The enhancement effect of the occluded sinus can provide important information about the diameter and course of the sinus for transvenous embolization because these characteristics are unidentifiable on angiography. Furthermore, we must be aware of the patency of the dural sinus in patients with DAVFs. The patency of the dural sinus should be evaluated by both postcontrast images and other sequences such as MR T1WI and T2WI.

There were several limitations in the current study. First, our study population was fairly small due to the relatively low incidence of DAVFs with sinus occlusion, and larger-scale studies are needed to confirm our hypothesis. Second, the retrospective nature of our data analysis cannot preclude the bias associated with patient selection and imaging evaluation.

Conclusions

MR images can be useful for evaluating occluded sinuses in patients with DAVFs. The signal intensity corresponds to the residual sinus lumen as well as the intrasinusal thrombosis. The enhancement effect observed on postcontrast T1WI in all patients in this study may have been due to thrombotic organization, vascular channels receiving the drainage flow from both the AVF and the normal dural veins, and pseudo-occlusion. This enhancement demonstrates the existence and course of the occluded sinus; however, care must be taken to avoid misdiagnosis of the sinus as patent.

Conflict of interest: The authors has no conflict of interest to disclose with respect to this article.

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