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Two-Step Effective Onyx Embolization from the Occipital Artery for the Treatment of Intracranial Dural Arteriovenous Fistula: A Technical Note

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ABSTRACT

AIM: To report our experience and the technique of two-step effective Onyx embolization from occipital artery (OA) for the obliteration of dural arteriovenous fistulas (DAVFs) with OA feeders.

MATERIAL and METHODS: The medical records of patients with intracranial DAVFs treated with trans-arterial embolization (TAE) using Onyx from the OA were retrospectively reviewed.

RESULTS: Seven patients were included. The methods of Onyx injection from the OA were categorized as simple Onyx injection into the shunt, and two-step embolization. Two-step embolization involved the Onyx or coil embolization of the OA distal to the branching site of the feeders in the first step, and Onyx was injected toward the target shunt in the second step. Simple Onyx injection was performed in two cases; in both cases, the residual shunt remained. By contrast, the two-step embolization technique was performed in five cases, and in all those cases, sufficient embolization of the DAVFs was achieved.

CONCLUSION: Prior embolization using Onyx or coil of the distal OA helped prevent Onyx from unexpected embolization through the subcutaneous branches that were not associated with the shunt, thereby leading to effective embolization. This new two-step embolization technique from the OA may improve the obliteration rate of DAVFs with OA feeders using TAE with Onyx.

KEYWORDS: Intracranial dural arteriovenous fistula, Onyx embolization, Endovascular surgery, Technical note

ABBREVIATIONS: TSS: Transverse-sigmoid sinus, **TAE:** Trans-arterial embolization, **DAVF:** Dural arteriovenous fistulas, **OA:** Occipital artery

INTRODUCTION

Intracranial dural arteriovenous fistulas (DAVFs) are arteriovenous shunts located in the dural wall of a venous structure that account for 10%-15% of all intracranial arteriovenous malformations (10). Most DAVFs involve the transverse-sigmoid sinuses (TSS) (8,10), and treatment options for DAVFs of the TSS include observation, microsurgery, stereotactic radiosurgery, endovascular surgery, and a combination of these modalities (1). Among these treatment options, trans-arterial embolization (TAE) has recently been recognized as a curative and safe therapeutic option for DAVF of the

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TSS, especially after the introduction of Onyx (ev3, Irvine, CA) (1,7,8,11,13,14,16). Onyx is a non-adhesive agent that gradually polymerizes after coming in contact with blood and enables controllable penetration, high occlusion rates, and low procedure-related complications (1); However, achieving a complete cure for DAVF with feeding arteries from the occipital artery (OA) remains challenging. Because the OA feeders were often too tortuous and too tiny to catheterize to embolization and because the pressure gradient of the small transosseous part may limit satisfactory Onyx penetration, the presence of the OA feeder is considered to be a significant predictor of non-obliteration of DAVF by embolization with Onyx (3,11).

In this study, we describe our initial experience and technical aspects of the two-step effective Onyx embolization from the OA for achieving embolization of the DAVF of the TSS with the OA feeders.

MATERIAL and METHODS

Study Design and Ethics Approval

This retrospective, single-center study was conducted in accordance with the Strengthening the Reporting of Observational Studies in Epidemiology guidelines between September 2017 and August 2022. This study was approved by the Institutional Ethics Board (Affiliated Tokyo Medical and Dental University; Date: 2020-11-02; No: M2020-102). The requirement for informed consent was waived owing to the retrospective nature of the present study.

Data Collection

All data were retrospectively reviewed from medical records. The inclusion criteria were as follows: 1) patients with intracranial DAVFs, 2) fistulas located at the TSS or multi-sinus walls including the TSS, and 3) DAVF treated with TAE using Onyx from the OA. The collected preoperative data included age, sex, clinical presentation, Cognard type, DAVF location, feeding arteries, and device use. Operative data included treated fistula, accessed arteries, use of microcatheters and/or balloons, embolic agents, and technical complications. Postoperative evaluation included the occlusion rate of the targeted feeding arteries reassessed by conventional angiography immediately after TAE.

Endovascular Procedure

All endovascular procedures were performed under general anesthesia. A 7- or 8-Fr catheter was positioned in the external carotid artery, and a Marathon (Medtronic, Minneapolis, MN, USA) or a double-lumen balloon catheter (Scepter XC, MicroVention, Tustin, California, USA) was advanced into the OA. Onyx embolization was performed through the catheter. When Scepter XC was used for Onyx injection, the balloon was temporarily inflated to increase proximal resistance to aid Onyx injection.

RESULTS

The clinical presentation and angiographic outcomes are summarized in Table I. In all cases, DAVFs were fed by branches from the OA. The methods of Onyx injection were categorized as follows; 1) “Simple Onyx injection” was Onyx injection toward the target fistulous points from the OA where a Marathon or a Scepter XC was advanced (Figure 1A). 2) “Two-step embolization” was Onyx embolization of the OA distal to the branching site of the feeders in the first step. In the second step, a Marathon or a Scepter XC was positioned as close to the feeding arteries as possible, and Onyx was injected into the target fistulous points for the obliteration of the DAVF (Figure 1B). 3) “Modified two-step embolization” was embolization of the OA distal to the branching site of the feeders using detachable coils instead of Onyx as the first step. In the second step, Onyx was injected into target fistulous points (Figure 1C). The purpose of the first embolization of the distal OA in “two-step embolization” and “modified two-step embolization” was the prevention of Onyx from proceeding into only distal subcutaneous branches from the OA. “Simple Onyx embolization” was performed for Cases 1 and 2, “two-step embolization” was performed for

Table I: Clinical Presentation and Angiographic Outcomes of This Case Series

Case	Sex	Age	Location	Cognard classification	Method of Onyx injection	Microcatheter using Onyx embolization	Occlusion rate
1	Female	75	TSS*, SSS†, Torcula	Type IIa+b	Simple injection	Marathon	Residual filling
2	Male	58	TSS, SSS, Torcula	Type IIa+b	Simple injection	Scepter XC, Marathon	Residual filling
3	Male	80	TSS	Type IIa+b	Two-step embolization	Scepter XC	Almost no filling
4	Female	79	TSS	Type IIa+b	Two-step embolization	Scepter XC	Almost no filling
5	Male	45	TSS	Type I	Modified two-step embolization	Scepter XC	Almost no filling
6	Male	80	TSS	Type IIa+b	Modified two-step embolization	Marathon	Almost no filling
7	Male	50	TSS	Type IIa+b	Modified two-step embolization	Scepter XC, Marathon	Almost no filling

****TSS:*** *transverse-sigmoid sinus* †***SSS:*** *superior sagittal sinus*

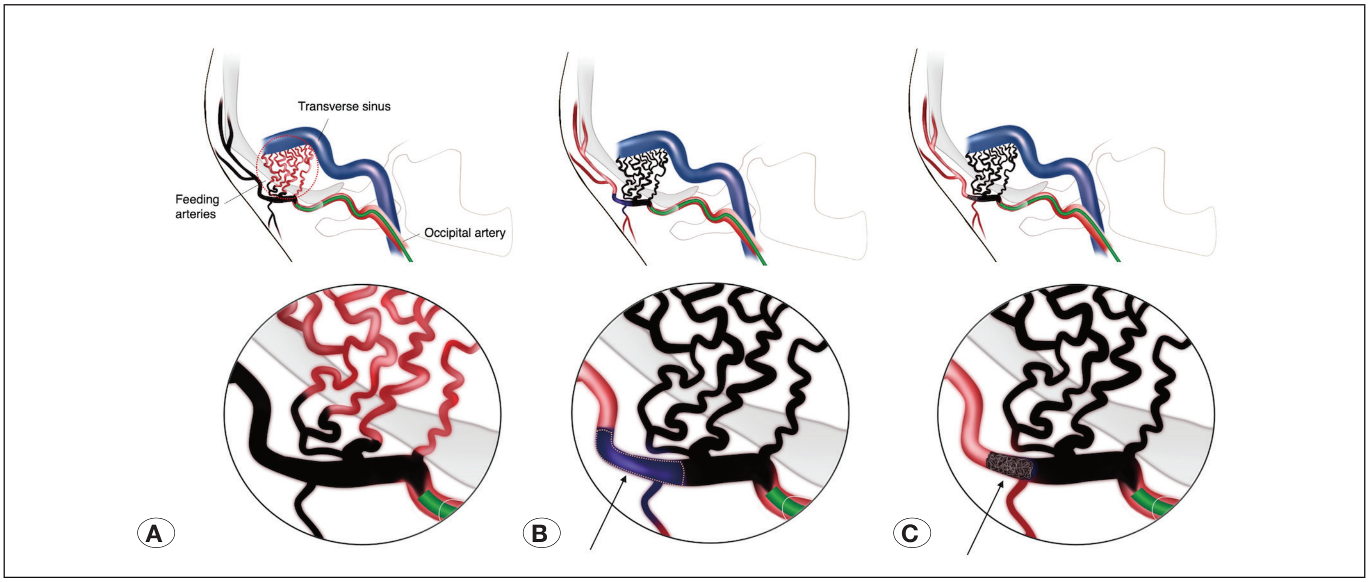

Figure 1: Schematic of the Onyx embolization technique. **A)** Demonstration of the "Simple Onyx embolization": Onyx (black) injection was administered toward the target fistulous points from the occipital artery (OA) where the microcatheter was advanced. In this method, the Onyx usually proceeds only to the distal part of the OA, and it is difficult to achieve effective embolization. **B)** Demonstration of the "two-step embolization": Onyx embolization of the OA distal to the branching site of the feeders was performed in the first step (black arrow). In the second step, the microcatheter was positioned close to the feeding arteries, and Onyx (black) was injected into the target fistulous points to obliterate the dural arteriovenous fistula (DAVF). **C)** Demonstration of the "modified two-step embolization": Embolization of the OA distal to the branching site of the feeders using detachable coils (black arrow) instead of Onyx in the first step. In the second step, Onyx (black) is injected into the target fistulous points through a microcatheter.

Cases 3 and 4, and "modified two-step embolization" was performed for Cases 5, 6 and 7. Two cases of "Simple Onyx embolization" had residual filling from the OA feeders because Onyx did not completely occlude the ideal part of the OA feeders and proceeded mainly to the distal part of the OA. All cases of "two-step embolization" and "modified two-step embolization" showed complete filling from the targeted OA feeders immediately after the procedure. Catheter removal was performed uneventfully in all cases. No procedure-related complications such as cerebral infarction of the posterior circulation, sinus occlusion, or occipital skin complications occurred.

Representative Cases

1) Simple Onyx embolization (Case 2)

A 58-year-ole male presented with papilledema and headache. Cerebral angiography revealed the DVF of the TSS, the torcula, and the superior sagittal sinus. This DAVF was fed by branches from the right OA (Figure 2A, B), left OA, and other branches from the external carotid artery. TAE from the right OA was attempted, and multiple Onyx injections were administered from the right OA close to the shunt point. However, Onyx mainly proceeded to the distal cutaneous branches of the OA (Figure 2C, D), and residual shunts remained (Figure 2E, F).

2) Two-step embolization (Case 4)

A 79-year-old female presented with tinnitus. Cerebral angiography revealed that the DAVF of the TSS was mainly fed by the right OA (Figure 3A). First, the Scepter XC was advanced into the OA and positioned at the distal part of the OA, and Onyx injection through Scepter XC was performed (Figure 3B). After the first embolization, the Scepter XC was removed, and another Scepter XC was advanced close to the feeding arteries from the OA; subsequently, Onyx embolization was performed again (Figure 3C-E). Effective embolization of the targeted feeding arteries and fistulous points was achieved, and the shunt flow disappeared (Figure 3 F, G).

3) Modified two-step embolization (Case 5**)**

A 45-year-old male presented with severe headache. Cerebral angiography showed the DAVF of the TSS fed by the left middle meningeal artery (MMA) and the OA (Figure 4A). First, the MMA was selectively catheterized, and Onyx was injected; however, the shunt flow from the feeders from the OA remained. Second, the Marathon catheter was advanced to target arteries from the OA, and Onyx injection was performed. Although some feeding arteries vanished, the shunt flow from the OA remained (Figure 4A). Finally, after coil embolization of the OA distal to the origin of the targeted feeders (Figure 4B, C), Onyx embolization through the Scepter XC placed in the OA close to the shunt was performed again (Figure 4D-F). Effective embolization was achieved, and there was no filling from the targeted OA feeders (Figure 4G, H).

DISCUSSION

In our series, five of the seven DAVFs with the OA feeders were successfully treated by transarterial Onyx injection from the OA owing to the two-step embolization technique. Prior

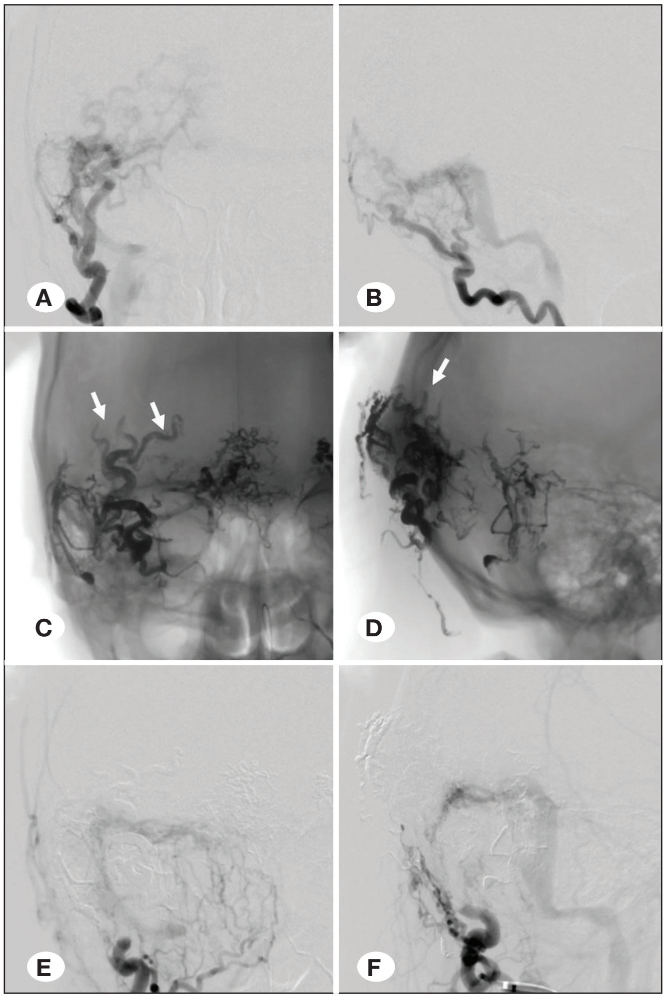

Figure 2: Angiographic presentation of Case 2. **A, B)** Occipital artery (OA) angiogram revealed a transverse dural arteriovenous fistula with the OA feeders. **C, D)** The Onyx proceeded mainly to the distal subcutaneous branches (white arrow). **E, F)** The residual shunt from the OA feeders remained after embolization.

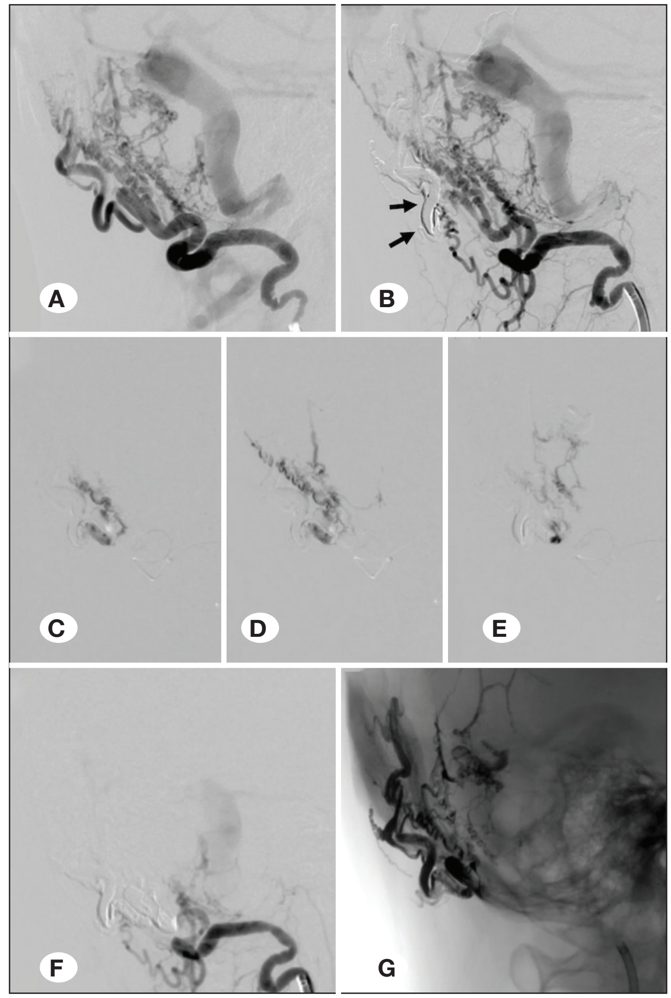

Figure 3: Angiographic presentation of Case 4. **A)** Occipital artery (OA) angiogram revealed a transverse dural arteriovenous fistula with the OA feeders. **B)** Prior embolization with Onyx (black arrow) distal to the branching site of the feeders. **C-E)** The Onyx injection was administered again for embolization of the shunt. **F, G)** After Onyx embolization from the OA, almost all the shunt flow disappeared.

embolization of the distal part of the OA with Onyx or coils helped prevent Onyx from unexpected embolization through the subcutaneous branches that were not associated with the fistulous point and led to effective embolization.

During the past few decades, transarterial treatment of DAVFs with Onyx has gained acceptance for high occlusion rates and long-term stability of fistula obliteration. Prior studies suggest an initial cure rate of 62.5%-100%, and once obliteration was initially achieved, stability of obliteration over mid- and long-term follow-up was relatively high (2,15). There are several approaches for transarterial treatment advocated by Onyx. Among them, balloon-assisted TAE using double-lumen balloon microcatheters combined with transvenous balloon protection of the venous sinus has been reported to be a useful adjunctive technique for the treatment of DAVFs and has shown encouraging results. The main advantages of double-lumen balloon-assisted TAE are immediate control of the antegrade flow of Onyx without the proximal plug formation, more effective distal penetration into the fistula, and the prevention of reflux into dangerous anastomosis (8-10). Transvenous balloon protection of the affected sinuses is mainly associated with the reduction of unexpected occlusion of the lumen of a functional sinus, the preservation of cortical venous patency, and increased penetration of Onyx by retrograde reflux into other dural feeders or the fistula network (4).

TAE with Onyx is an effective treatment option; however, DAVFs with the OA feeders remain difficult to cure (11). Usually, the DAVFs of the TSS are fed by branches from the MMA and OA (12). MMA has been described as an ideal route for successful embolization of DAVFs of the TSS owing to superior flow control and Onyx progression. Therefore, most TAEs are performed through MMA (4,6). However, in some cases, navigation of the microcatheters through the MMA

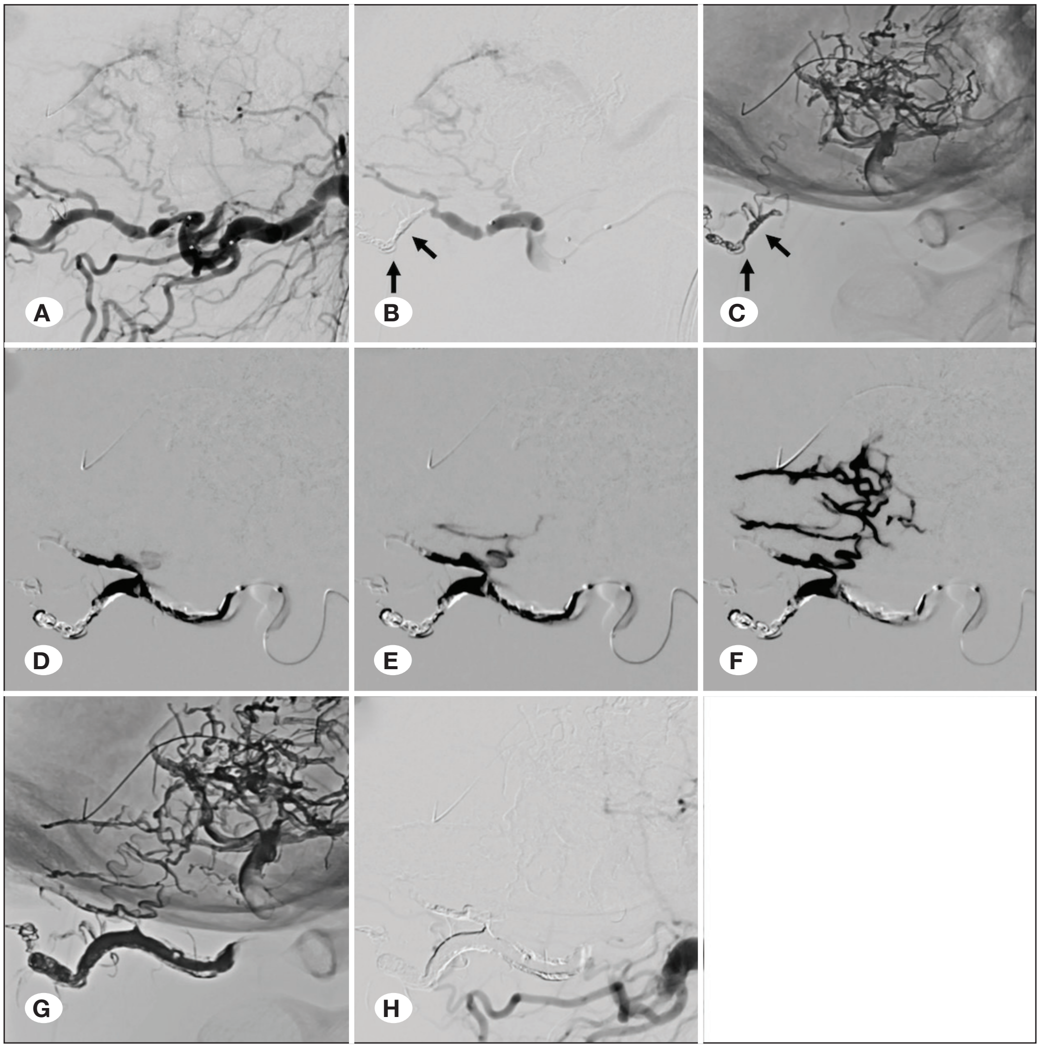

Figure 4: Angiographic presentation of Case 5. **A)** Occipital artery (OA) angiogram revealed a residual transverse dural arteriovenous fistula with the OA feeders after Onyx injection from the middle meningeal artery. **B, C)** Prior embolization with a coil (black arrow) distal to the branching site of the feeders. **D, E, F)** Onyx injection was administered again for embolization of the shunt. **G, H)** After Onyx embolization from the OA, almost all the shunt flow disappeared.

may be difficult because of the small caliber of the MMA and insufficient embolization. On the contrary, even if the main trunk of OA is often larger in caliber than the MMA, OA is known to be less suitable for Onyx injection because of the numerous tiny and tortuous feeders that are difficult to catheterize. In addition, the pressure gradient of the transosseous route of the OA feeders limits the Onyx penetration toward the fistulous point (3), and the Onyx from the OA often proceeds only to the distal part of the OA that is not associated with the shunt. For these reasons, Li et al. described that the presence of an OA feeder was a significant predictor of non-obliteration of DAVFs in their multi-institutional study (11).

By contrast, the two-step embolization, which was the prior embolization of the OA distal to the branching site of the feeders and following Onyx injection toward the fistulous point, achieved effective obliteration of the shunt of the DAVF with the OA feeders in this report. The main advantage of this two-step embolization technique is the initial formation of the coil mass or Onyx plug that can block Onyx proceeding only to the distal subcutaneous branches, leading to an increase in the resistance of the extracranial segment of the OA and helping to achieve satisfactory Onyx penetration to the fistulous point regardless of the gradient pressure of the transosseous route. In the absence of coil or onyx blockage of the distal portion of the OA, the shunt points through the trans-osseous are under high pressure; hence, the liquid materials advance to the subcutaneous blood vessels, which are under low pressure.

There are several essential points to consider when performing this two-step embolization without technical complications. First, it is important to note that excessive injection of Onyx into the distal part of the OA might lead to the necrosis of the normal occipital skin (5). Therefore, careful observation during Onyx injection of the distal OA and optimal extent of embolization are needed to prevent the necrosis of the occipital skin. Second, when Onyx is injected toward the target fistulous points next to the prior embolization of the distal OA, use of a double-lumen balloon and sinus protecting balloon should be considered for the prevention of Onyx migration to the dangerous anastomosis of the OA, such as occipito-vertebral anastomoses, or to functional sinuses through the affected sinuses.

Although DAVFs with the OA feeders are known to be difficult to efficiently obliterate by TAE, the two-step embolization achieved sufficient obliteration of the shunt in our first experience. The technique of the distal occlusion in the OA with Onyx or coil blockage and proximal occlusion with a balloon catheter enables a reliable Onyx pressure injection, and the two-step embolization technique may make obliteration of the shunt feasible.

The present study has one major limitation. This study has been limited to small-sized experiences in a single center. Further experience and multicenter studies are needed.

CONCLUSION

Two-step embolization with prior embolization of the distal part of the OA using Onyx or coils helped effectively embolize the DAVFs of the TSS fed by the OA. This technique may improve the obliteration rate of DAVFs fed by the numerous tortuous and small transosseous feeding arteries from the OA by transarterial Onyx embolization.

AUTHORSHIP CONTRIBUTION

Study conception and design: SF, KS

Data collection: SF

Analysis and interpretation of results: SF, KS

Draft manuscript preparation: SF, KS

Critical revision of the article: SH, KF, HY, MI, JA, HS, KM, SN

Other (study supervision, fundings, materials, etc...): SF

All authors (SF, SH, KF, HY, MI, JA, HS, KM, SN, KS) reviewed the results and approved the final version of the manuscript.

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