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TECHNICAL NOTE - VASCULAR

Double-lumen balloon for Onyx® embolization via extracranial arteries in transverse sigmoid dural arteriovenous fistulas: initial experience

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Abstract Transverse-sigmoid dural arteriovenous fistulas (TS DAVFs) can be challenging to treat by endovascular means. Indeed, a total cure of the fistula can only be achieved when complete occlusion of the fistulous point(s) is obtained by penetration of the embolic agent. However, in some cases, especially for transosseous branches from extracranial arteries like the occipital artery (OcA) or the superficial temporal artery (STA), such penetration is usually poor, leading to major proximal reflux and incomplete fistula obliteration. We present three cases of embolization in two patients with TS DAVF through the OcA and/or the STA with Onyx® using a double-lumen balloon (Microvention, Tustin, CA, USA). This technique allows the penetration of the embolic agent in the transosseous branches by forming a counter-pressure with the inflated balloon. This technique may be useful to achieve complete occlusion of TS DAVFs by endovascular means.

Keywords Transverse sinus · Dural arteriovenous fistula · Embolization · Onyx® · Double lumen balloon · Occipital artery · Superficial temporal artery

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Abbreviations

APA	Ascending pharyngeal artery
DAVF	Dural arteriovenous fistula
DMSO	Dimethyl sulfoxide
EVOH	Ethylene vinyl alcohol
LMWH	Low molecular weight heparin
MMA	Middle meningeal artery
OcA	Occipital artery
PMA	Posterior meningeal artery
STA	Superficial temporal artery
TS DAVF	Transverse-sigmoid dural arteriovenous fistula

Introduction

Transverse-sigmoid sinus dural arteriovenous fistulas (TS DAVF) are rare intracranial vascular lesions that may be revealed by pulsatile tinnitus [14] or intracranial bleeding when a cortical vein is involved in the venous drainage of the malformation [5]. Indications for the treatment of such fistulas are the reflux into cortical vein(s), which carries a bleeding risk or unbearable tinnitus interfering on daily living [17]. Usually, TS DAVF are fed by branches from the middle and posterior meningeal artery (MMA, PMA), by meningeal branches from the ascending pharyngeal artery (APA), and by transosseous branches of the occipital artery (OcA) or, more rarely, of the superficial temporal artery (STA) [14].

Despite being still controversial for some authors [10], transarterial embolization with non-adhesive, cohesive copolymer agent like ethylene vinyl alcohol (EVOH, Onyx®, eV3/Covidien, Irvine, CA, USA), has gained acceptance during the past decade, allowing for high occlusion rates and low procedure-related complications. Most of these transarterial embolization procedures are performed via the MMA. Slow injection of Onyx® allows for progression of the embolic agent toward the venous side of the shunt point leading to retrograde occlusion of the surrounding arterial feeders [11]. However, in some cases, navigation through the MMA may be difficult due to marked tortuosity, resulting in too proximal positioning of the microcatheter's tip from the shunt. Additionally, in some cases, major embolic agent reflux along the microcatheter may be observed, compelling the operator to stop the injection in order to avoid reflux into eloquent arteries (like the MMA petrous branch feeding the facial nerve) or to prevent microcatheter gluing. Even if often larger in caliber than MMA, OcA or STA are known to be poorly suitable for liquid embolic material injection [6] since a possible pressure gradient of the transosseous branches feeding the fistula may limit the embolic agent penetration toward the shunt point.

We present in this technical note how a double-lumen balloon may help to facilitate Onyx® embolization of TS DAVF via extracranial arteries (OcA and STA).

Materials and methods

We reviewed the charts of two patients treated for TS DAVF through three embolization sessions using a dual-lumen balloon (Scepter XC, Microvention, Tustin, CA, USA), in our institution from November 2014 to March 2015. In each case, the number of branches catheterized by the dual-lumen balloon, number of times the balloon was repositioned, volume of Onyx® injected, and injection time were recorded.

Technical complications (i.e., arterial rupture, balloon trapping, or balloon rupture) were recorded. Procedure-related clinical complications (hemorrhagic or ischemic complication) were also evaluated.

Cases presentation

Case #1

A 31-year-old male, ex-professional boxer, complained of progressive headaches, visual disturbance, vertigo, lower limb weakness, and memory loss lasting for several months. Physical examination revealed a paralysis of the right VIth cranial nerve responsible for diplopia.

Brain MRI showed diffuse venous engorgement with dilatation of the deep venous system and mass effect on the brainstem. DSA revealed the presence of multiple dural arteriovenous shunts along both lateral sinuses and the torcular herophili, fed by the MMAs and PMAs as well as by both OcAs, the right deep cervical artery, and the marginal arteries of the tentorium bilaterally. A venous reflux into the straight and superior sagittal sinuses was also observed. The dural AV fistula was a Cognard grade IIA [5] (Figs. 1a, b and 2a, b). An endovascular treatment of the DAVF was considered after a multidisciplinary meeting due to the clinical symptoms related to the venous engorgement.

Treatment was carried out endovascularly in two sessions distanced by 7 days. Via an arterial femoral access, the right MMA first was selectively catheterized as the approach of choice for injection with a Marathon 1.3 microcatheter (Medtronic-Covidien Neurovascular, Irvine, CA, USA) through a 6-F guiding catheter in the ECA. Injection was carried out under protection of the torcular by an inflated Copernic RC 10×80-mm balloon (Balt, Montmorency, France) (Fig. 1c) navigated via a left internal jugular vein access. However, the result after injection was judged incomplete due to insufficient reflux into the numerous shunts fed by the transosseous arteries. Catheterization of the right OcA (first session) and left OcA (second session) with a double-lumen Scepter XC 4×11-mm balloon (Microvention, Tustin, CA, USA) was then performed (Figs. 1d and 2c). Onyx was then injected through the working lumen of the inflated balloon until distal penetration was judged sufficient. Balloon inflation also allowed control of the proximal reflux. During the embolization, the balloon was several times deflated and repositioned more proximally within the OcA in order to achieve a step-by-step filling of transosseous feeders from distally to proximally (Figs. 1e, f and 2d, e). After each session, a final control angiogram showed obliteration of the A-V shunts fed by the right and left OcAs, respectively (Figs. 1f, g and 2f, g).

Injection time was ≈ 50 min for the first embolization session and ≈ 40 min for the second session. The number of balloon repositioning was three for the first session and four the second one. The total volume of Onyx 18 injected was approximately 40 ml. The patient was then put on low molecular weight heparin (LMWH) (6000 UI twice a day) for 7 days after each treatment session to prevent excessive extension of the venous thrombosis.

Case #2

A 47-year-old female was admitted to our department for right pulsatile tinnitus persisting for 7 months. Pulsatile bruit at auscultation right mastoid was detected during physical examination. The rest of the neurological examination was normal. No past history of head trauma was recorded. Brain MRI (3 T) showed blood flow arterialization within the right lateral sinus, with prominence of the emissary veins and the transosseous vessels. These findings as well as the clinical presentation were suggestive of TS DAVF. Full cerebral DSA (including both ECAs and ICAs, and vertebral arteries catheterization) in AP, lateral, and oblique projections confirmed the diagnosis of TS DAVF fed by the right OcA and STA, with little contribution from the petrosquamous branch

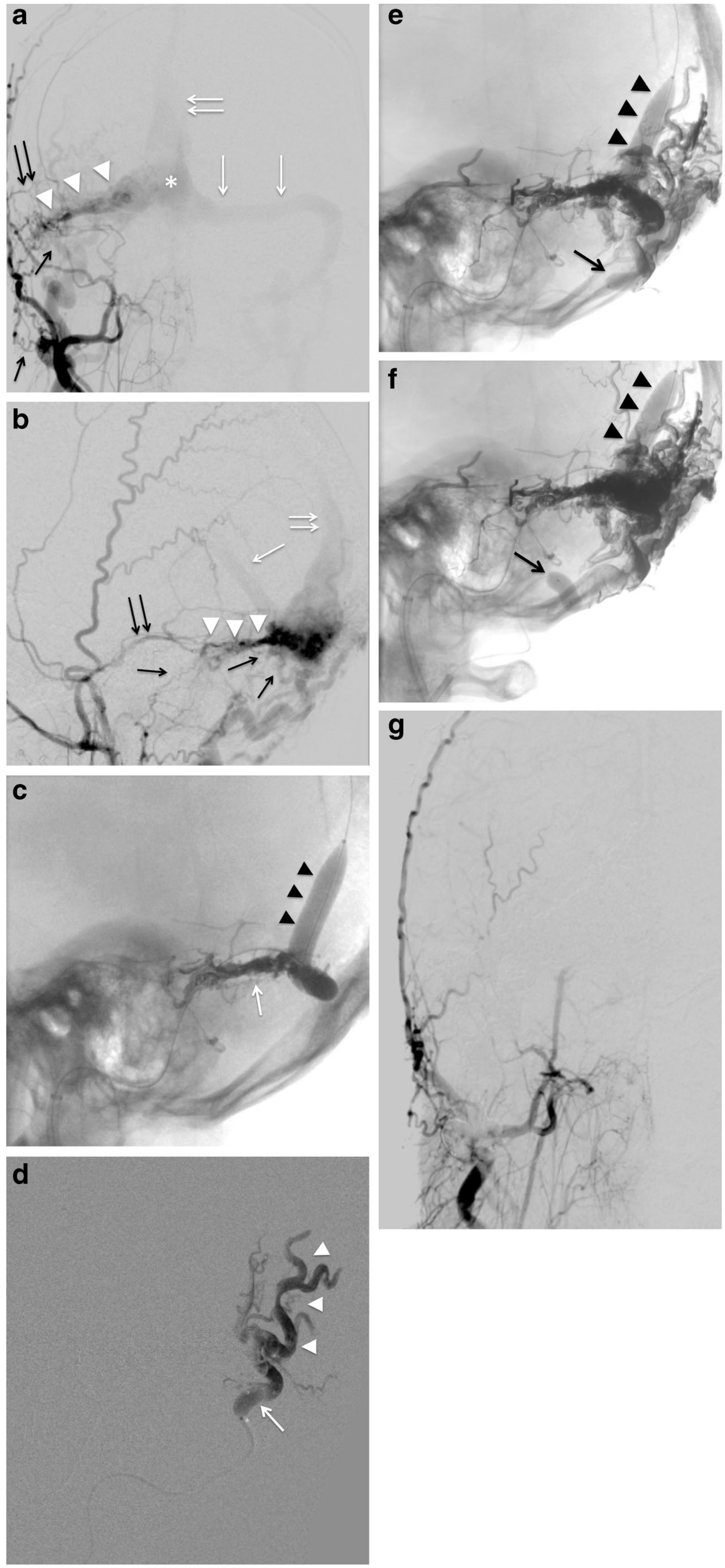

Fig. 1 First embolization session in patient #1. **a**, **b** Pretreatment right external carotid artery (ECA) digital subtraction angiography (DSA) in anteroposterior (AP) (**a**) and lateral (**b**) projections showing a transverse-sigmoid sinus dural arteriovenous fistula (TS DAVF) fed by branches from the right middle meningeal artery (MMA) (*double black arrow*), and transosseous branches from the right occipital artery (OcA) (*single black arrows*). Branches from the right posterior meningeal artery, right deep cervical artery, and the marginal arteries of the tentorium bilaterally also supplied the DAVF (not presented). Note the involvement of the torcular herophili in the DAVF (**a**, *) as well as the reflux in the left transverse sinus (**a**, *white arrows*), straight sinus (**b**, *white arrow*) and superior sagittal sinus (**a** and **b**, *double white arrows*). Also note the occlusion of the right sigmoid sinus (**c**). Unsubtracted snapshot in lateral projection. Onyx® injection via the right MMA (*white arrow*) under balloon (Copernic RC 10 × 80-mm balloon [Balt, Montmorency, France]) inflation in the left transverse sinus and the superior sagittal sinus (*black arrow heads*). **d** Blank road map; lateral projection. Onyx® injection (*arrowheads*) in the right OcA via the inflated dual-lumen balloon (*white arrow*). **e**, **f** Unsubtracted snapshot in lateral projection showing the Onyx® injection via the inflated dual-lumen balloon (**e**, **f**, *black arrows*). In **f**, the dual-lumen balloon has been repositioned more proximally in order to enhance the penetration of the embolic agent in the proximal feeders. Note the protection balloon inflated in the left transverse sinus and in the superior sagittal sinus (**e** and **f**, *arrowheads*). **g** Control right ECA DSA in AP projection at the end of the first embolization session showing a complete exclusion of the A-V shunt on the right transverse sinus

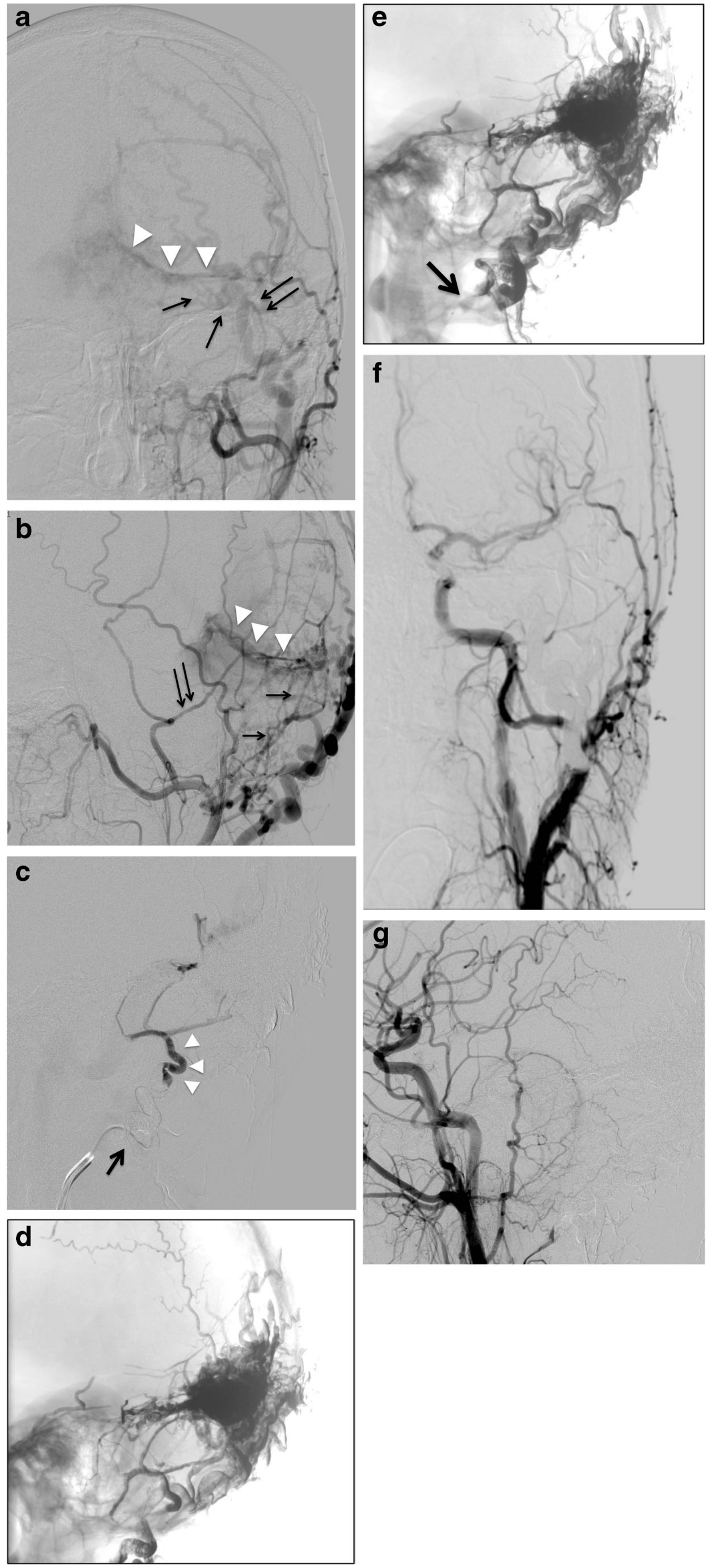

Fig. 2 Second embolization session in patient #1. **a**, **b** Pretreatment left ECA DSA in AP (**a**) and lateral (**b**) projections. Residual A-V shunt along the left transverse sinus (*white arrowheads*) is seen, fed by the left MMA (*double black arrows*) and transosseous branches from the left OcA (*black arrows*). **c** Blank road map in lateral projection during the Onyx® injection (*white arrowhead*) via the dual-lumen balloon (*arrow*) inflated in the OcA. **d** Unsubtracted snapshot in lateral projection before proximal repositioning of the dual-lumen balloon in the OcA. **e** Unsubtracted snapshot in lateral projection during the Onyx® injection more proximally in the OcA via the inflated dual-lumen balloon (*arrow*). **f**, **g** Left common carotid artery DSA in AP (**f**) and lateral (**g**) projections showing a complete exclusion of the A-V shunt

of the right middle meningeal artery (Fig. 3a and b). Venous reflux in the contralateral transverse sinus was seen (Fig. 3a) but no reflux in a cortical vein was observed (type IIA DAVF in the Cognard's classification [5]).

After a multidisciplinary meeting, a curative treatment of the fistula was considered since the pulsatile tinnitus was invalidating, especially responsible for insomnia.

The embolization procedure was performed under general anesthesia via a femoral arterial access.

Onyx injection was performed through the working lumen of a Scepter XC 4 × 11-mm balloon inflated successively within the STA (Fig. 3c, d) and the OcA (Fig. 3f). The petrosquamous branch of the MMA was not selectively catheterized to avoid any possible risk of VIIth cranial nerve palsy. The whole procedure was carried out under balloon protection of the right transverse sinus by a Copernic RC 11 × 80-mm (Balt), navigated from a right internal jugular vein access (Fig. 3c). The protection balloon was then repositioned once towards the sigmoid sinus when Onyx® was penetrating into the more proximal feeders (Fig. 3d). Total exclusion of the fistula was achieved and documented on the final control angiogram (Fig. 3g).

Injection time was ≈ 40 min. No balloon repositioning was required to achieve complete occlusion of the fistula. Total volume of Onyx 18 injected was approximately 20 ml. The patient then was put on LMWH (6000 UI twice a day) for 5 days.

Neither ischemic nor hemorrhagic complications were observed in either patient. No technical complications (arterial rupture, balloon trapping, or balloon rupture) were recorded. No complication related to the potential toxicity of DMSO was observed as well.

Discussion

Double-lumen-compliant and Onyx/DMSO-compatible balloons are a new-generation device that allows new approaches in neuroendovascular procedures. These devices have two lumens: the first one is dedicated for the microguidewire and the second one is used for balloon inflation. The wire lumen can be used for coil deployment [4] and, since the catheter is dimethyl sulfoxide (DMSO)-compatible, ethylene vinyl alcohol (EVOH) may be injected through this wire lumen [3]. Three dual-lumen balloons are now available on the market: the Ascent balloon (Micrus Endovascular, San Jose, CA, USA), the Scepter C/XC balloons (Microvention, Tustin, CA, USA) and the Eclipse/Copernic 2 L balloons (Balt, Montmorency, France).

These new balloons may be helpful for the treatment of DAVFs in general, and especially in TS DAVFs. The possibility to inject Onyx® via the double-lumen balloon through extracranial subcutaneous arterial feeders may change the treatment strategy of TS DAVF and may help to increase the occlusion rate of these fistulas during embolization treatments.

Recently, an animal study has shown better penetration on the EVOH embolic agent injected in swine *rete mirabile* from the APA with the double-lumen balloon, compared to the so-called "pressure cooker" technique [1] or regular injection through a DMSO-compatible microcatheter [9]. Additionally, less reflux along the microcatheter in the parent artery was observed using a double-lumen balloon in this animal study [9].

The use of dual-lumen balloons for Onyx® injection in the treatment of intracranial or head and neck vascular malformations has been first described in 2013 [8, 13] and has expanded since then [7, 16]. To the best of our knowledge, only four case series [2, 7, 12, 15] focused on Onyx® injection via the wire lumen of a double-lumen balloon have included treatments of TS DAVF via the OcA. However, these series, mixing for most of them brain and head and neck AVMs and DAVFs, did not specifically focus on Onyx® penetration through the transosseous branches of extracranial arteries. Adding the cases described in these case series, only seven embolizations of TS DAVF through the OcA via a dual-lumen balloon have been reported so far.

The new insights opened by the use of double-lumen balloons may change the strategy for the treatment of TS DAVF. Indeed, with the aid of these new devices, extracranial arteries like the OcA may now represent a valuable alternative to MMA for the embolization of TS DAVF with Onyx®. The advantages of this technique compared to the "pressure cooker" technique are that there is no need for navigation of two microcatheters. Additionally, as shown in the first of our two cases, the balloon can be easily deflated and repositioned more proximally during the embolization session, in order to fill additional proximal feeders. One of the main disadvantages of this technique is a poorer navigability of the double-lumen balloons compared to other DMSO-compatible microcatheters. Indeed, in one of the previously published case series, navigation of the dual-lumen balloon in the OcA was impossible [15]. However, in such big arteries as OcA or STA, navigation is most of time not so difficult. Additionally, there is a theoretical risk of gluing the double-lumen balloon. Nevertheless, this type of adverse event, to the best of our knowledge, has not been recorded in the previously reported cases [2, 12, 15] or in the animal studies [9]. Another potential risk of using such balloons is the migration of an Onyx® fragment adherent on the balloon's wall. However, an animal study has shown, using stereomicroscope for examination of the device after withdrawal, that no large liquid embolic agent fragment was attached on the dual-lumen balloon after Onyx® injection via the device [9]. In addition, it should be mentioned that the consequences of Onyx® fragment distal migration in the OcA or STA would not, most of the time, lead to clinical consequence. Finally, the neurointerventionalists using this

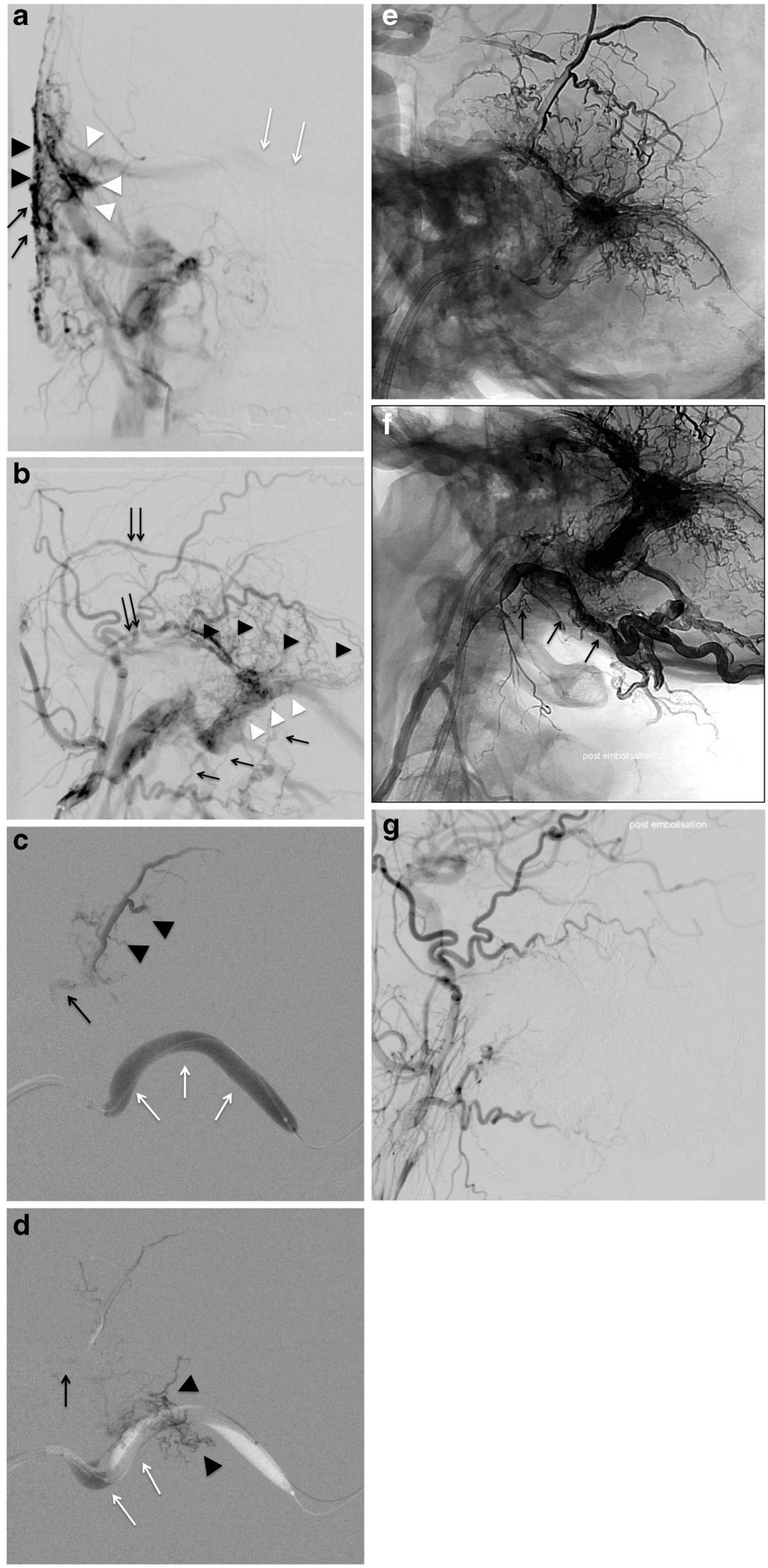

Fig. 3 Embolization session of patient # 2. **a**, **b** Pretreatment DSA via the right ECA in AP (**a**) and lateral (**b**) projections. The right TS DAVF (white arrowheads) fed by transosseous branches from the right OcA (*single black arrows*) and STA (*black arrowheads*) is seen, as well as feeders from the right MMA (*black double arrows*). Note the reflux into the contralateral sinus (**a**, *white arrows*). **c**, **d** Blank road map in lateral projection. The protection balloon in the right transverse-sigmoid sinus is seen (*white arrows*). Onyx® (*black arrowheads*) is injected through the inflated dual-lumen balloon in the STA (*black arrow*). When the Onyx® started to reach the small arterial feeders close to the sigmoid sinus (**d**, *black arrow heads*), the protection balloon has been pulled back and reinflated (**d**, *white arrows*). **e** Unsubtracted snapshot in lateral projection showing the cast of Onyx® injected via the double-lumen balloon in the right STA. **f** Unsubtracted snapshot in lateral projection after Onyx® injection through the dual-lumen balloon placed in the right OcA. Note the filling of the OcA and its transosseous branches (*black arrows)*. **g** Control right ECA DSA in lateral projection showing a complete occlusion of the A-V shunt

technique should keep in mind the potential risk of liquid embolic agent migration toward the vertebrobasilar system via the first and second cervical segmental arteries. Thus, the Onyx® injection via the balloon should only be performed distally to the origin of these anastomoses.

Conclusions

Dual-lumen balloon seems to be a useful tool for the treatment of TS DAVF. It may help to facilitate the penetration of cohesive liquid embolic agents like Onyx® in the transosseous branches from the occipital or superficial temporal arteries.

Compliance with ethical standards

Conflict of interest FC is consultant for Covidien (paid lectures) and Codman (study core lab). NS is proctor for the Pipeline Embolization Device and Medina Embolization device (eV3/Covidien).

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Ethical approval All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards.

For this type of study formal consent is not required.

References

1. Chapot R, Stracke P, Velasco A, Nordmeyer H, Heddier M, Stauder M, Schooss P, Mosimann PJ (2014) The pressure cooker technique for the treatment of brain AVMs. J Neuroradiol 41:87–91
2. Chiu AH, Aw G, Wenderoth JD (2014) Double-lumen arterial balloon catheter technique for Onyx embolization of dural arteriovenous fistulas: initial experience. J Neurointerv Surg 6:400–403
3. Clarencon F, Nouet A, Redondo A, Di Maria F, Iosif C, Le Jean L, Chiras J, Sourour N (2014) Occlusion of M1 segment after superficial temporal artery-middle cerebral artery bypass in a giant M1 aneurysm with Onyx-34 injected via a double-lumen balloon under balloon inflation. J Neurointerv Surg 6, e27
4. Clarencon F, Perot G, Biondi A, Di Maria F, Szatmary Z, Chiras J, Sourour N (2012) Use of the Ascent balloon for a 2-in-1 remodeling technique: feasibility and initial experience: case report. Neurosurgery 70:170–173, discussion 173
5. Cognard C, Gobin YP, Pierot L, Bailly AL, Houdart E, Casasco A, Chiras J, Merland JJ (1995) Cerebral dural arteriovenous fistulas: clinical and angiographic correlation with a revised classification of venous drainage. Radiology 194: 671–680
6. Cognard C, Januel AC, Silva NA Jr, Tall P (2008) Endovascular treatment of intracranial dural arteriovenous fistulas with cortical venous drainage: new management using Onyx. AJNR Am J Neuroradiol 29:235–241
7. Dabus G, Linfante I, Martinez-Galdamez M (2014) Endovascular treatment of dural arteriovenous fistulas using dual lumen balloon microcatheter: technical aspects and results. Clin Neurol Neurosurg 117:22–27
8. Fifi J, Niimi Y, Berenstein A (2013) Onyx embolization of an extensive mandibular arteriovenous malformation via a dual-lumen balloon catheter: a technical case report. J Neurointerv Surg 5:e5
9. Gentric JC, Raymond J, Batista A, Salazkin I, Gevry G, Darsaut TE (2015) Dual-lumen balloon catheters may improve liquid embolization of vascular malformations: an experimental study in swine. AJNR Am J Neuroradiol 36:977–981
10. Guedin P, Gaillard S, Boulin A, Condette-Auliac S, Bourdain F, Guieu S, Dupuy M, Rodesch G (2010) Therapeutic management of intracranial dural arteriovenous shunts with leptomeningeal venous drainage: report of 53 consecutive patients with emphasis on transarterial embolization with acrylic glue. J Neurosurg 112:603–610
11. Hu YC, Newman CB, Dashti SR, Albuquerque FC, McDougall CG (2011) Cranial dural arteriovenous fistula: transarterial Onyx embolization experience and technical nuances. J Neurointerv Surg 3:5–13
12. Jagadeesan BD, Grigoryan M, Hassan AE, Grande AW, Tummala RP (2013) Endovascular balloon-assisted embolization of intracranial and cervical arteriovenous malformations using dual lumen coaxial balloon microcatheters and onyx: initial experience. Neurosurgery. doi:10.1227/NEU.0b013e31828d602b
13. Kim ST, Jeong HW, Seo J (2013) Onyx embolization of Dural arteriovenous fistula, using scepter C balloon catheter: a case report. Neurointervention 8:110–114
14. Lv X, Jiang C, Li Y, Liu L, Liu J, Wu Z (2010) Transverse-sigmoid sinus dural arteriovenous fistulae. World Neurosurg 74:297–305
15. Paramasivam S, Niimi Y, Fifi J, Berenstein A (2013) Onyx embolization using dual-lumen balloon catheter: initial experience and technical note. J Neuroradiol 40:294–302
16. Spiotta AM, James RF, Lowe SR, Vargas J, Turk AS, Chaudry MI, Bhalla T, Janjua RM, Delaney JJ, Quintero-Wolfe S, Turner RD (2015) Balloon-augmented Onyx embolization of cerebral arteriovenous malformations using a dual-lumen balloon: a multicenter experience. J Neurointerv Surg 7:721–727
17. Weissman JL, Hirsch BE (2000) Imaging of tinnitus: a review. Radiology 216:342–349