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Special Report

Endovascular Treatment for Dural Arteriovenous Fistulae Using a Sinus Protection Balloon to Maintain the Patency of the Dural Sinus

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We introduce our technique to treat dural arteriovenous fistulae (dAVFe) under sinus balloon protection. The Kaneka Shoryu 7 × 7 mm balloon was used for sinus occlusion. Initially, the balloon was inflated slowly using 1.5–2.0 mL of saline on the table. A 6F guiding catheter was navigated into the proximal portion of the lesion from the jugular vein of the affected side. The balloon catheter was introduced to the point occluding the shunt. The balloon was temporarily inflated to determine the occlusion point without occluding the outlet of the vein of Labbe. ONYX injection was started from the microcatheter located at just proximal to the shunt point under sinus balloon occlusion. ONYX penetrated the feeding arteries in an antegrade and retrograde manner. After the penetration of ONYX into each feeding artery, the inflated balloon was temporarily deflated to examine the residual shunt. If a small shunt remained, the balloon was inflated again and ONYX injection was continued. To cure dAVF, the location of the balloon is important. The guiding catheter should be placed just proximal to the shunt and the balloon catheter should be gently pulled to stabilize the balloon position.

Keywords ▶ dural arteriovenous fistula, embolization, balloon, ONYX, sinus protection

Introduction

Obliteration of the sinus is radical treatment for dural arteriovenous fistulae (dAVFe), but a sinus-occlusion-related increase in venous pressure may induce a new AVF.[1)] ONYX facilitates the treatment of most dAVFe by transarterial embolization (TAE), but radical sinus-preserved embolization was difficult before the development of the Copernic balloon catheter for preserving the sinus (BALT, Montmorency, France) in patients with a patent sinus.[2)] However, the Copernic balloon catheter, which is available in Europe and the United States, has not been approved in Japan. After 2008, numerous balloon catheters available in Japan (percutaneous transluminal angioplasty (PTA) and aneurysmal neck remodeling balloons) were used to obliterate the sinus. However, there was no balloon whose properties or size facilitated accurate obliteration of the sinus without a gap. When the Shoryu 7 × 7 mm (Kaneka Medics, Kanagawa, Japan) became commercially available, we investigated the rupture volume of the balloon, and confirmed that 2-mL liquid infusion prevented the rupture of most balloons. At an infusion volume of 2 mL, the balloon diameter and length were 10–12 and 20–30 mm, respectively, although the size was not uniform, suggesting that most sinuses can be safely and accurately obliterated.[3,4)] As an advantage of this balloon, it is supercompliant, facilitating accurate obliteration of irregular sinuses. In this study, we introduce radical embolization of dAVFe under sinus preservation using this balloon in patients with a patent sinus.

Note: Currently, larger-volume, larger-diameter balloon catheters are being developed by Kaneka Medics. Furthermore,

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the manufacturing of Copernic balloons was discontinued due to multiple reasons (Chapot: personal communication).

Characteristics and Usage of Balloon Catheters

In Europe and the United States, Copernic RC balloon catheters for sinus obliteration are manufactured by BALT, being commercially available. There are two types of this balloon measuring 8 mm × 80 mm and 10 mm × 80 mm in diastolic diameter and length, respectively. They are appropriate for obliteration of the sinus involving a long distance. However, the sinus diameter exceeds 10 mm in some cases, in which parallel arrangement of several balloons may be adopted.[4]

Using balloons available in Japan, it is difficult to obliterate the normal sinus using those for standard aneurysmal neck remodeling due to their inflated diameters. Furthermore, PTA balloons for the carotid artery or peripheral blood vessels were also initially used after the introduction of this procedure (2008). However, it was difficult to accurately obliterate the sinus and leakage of a liquid embolic substance into the balloon gap may lead to occlusion at the outflow part of the vein of Labbe (**Fig. 1**). Furthermore, the sinus size is not constant, as presented below; obliteration using this balloon is impossible at stenotic or dilated areas. The Shoryu 7 × 7 mm (Kaneka Medics) was not developed to obliterate the sinus, but it is flexible and does not rupture through 2-mL liquid infusion. When 3 mL of liquid is infused, approximately half of the balloons rupture. Therefore, as a rule, the infusion volume should be restricted to ≤2 mL. Furthermore, this balloon dilates to approximately 10 × 16 mm, 12 × 24 mm, and 14 × 32 mm, respectively, through 1-, 2-, and 3-mL liquid infusion (**Fig. 2**), although neither the length nor thickness at the time of dilation is constant. This balloon is shorter than the Copernic RC, but becomes thicker, which is advantageous for obliteration of the dilated sinus. A balloon may migrate along blood flow with balloon inflation, but if a 6F parent catheter for balloon introduction is inserted to an area slightly proximal to the site to be obliterated and a dilated balloon is slightly pulled into the parent catheter as a preventative strategy, the balloon may not migrate. In areas with a vascular diameter of >14 mm, such as the sinus confluence, it is possible to obliterate the orifice of a shunt to the sinus by inserting several balloons in parallel.[4]

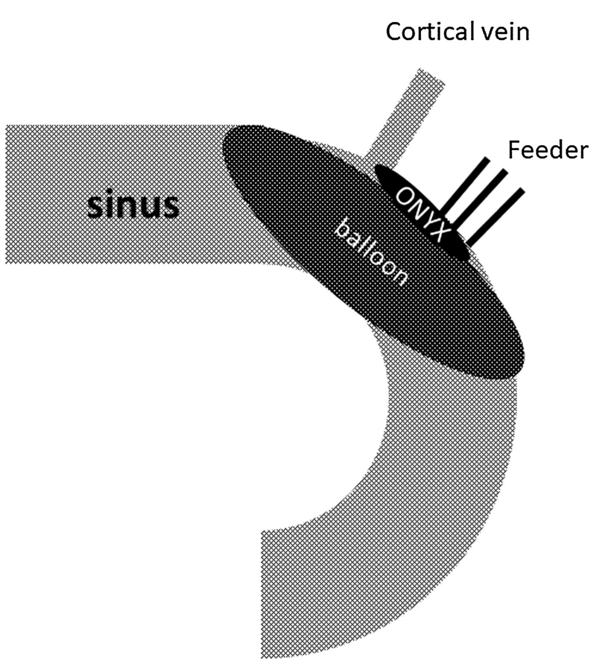

Fig. 1 Schema of balloon protection. Complete occlusion of the sinus is difficult using a PTA balloon catheter due to its low conformability. There is a risk of ONYX migration into the open space between the sinus wall and inflated balloon. If the vein of Labbe drains into this space, migrated ONYX may occlude it. PTA: percutaneous transluminal angioplasty

The usage of the Shoryu is summarized below.

- Balloon dilation: A balloon should be slowly dilated over a few minutes ex vivo until a volume of 2 mL is reached.
- The concentration of contrast medium should be 1:1 (this concentration may be slightly reduced).
- After confirming the position of the vein of Labbe, a balloon should be dilated such that it is not occluded as a rule. When obliterating the vein of Labbe using a balloon, a collateral pathway should be confirmed using cerebral angiography (CAG).
- After obliteration, angiography should be performed. If shunt obliteration is successful, there may be no AVF visualization.
- A 6F parent catheter should be inserted to an area adjacent to a balloon and the balloon should be slightly pulled to prevent migration.
- If ONYX infusion is considered sufficient, the balloon should be deflated at an appropriate time and the state of dAVF obliteration should be confirmed.

Concrete usage methods in clinical practice

Initially, an access route (artery) should be determined. The most important point is to select a blood vessel through which the shunt point can be reached. It is not necessary to stick to a main feeder (vessel diameter). As a rule, obliteration of other feeders should not be conducted before the

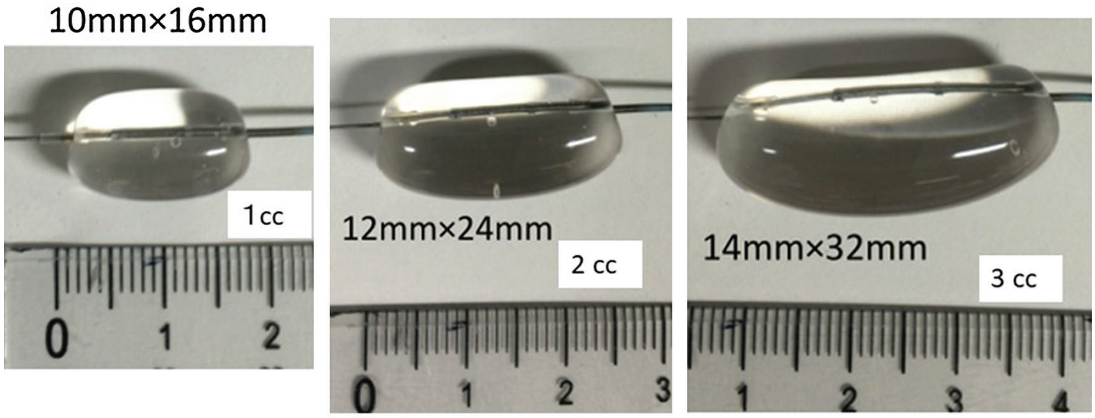

Fig. 2 Shape and size of the Shoryu 7 × 7 mm. The shape of the balloon inflated with 1 mL, 2 mL, and 3 mL of saline.

infusion of a liquid embolic substance. These blood vessels are available as an access route for a residual shunt. The middle meningeal artery is routinely selected in many cases, but the occipital or posterior auricular arteries are sometimes selected depending on the shunt location. Even when the occipital artery is selected, a microcatheter should be inserted to a position where the shunt is as close as possible. If impossible, a liquid embolic substance should be infused under flow control with a double-lumen balloon catheter.

A liquid embolic substance should be infused using the "plug and push" method when a balloon catheter is not used. The middle meningeal artery is relatively straight, and if a distal access catheter (DAC) is used, it can be retrieved even with a plug measuring 2 or 3 cm. If the sinus is embolized using a Shoryu and NBCA, the balloon may rupture the moment NBCA comes in contact with the balloon; therefore, NBCA is contraindicated.

As an access route to the sinus, direct puncture through the jugular vein is appropriate. We selected an approach via the jugular vein due to simple catheter operations. A 6F standard catheter can be easily inserted to the transverse sinus. When placing a Shoryu in parallel, a 7F parent catheter should be used. The catheter end should be inserted to the slightly proximal side of the site to be obliterated with a balloon. A balloon for obliteration should be guided using a 0.014-inch guidewire and dilated. When the balloon migrates, it should be slightly pulled into the parent catheter to prevent migration. The site of balloon dilation is important and the balloon should be fixed to a site where the entire shunt can be obliterated without occluding the vein of Labbe. When obliterating the vein of Labbe with anterograde blood flow, the duration of obliteration should be restricted to a few minutes and liquid should be intermittently infused. If the sinus is obliterated using a balloon at an area proximal to a shunt, cortical vein reflux may occur, inducing hemorrhagic complications; therefore, caution is needed. Furthermore, it is necessary to investigate the basal temporal vein, orifice of the superior petrosal sinus, and collateral pathway in addition to the vein of Labbe. When the bilateral transverse-sigmoid sinuses are normally patent, it is not necessary to restrict the duration of sinus obliteration.

When selecting ONYX as an embolic substance, ONYX 18 should be used. If embolism progresses, ONYX infused through the middle meningeal artery may penetrate into the occipital artery or other feeders. Before embolization, the permissible degree of ONYX reflux into feeders from the internal carotid artery, dural branch of the vertebral artery, or ascending pharyngeal artery in addition to the middle meningeal/occipital arteries should be confirmed. If ONYX reaches the point, infusion should be discontinued and resumed after pausing. If the infusion pressure increases in the final stage, ONYX may migrate along the balloon wall. In most cases, the disappearance of a shunt is confirmed at this point. Lastly, the balloon should be released, but if a shunt remains, infusion should be again performed through a feeder that facilitates access. Additional access through the remaining blood vessel is possible in most patients.

As a rule, TAE should be performed, but transvenous embolization (TVE) may be considered in patients with a venous pouch.[5] In these cases, there is reflux from the venous side to an artery and attention must be paid to prevent excessive reflux.

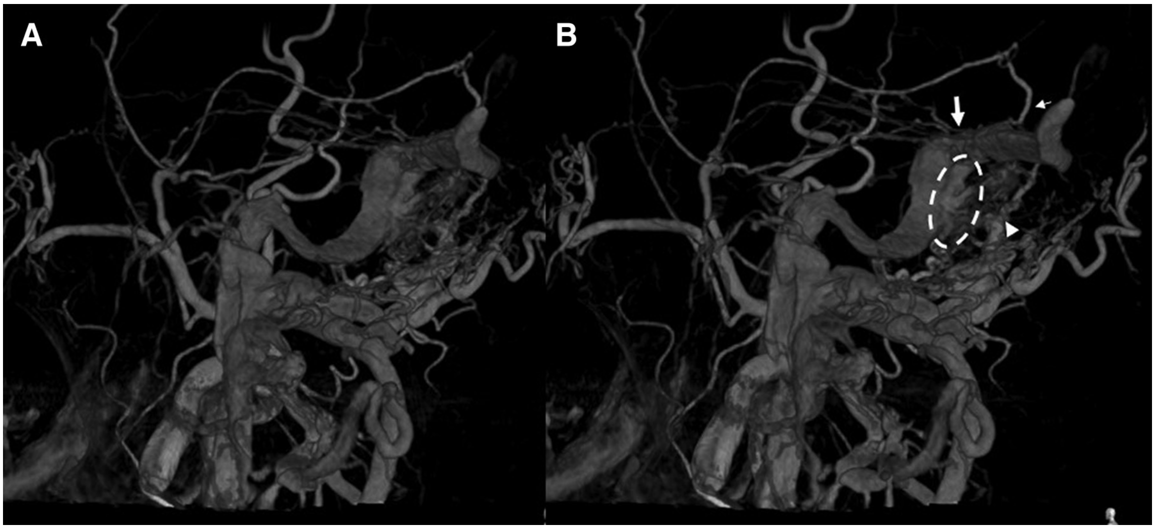

Fig. 3 Three-dimensional rotational angiographic findings on right external carotid angiography (stereoscopic view). The main feeder was the right occipital artery (arrow head) and the main fistula (dotted circle) formed at the posterior wall of the right sigmoid sinus. The shunt flow drained into the parallel sinus located at the posterior part of the right sigmoid sinus. A small shunt supplied from the right middle meningeal artery (arrow) formed around the stenosed right transverse sinus (large arrow).

Representative cases are presented

Case 1: A 61-year-old man with right pulsatile tinnitus. A dAVF of the right transverse to sigmoid sinuses was observed. Stenosis of the affected sinuses was noted. The main feeder was the right occipital artery, forming a pouch involving shunt aggregation in an area posterior to the sigmoid sinus. Furthermore, the right middle meningeal artery formed a small shunt around the stenotic site of the sinus. There was no cortical venous reflux (**Fig. 3**). Selective right occipital arteriography revealed that shunt blood flow into the pouch was open on the peripheral side of the stenotic site of the sinus (**Fig. 4**). The sinus was obliterated on the slightly proximal side of the shunt orifice and shunt blood flow regurgitated to the vein of Labbe through the sinus (**Fig. 4**). When obliterating the sinus by slightly transferring the balloon onto the peripheral side, obliteration of the shunt was confirmed. Furthermore, the balloon fits the sinus shape, completely occluding the sinus (**Fig. 5**). ONYX 18 was infused after navigating a Scepter C to the periphery of the occipital artery and dilating a balloon for feeder blockage. The shunt pouch was filled with ONYX and the shunt from the occipital artery disappeared (**Fig. 6**). However, right external carotid angiography confirmed a residual small shunt involving the middle meningeal artery to an area proximal to the stenotic site of the transverse sinus. Angiography through the insertion of a TACTICS into the right middle meningeal artery confirmed a residual small shunt (**Fig. 7**). A Defrictor (Medicos Hirata, Osaka, Japan) was inserted to the point adjacent to the shunt through the posterior convexity branch of the middle meningeal artery, and angiography confirmed that a small shunt was open at the transverse to sigmoid sinus corner (**Fig. 7**). The sinus was again obliterated using a balloon and ONYX 18 was infused, leading to the disappearance of the shunt (**Fig. 8**). Furthermore, it was confirmed that the sinus was preserved (**Fig. 9**).

Case 2: A 27-year-old woman. To treat multiple juvenile dAVFe, feeder obliteration was previously performed. Sinus plasty by stenting for stenosis of the right transverse sinus was previously conducted. In this patient, treatment was performed to reduce symptoms such as exophthalmos related to increased intracranial pressure. To obliterate a shunt involving the left transverse sinus to confluence, ONYX 18 was infused through the middle meningeal artery as a feeder under sinus preservation with a balloon (**Fig. 10**); the shunt orifice was initially obliterated using a Shoryu 7 x 7 mm balloon (**Fig. 11**). A Scepter C inserted into the middle meningeal artery was dilated for blood flow blockage and ONYX 18 was infused. The shunt cavity was filled with ONYX penetrating into other feeders. Under sinus preservation, the shunt at this site was obliterated (**Fig. 11**). Similarly, ONYX was infused through the petrosquamous branch of the middle meningeal artery and the shunt at this site was obliterated. However, non-treated another shunt was present at the contralateral skull base (**Fig. 12**).

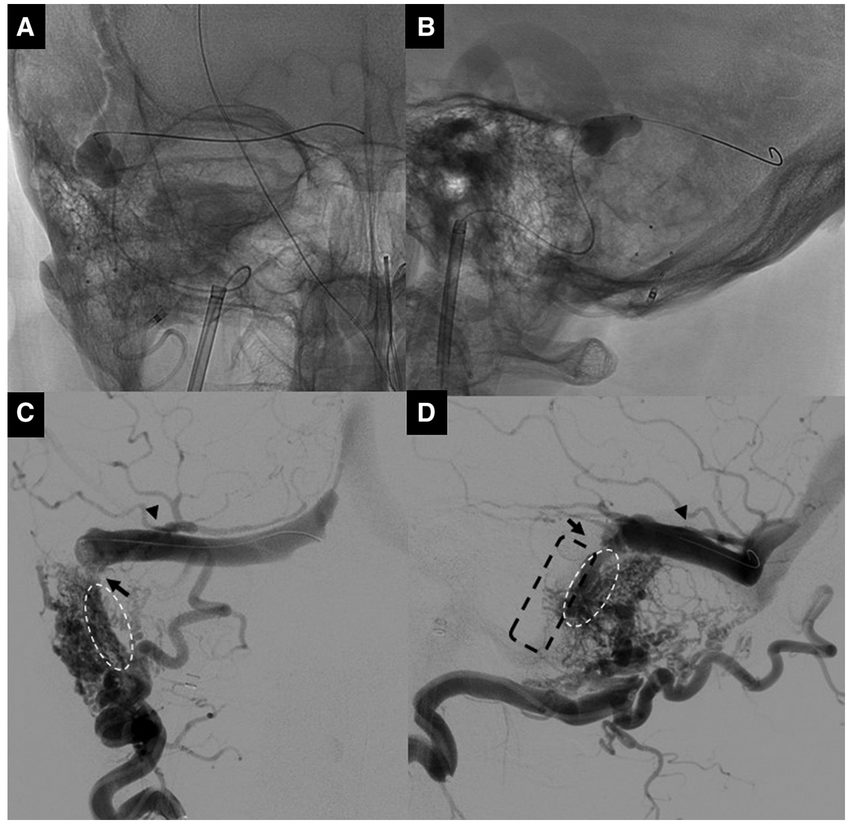

Fig. 4 PCG and angiographic findings on right occipital artery angiography during balloon occlusion at the proximal portion of the right transverse sinus. (**A**) Plain craniography, AP view. (**B**) Plain craniography, lateral view. The balloon was inflated and occluded the proximal part of the stenosed transverse sinus. (**C**) Selective right occipital artery angiography. AP view. (**D**) Lateral view. The proximal part of the stenosed right transverse sinus was obliterated using the balloon catheter. However, the shunt was not completely occluded. Therefore, retrograde cortical venous drainage (arrow head) was noted after balloon occlusion. Arrow show the stenosed sinus. The dotted square circle shows the obliterated sigmoid sinus and dotted circles show the shunt pouch. PCG: phonocardiography

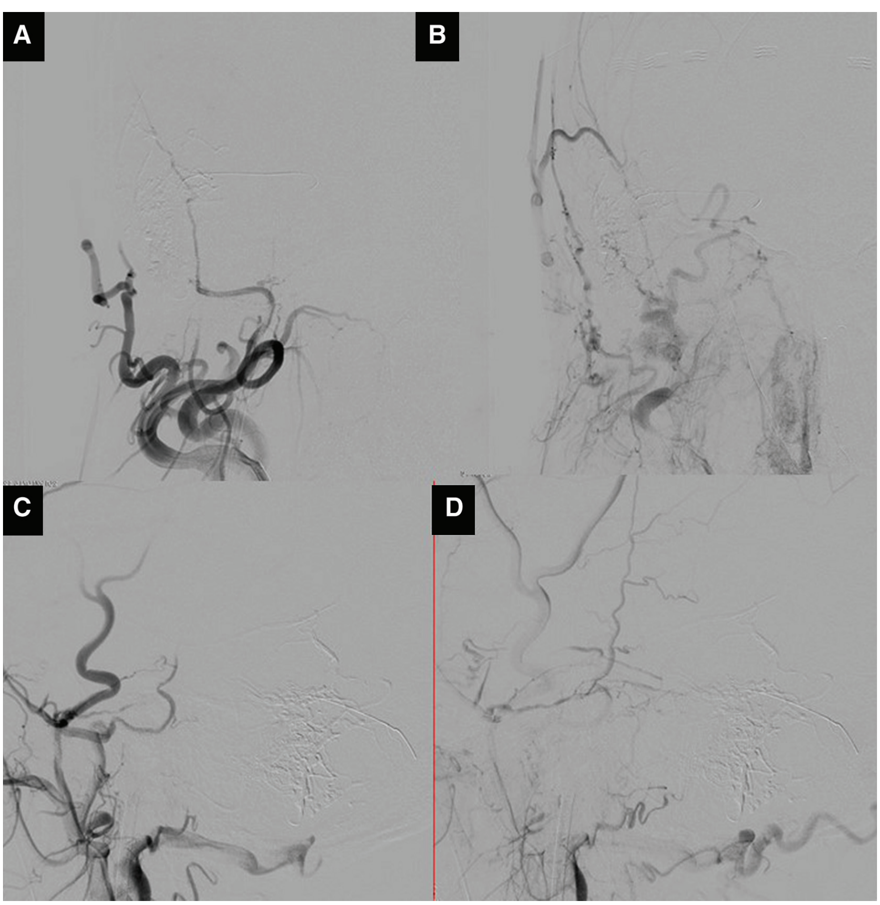

Fig. 5 PCG and angiographic findings of the right occipital artery during balloon occlusion at the proximal portion of the right transverse sinus. (**A**) Plain craniography, AP view. (**B**) Plain craniography, lateral view. The balloon catheter was inflated at the distal and proximal areas of the right transverse sinus, including the stenotic portion. (**C**) Selective right occipital angiography. AP view. (**D**) Lateral view. The right transverse sinus was completely occluded by the balloon including the entire shunt. The shunt was not opaque on right occipital artery angiography. PCG: phonocardiography

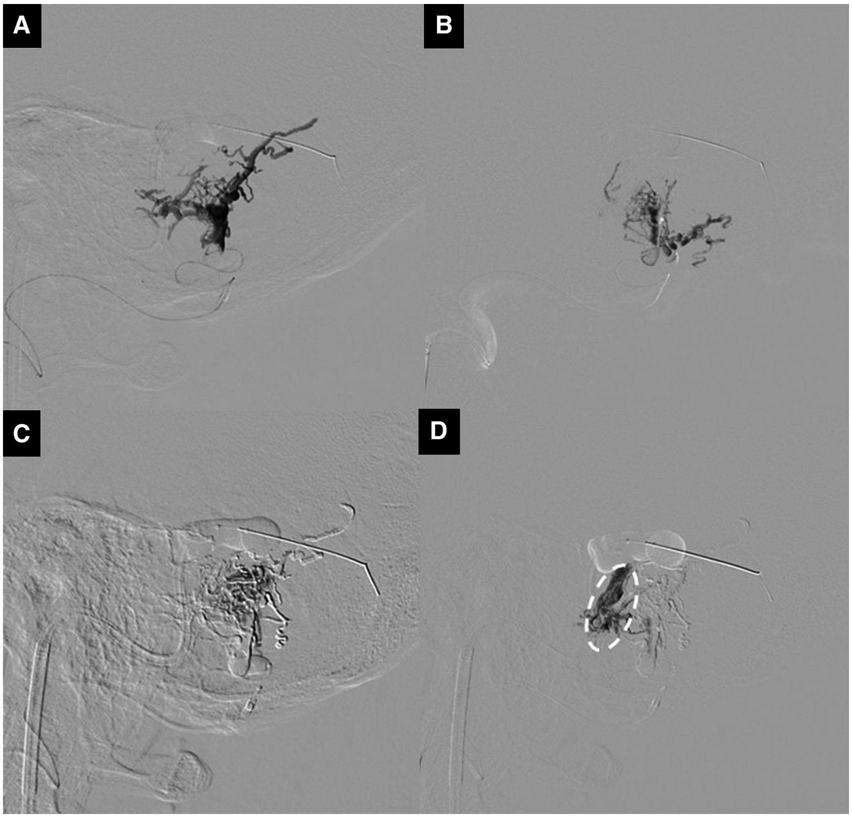

Fig. 6 ONYX injection from the inflated Scepter C balloon catheter. (**A–D**) Angiography during ONYX injection. ONYX was injected from the Scepter C balloon catheter. ONYX diffused into the occipital artery and parallel sinus located at the posterior region of the right sigmoid sinus beyond the shunt (dotted circle).

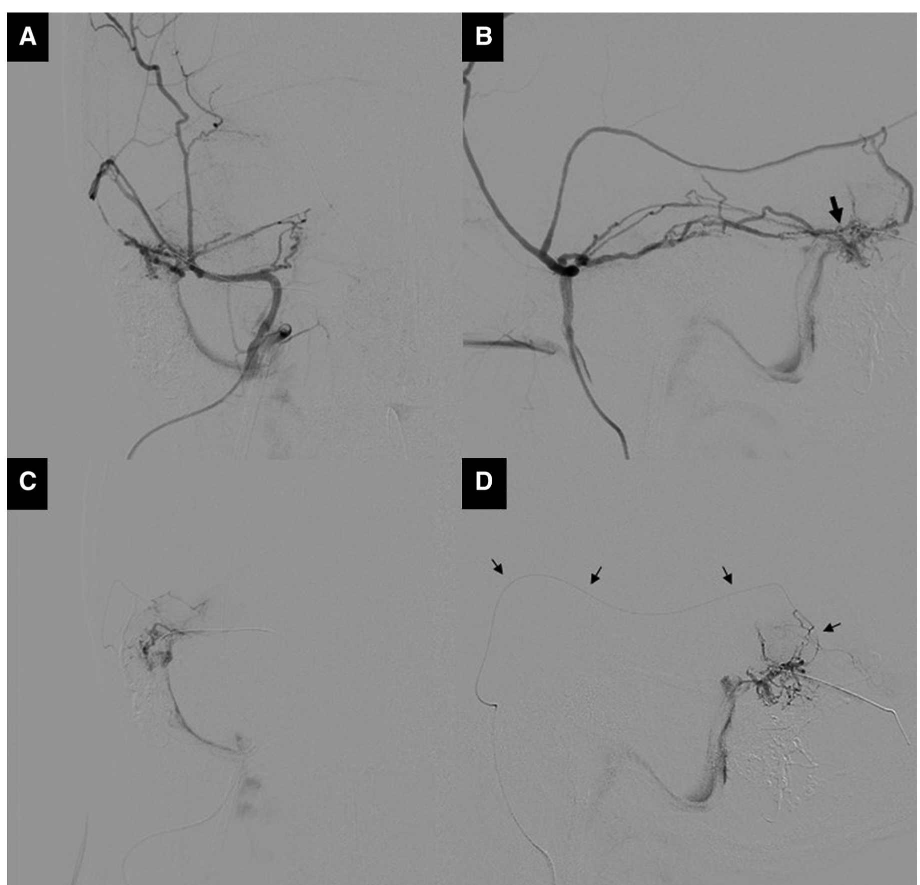

Fig. 7 Selective and superselective right middle meningeal artery angiography. (**A**) AP view, (**B**) lateral view. A tiny shunt supplied from the posterior convexity branch of the right middle meningeal artery was observed at the stenosed portion of the right transverse sinus (arrow). Superselective angiography from the Defrictor navigated just proximal to the shunt point. (**C**) AP view, (**D**) lateral view. The tiny shunt draining into the distal portion of the sigmoid sinus was opaque. Arrows indicate the navigated Defrictor.

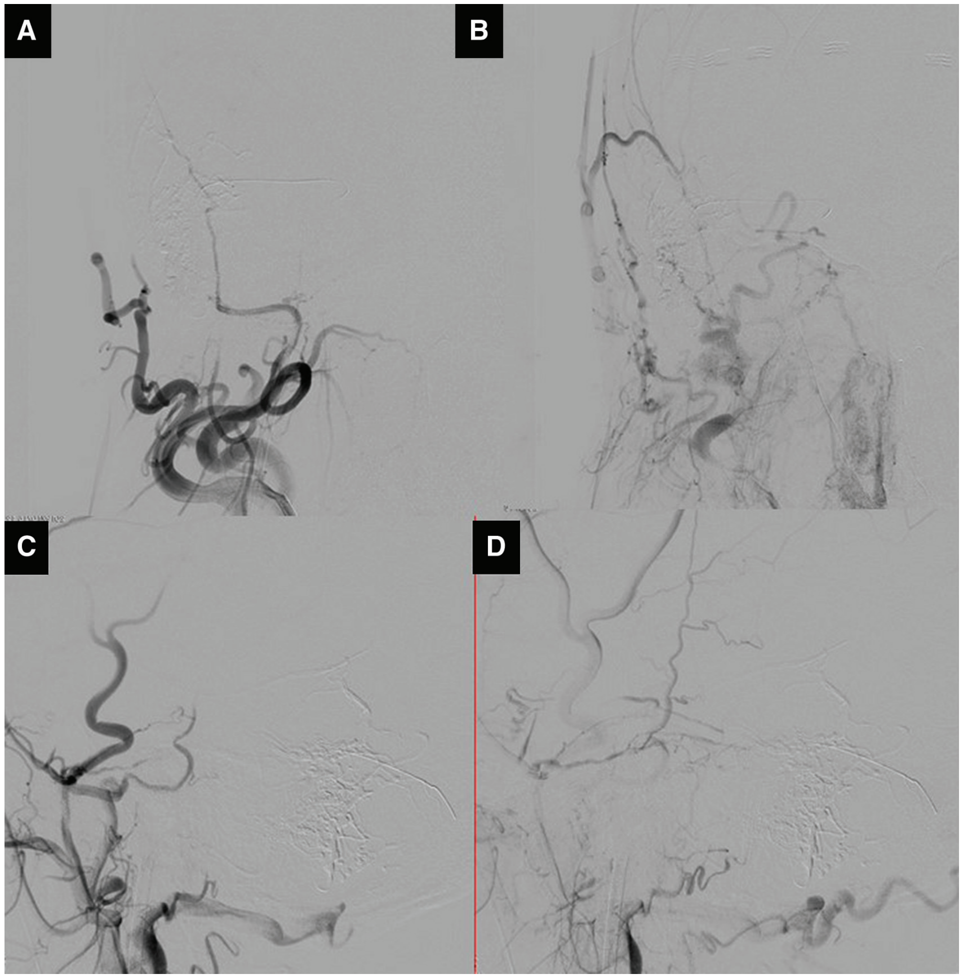

Fig. 8 Right external carotid angiography after occlusion of the shunt under sinus protection. (**A** and **B**) AP view and (**C** and **D**) lateral view. Dural shunts were obliterated.

Fig. 9 Right internal carotid angiography after embolization. (**A**) AP view, (**B**) lateral view. The normograde flow of the right transverse sinus, sigmoid sinus (arrow), and the vein of Labbe were patent (arrowhead).

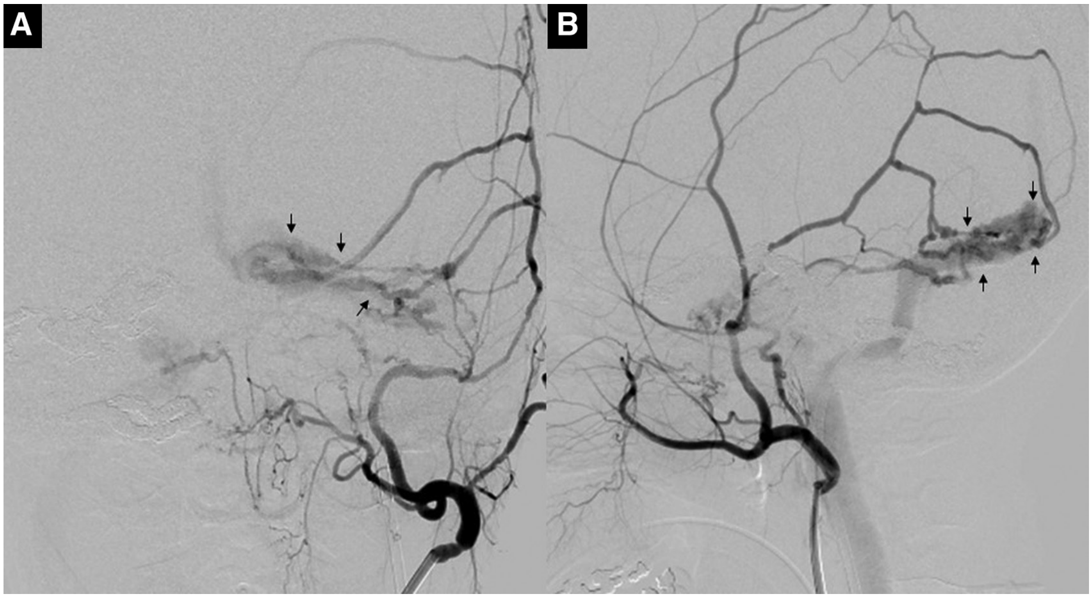

Fig. 10 External carotid angiography beyond the posterior auricular artery. (**A**) Antero-posterior view on angiography and (**B**) lateral view on angiography. The shunt formed around the distal part of the transverse sinus and shunt flow drained from the right confluence to the transverse-sigmoid sinus. Arrows show the shunt pouch.

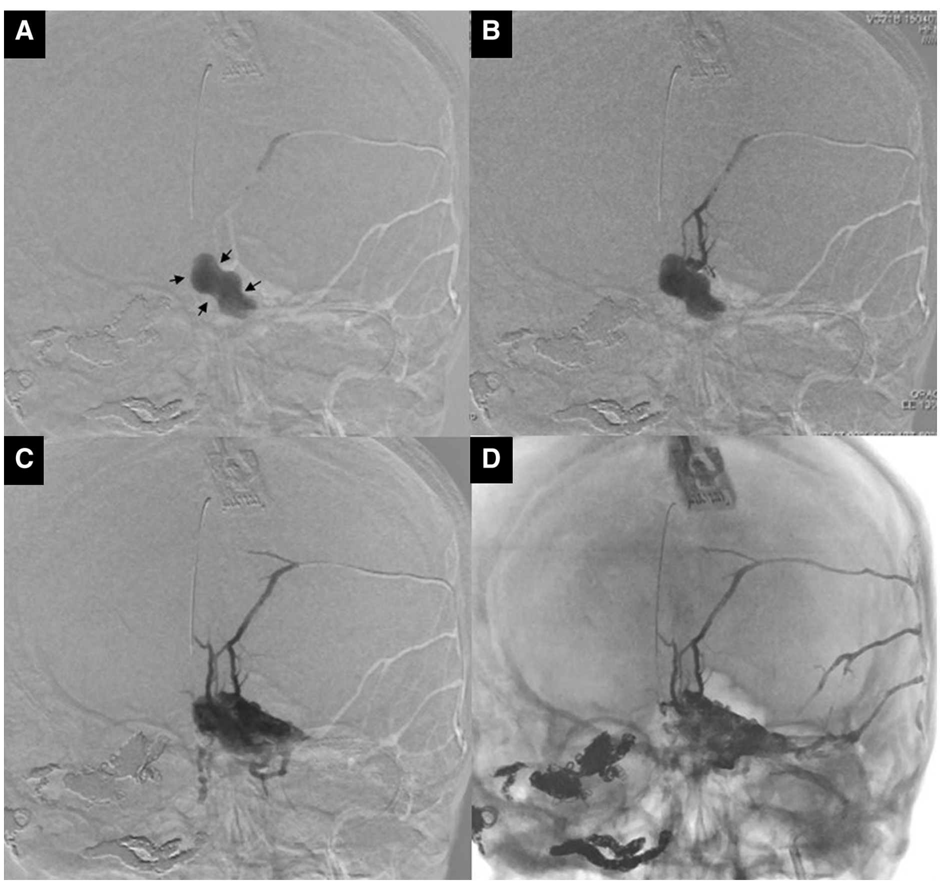

Fig. 11 Road mapping images and plain craniography before and after treatment. (**A**) The balloon was inflated at the confluence to occlude the entry of ONYX into the sinus. Arrows show the figure of the inflated balloon. (**B**) The migration of ONYX into the confluence was prevented by the inflated balloon. (**C**) ONYX diffused into the shunt pouch around the transverse sinus. (**D**) ONYX was injected from the proximal branch of the middle meningeal artery. The shunt pouch around the left transverse sinus was completely closed. Coils indicate occlusion of the feeding artery for the other shunts during previous treatment sessions.

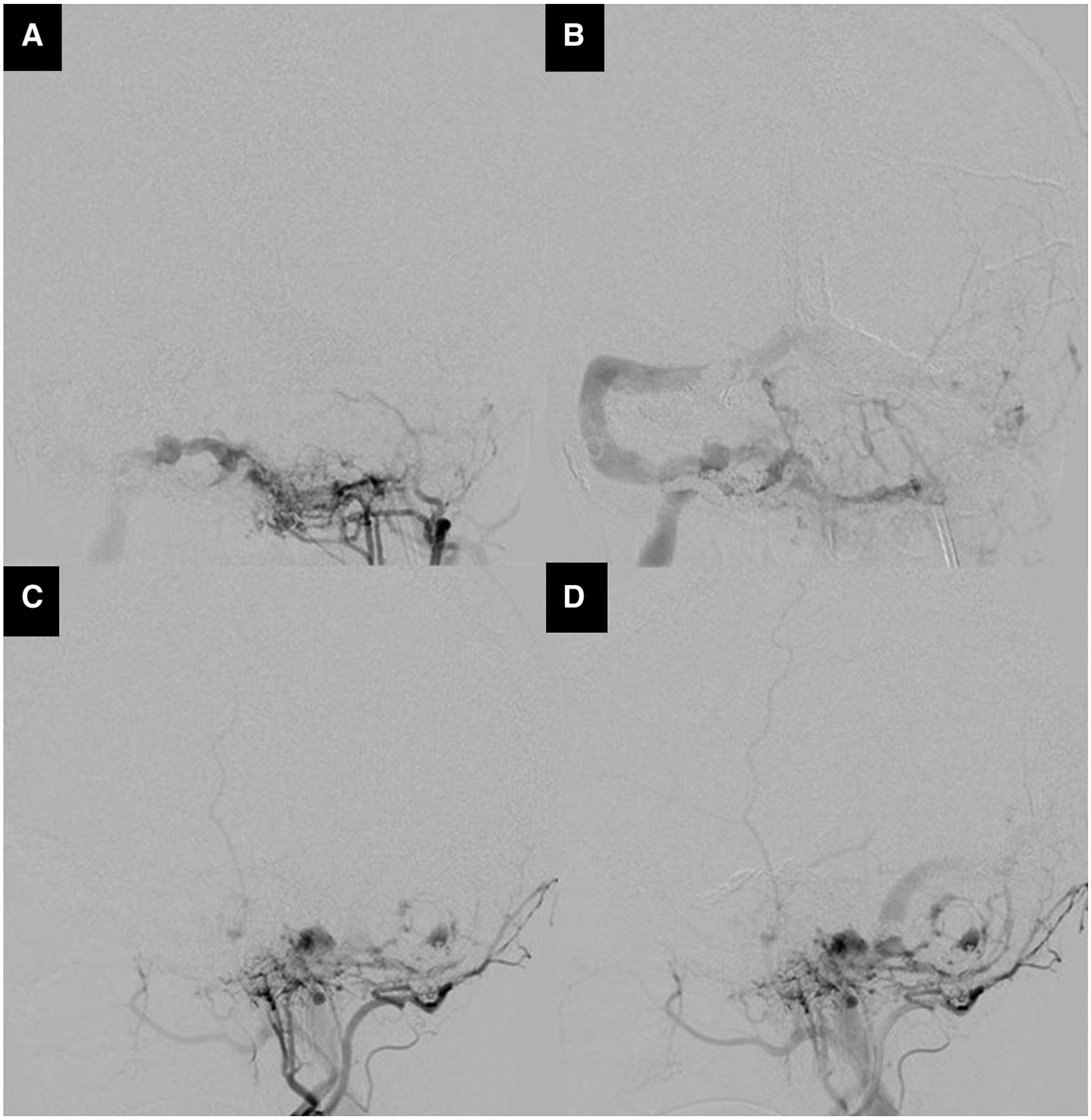

Fig. 12 Left external carotid angiography. (**A**, **B**) Antero-posterior view and (**C**, **D**) lateral view. The shunt located at the left transverse sinus disappeared, although another shunt was found at the skull base.

Discussion

In the treatment of dAVFe of patent transverse to sigmoid sinuses, the incidence of complications is markedly low in patients in whom the sinus was preserved using a balloon and the long-term outcome is favorable.[6,7] Considering these data, this procedure should be positively applied for Borden type I[8] patients presenting with pulsatile tinnitus and a patent sinus. However, as complications related to this treatment, those related to sinus obliteration with a balloon may develop. As presented in Case 1, shunt blood flow reflux to a cortical vein or occlusion of an anterograde cortical vein outflow for many hours may cause venous infarction or hemorrhagic complications. Therefore, determining the sinus occlusion point where the balloon is dilated takes time. For this, a balloon should be stabilized and dilated at a satisfactory position, that is, a site where the shunt orifice can be obliterated without disturbing normal venous perfusion. Concerning dAVFe at the TS-SS corner, most shunts are present on the proximal side of the Labbe orifice. Therefore, it is necessary to preserve the Labbe orifice and dilate a balloon at a site where the shunt orifice can be accurately obliterated. At this point, balloon migration to the periphery may lead to occlusion of the vein of Labbe. Such occlusion for a few minutes is not problematic (personal communication, Chapot), but when noted, its flow pattern must always be examined using internal carotid angiography.

Even when the sinus is tightly obliterated using a balloon, ONYX migration to the sinus via the space between the balloon and sinus wall is observed in the final stage of embolization. In this case, additional infusion should be conducted after a single pause. If ONYX migration to the sinus is noted despite additional infusion, treatment should be completed at this point. In most patients, a shunt is occluded when ONYX migrates into the sinus; therefore, this may be a standard for the completion of infusion. ONYX may not induce thrombus formation, but it may migrate into the pulmonary artery due to its low-level adhesiveness. Furthermore, massive adhesion to the sinus wall may cause occlusion of the sinus; therefore, massive ONYX migration to the sinus should be avoided.

Lastly, regarding carotid artery stenosis or obliteration of the sinus using a PTA balloon for peripheral blood vessels, we attempted sinus obliteration using a large-diameter PTA balloon when introducing this procedure in 2008. However, it is impossible to obliterate the sinus using this balloon. As shown in **Fig. 1**, the presence of ONYX in a space that is not fully obliterated may result in occlusion of important veins such as the vein of Labbe. In addition, dilation at a high pressure may lead to occlusion of a shunt channels existing in the sinus wall; therefore, shunt obliteration with ONYX may be impossible (personal communication: Chapot) and it should not be used.

Conclusion

We introduced embolization of dAVFe under sinus preservation using a Shoryu (Kaneka Medics). If the balloon is carefully used in accordance with the precautions described above, a shunt can be obliterated under sinus preservation.

Disclosure Statement

The authors declare no conflict of interest.

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