Online September 1, 2020
Journal of Neuroendovascular Therapy 2021; 15: 64–70
DOI: 10.5797/jnet.tn.2020-0067

Technical Note

Usefulness of an Electromagnetic Navigation System for Direct Percutaneous Puncture of the Superior Ophthalmic Vein

Yoshiki Sato, Kenichi Hattori, Takeshi Okamoto, Shigeru Fujitani, Kentaro Wada, Tsuyoshi Saito, Taro Okumura, and Hisashi Hatano

Objective: We report a case of dural arteriovenous fistula (dAVF) at the cavernous sinus treated by direct puncture of the superior ophthalmic vein (SOV) using an electromagnetic navigation system.

Case Presentation: The case involved a 70-year-old male patient who presented with mild chemosis, proptosis, and abducens palsy of the right eye. In this case, we used an electromagnetic navigation system for direct puncture of the SOV. Angiographic obliteration of the fistula was confirmed and the visual symptoms recovered well after surgery. There were no complications associated with direct puncture of the SOV using the electromagnetic navigation system.

Conclusion: Direct puncture of the SOV to obliterate a dAVF is a possible alternative choice of treatment when the usual transvenous access route fails. To reduce the risk of complications, an electromagnetic navigation system is useful.

Keywords ▶ dural arteriovenous fistula, cavernous sinus, direct puncture, superior ophthalmic vein, electromagnetic navigation system

Introduction

Transvenous embolization (TVE) of sinusal-type dural arteriovenous fistula (dAVF), which exist in the sinus wall, is selected as a first-choice treatment in many cases because it facilitates radical treatment.

Recently, treatment by ONYX TAE has been routinely performed in many countries, but the neurotoxicity of ONYX was reported in patients with cavernous sinus dAVF; TVE is therefore selected.

In patients with dAVF, occlusion of a venous outflow tract develops with the progression of the diseases, making an approach to the affected sinus difficult and inducing aggressive features, which must be treated. Due to occlusion of a venous outflow tract, strategies to guide a microcatheter to the affected sinus are required in many cases.

Department of Neurosurgery, Japanese Red Cross Nagoya Daiichi Hospital, Nagoya, Aichi, Japan

Received: April 11, 2020; Accepted: June 23, 2020
Corresponding author: Yoshiki Sato. Department of Neurosurgery, Japanese Red Cross Nagoya Daiichi Hospital, 3-35, Michishitacho, Nakamura-ku, Nagoya, Aichi 453-8511, Japan
Email: yskysk449@yahoo.co.jp

Physicians attempt to reach the affected sinus using the Kurukuru method, in which the occluded sinus is tunneled, but it is technically difficult, requiring many hours in some cases.

Percutaneous puncture of the affected sinus or outflow vein facilitates the simplification of an approach, but it is relatively invasive. In this study, we report a patient in whom the use of an electromagnetic navigation system (Medtronic Stealth Station) facilitated a safe, simple approach to the affected sinus.

No study has reported direct percutaneous puncture of the superior ophthalmic vein (SOV) using an electromagnetic navigation system. We present this case as a new attempt and review the literature.

Case Presentation

Case

A 70-year-old man presented with conjunctival congestion of the right eye, palpebral edema, exophthalmos, and abducens nerve paralysis. Right external carotid angiography revealed a cavernous sinus dAVF fed by the right middle meningeal artery (MMA) as a main feeder (**Fig. 1A**, red arrow) and draining mainly into the right SOV. The inferior petrosal sinus (IPS) was occluded (**Fig. 1B**).

Based on preoperative three-dimensional (3D)-computed tomography angiography (CTA) findings in addition to the

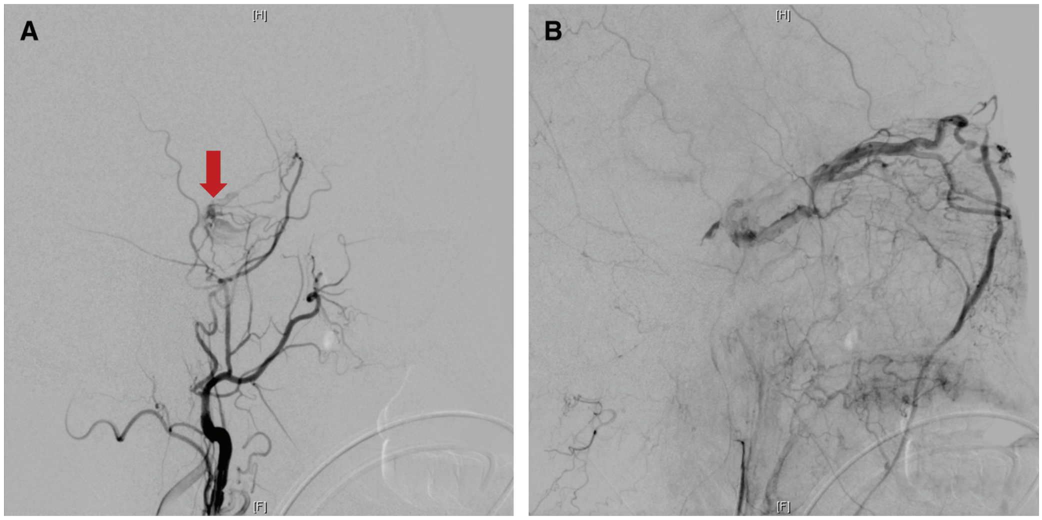

Fig. 1 Preoperative DSA images (right external carotid angiography) (**A**) Lateral view. A cavernous sinus dAVF was visualized, with the right MMA as a main feeder (red arrow). (**B**) Lateral view The right SOV functioned as a main drainage vein and the IPS was occluded. dAVF: dural arteriovenous fistula; DSA: digital subtraction angiography; IPS: inferior petrosal sinus; MMA: middle meningeal artery; SOV: superior ophthalmic vein

above findings, approaching via the superior or inferior roots of the SOV through the facial vein was considered to be difficult. An approach via the thrombosed IPS using the Kurukuru method was selected as the first option. We planned to adopt another approach to the affected sinus through direct puncture of the SOV if impossible. Initially, the thrombosed right IPS was tunneled using the Kurukuru method, but a route was unable to be secured, and the transfemoral approach was abandoned and switched to TVE through direct puncture of the SOV.

Treatment

Under general anesthesia, an electromagnetic navigation system (Medtronic Stealth Station) was used. Initially, a target site of SOV puncture was established before surgery (**Fig. 2A–2D**). The instrument tip was placed on the suprapalpebral sulcus and the passage route of a puncture needle was assessed to confirm that important structures, such as the eyeballs/blood vessels, were able to be avoided (**Fig. 3A** and **3B**). Even if puncture is conducted using a navigation system, there may be a puncture-related shift in the soft tissue in a deep area; therefore, the SOV was punctured using both the navigation system and digital subtraction angiography (DSA) to adjust this mechanical shift (**Fig. 3C** and **3D**).

After puncture of the SOV, an SL-10 (Stryker, Kalamazoo, MI, USA) and 0.014-inch CHIKAI (Asahi Intecc, Aichi, Japan) attached to a hemostatic valve were inserted into the needle (**Fig. 4A**). Usually, the SOV is large enough to avoid venous congestion by the insertion of a microcatheter (**Fig. 4B**).

The SL-10 was guided to the shunt point via the SOV, and a Target 360 ULTRA 4 mm x 15 cm (Stryker) was inserted as a first coil. Subsequently, a total of 19 coils, such as a Target HELICAL ULTRA (Stryker), SMART EXTRA SOFT (Penumbra Inc., Alameda, CA, USA), and SMART WAVE EXTRA SOFT (Penumbra Inc.), varying in size (total: 181 cm), were inserted. Angiography confirmed the disappearance of the shunt (**Fig. 5A** and **5B**).

In the present case, an ENVOY 6F (Codman & Shurtleff Inc., Randolph, MA, USA) was inserted into the right external carotid artery from the right femoral artery and an SL-10 1 marker (Stryker) was inserted into the right MMA for flow reduction if puncture failure induced venous hypertension.

Hemostasis was achieved by simple manual compression for 10 seconds after shunt obliteration. After surgery, there was no hematoma around the eyelid and puncture-related swelling of the right eyelid gradually reduced.

The postoperative course was uneventful. Conjunctival congestion and exophthalmos were reduced, and there was no oculomotor nerve paralysis.

Right abducens nerve paralysis remained. On the 6th postoperative day, the patient was discharged. During follow-up at the outpatient clinic, the course has been favorable.

Discussion

Transvenous approach routes to an affected sinus include the IPS, facial vein, superior petrosal sinus (SPS), SOV, and basilar plexus. However, tortuosity/stenosis or thrombosis of these routes may make access difficult.

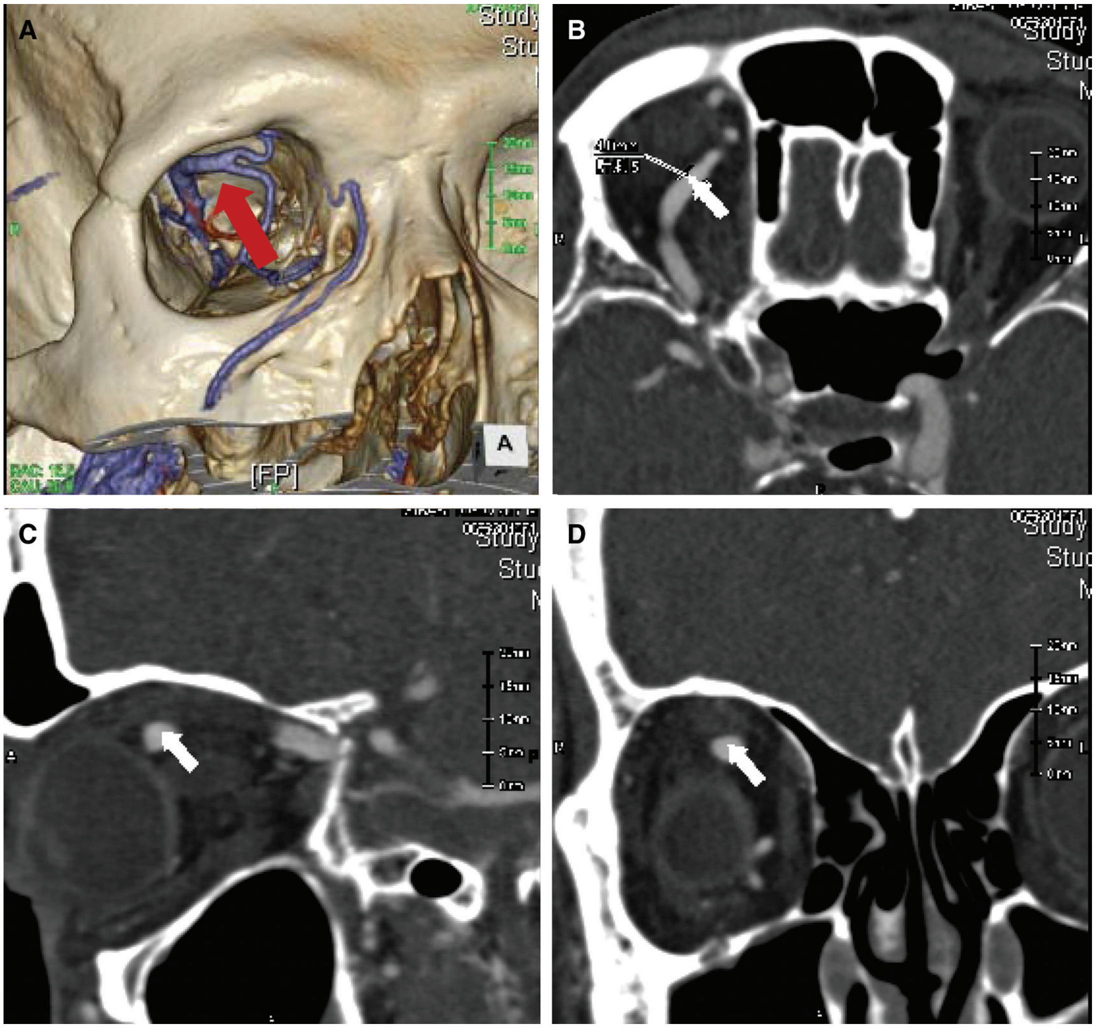

Fig. 2 Preoperative 3D-CTA. (**A**) Direct puncture of the SOV (red arrow) was planned. (**B, C, D**) Before surgery, a target was established. On preoperative assessment, the vascular diameter was approximately 4 mm. 3D-CTA: three-dimensional computed tomography angiography; SOV: superior ophthalmic vein

Currently, a trans-IPS approach using the Kurukuru method is frequently adopted. Thrombosed IPS passage is possible in many cases. A previous study reported that the cure rate after TVE via the IPS ranged from 54% to 99%. However, a specific time is required and the exposure dose increases; this may lead to an increase in the incidence of guidewire/catheter migration or migration-related complications.[1,2)]

Tang reported that neurological complications were observed in 4 of 20 patients in whom TVE was performed via the IPS with thrombosis-related occlusion, and the mean IPS approach time was 111 minutes.[3)]

In many patients with IPS occlusion, the SOV functions as a main drainage vein. The SOV itself is markedly swollen, but tortuosity/stenosis of the peripheral veins, such as the angular vein, are present, making transfemoral/-venous approaches difficult in many cases.[3,4)]

Previously, a microcatheter was inserted into the angular vein through a minor incision, but this was relatively invasive, being a disadvantage. Furthermore, an approximately 10-mm incision was required in many cases, being esthetically disadvantageous.

Several studies reported direct percutaneous puncture of the SOV under fluoroscopy or using cone-beam CT.[5–7)] However, on puncture failure, SOV blood flow may stagnate, aggravating symptoms. In this study, we measured the angle/depth of puncture using an electromagnetic navigation system to achieve accurate puncture. Using the electromagnetic navigation system (Medtronic Stealth Station), skull fixation with a head pin is unnecessary, and the seal-type

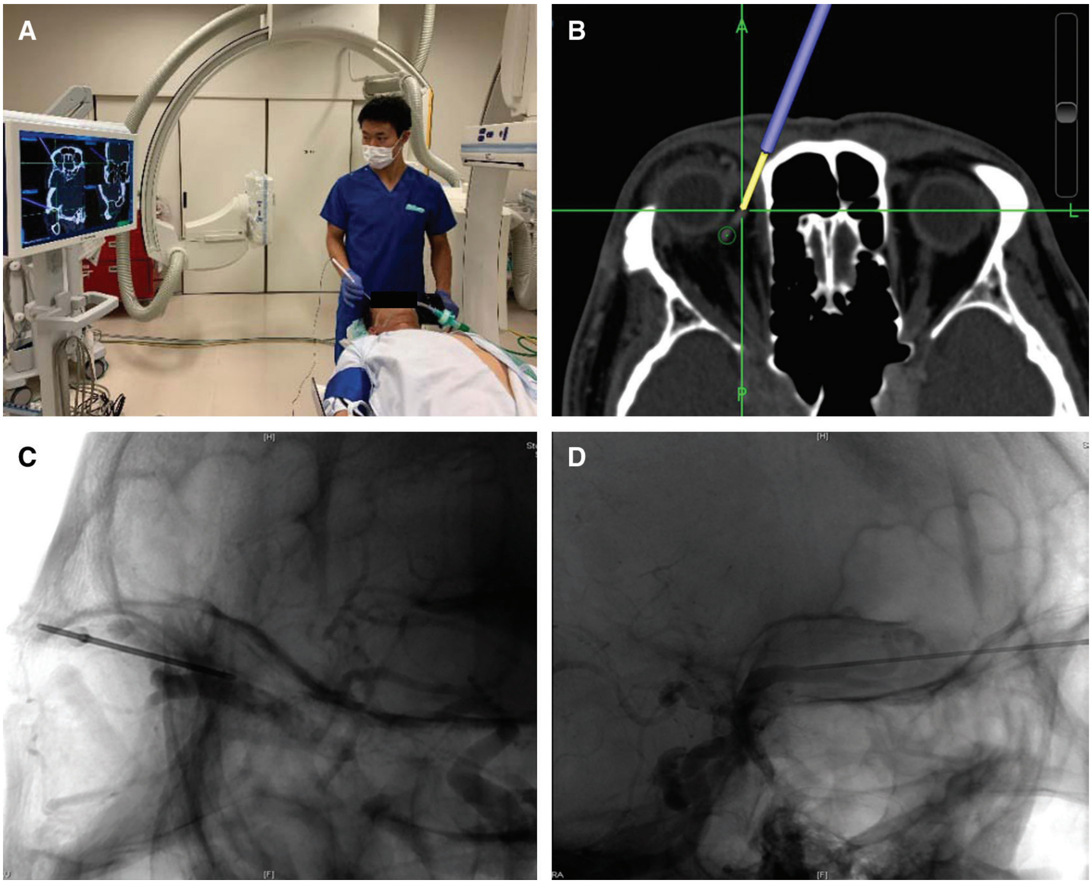

Fig. 3 Preoperative photograph, electromagnetic navigation image and intraoperative DSA images. (**A, B**) An entry point for the target was established, as shown in in **Fig. 2**, using an electromagnetic navigation system in order to avoid important structures, such as the eyeballs and blood vessels. (**C, D**) The deep area was directly punctured with an 18-G indwelling needle while confirming the SOV position in two directions on DSA. DSA: digital subtraction angiography; SOV: superior ophthalmic vein

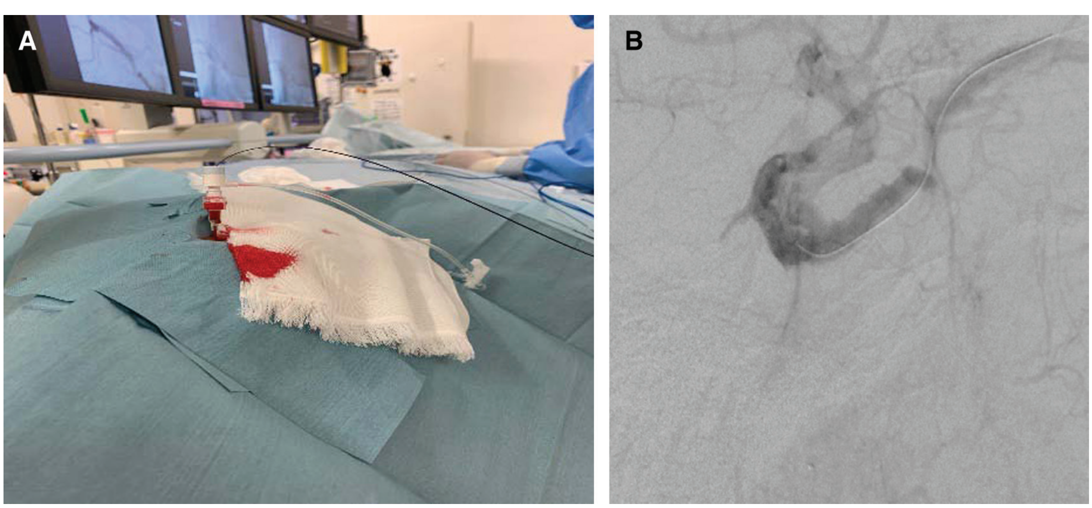

Fig. 4 Intraoperative images. (**A**) An SL-10 and 0.014-inch CHIKAI were guided into a check valve, and after inserting the former into the SOV following puncture, the check valve was attached to the indwelling needle. (**B**) The diameter of the SOV was sufficient for an SL-10. SOV: superior ophthalmic vein

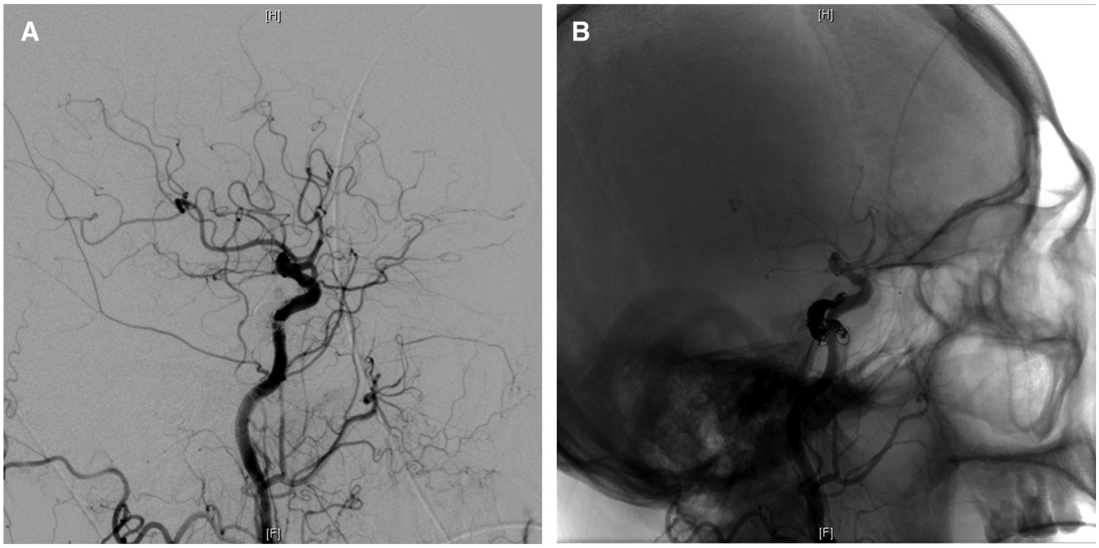

Fig. 5 DSA images after embolization. (**A, B**) Lateral view. DSA and DA confirmed the disappearance of the shunt. DA: digital angiography; DSA: digital subtraction angiography

electromagnetic reference frame attached to the forehead is small; therefore, it did not affect neuroendovascular surgery and this system was useful. In addition, an emitter (magnetic field generator) may be brought close to the patient only when using an electromagnetic navigation system; this can be operated by outside nurses. Therefore, preoperative fixation of an emitter was considered to be unnecessary.

Complications related to direct puncture of the SOV include ocular injury, intraorbital hemorrhage, postoperative subcutaneous palpebral hemorrhage, nerve injury, and internal carotid artery injury.[8]

Concerning ocular injury, mis-penetration of the sclera on puncture leads to rupture of the globe, requiring prompt surgical repair. The sclera is thin, and a previous study reported that when the sclera was penetrated, the risk of intraocular injury was higher than when the cornea was penetrated.[9] Postoperative low vision or loss of vision may be unavoidable. Regarding infection, endophthalmitis and unilateral sympathetic ophthalmitis may develop, although the latter is rare. In such cases, corticosteroid eye drops are effective, but the eye with irreversible injury is preventively extirpated before the onset of sympathetic ophthalmitis in some cases.[10,11]

The use of an electromagnetic navigation system facilitates the accurate assessment of the positions of important structures, such as the eyeballs/blood vessels, based on CT images, improving the safety and preventing complications, including ocular injury, as demonstrated in the present case.

Concerning the anatomical structure of the SOV, it is located in an area adjacent to the nasal side of the suprapalpebral sulcus on the body surface, and the mean vascular diameter is reportedly 2.2 mm.[12]

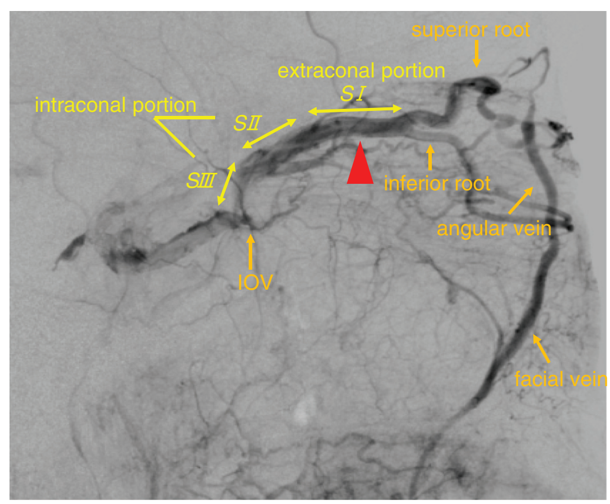

Fig. 6 Scheme of the anatomy around the SOV. After branching from the facial or frontal veins to the angular vein via the angular vein, the superior and inferior roots become one as the SOV. Then, it joins with the IOV and flows in the CS as an ophthalmic vein. SI, which was located in the extraconal portion, was directly punctured (red arrowhead). CS: cavernous sinus; IOV: inferior ophthalmic vein; SI: segment I; SOV: superior ophthalmic vein

The SOV is classified into three segments in the orbit. The course of segment I (SI) locates from the trochlea to extraconal portion in upper diagonal and horizontal directions. The course of segment II (SII) runs into the muscle cone, inferior surface of the superior rectus muscle, and posterolateral area. The confluence of the anterior apsidal vein as another branch from the facial vein, other than the angular vein, is regarded as a mark to distinguish SI from SII. After the posterior apsidal vein joins, segment III (SIII) is formed. Briefly, SI is located in the extraconal portion, and SII and SIII are located in the intraconal portion[4,12] (**Fig. 6**).

In the extraconal portion of the SOV, the venous wall is thicker than in its intraconal portion, and anatomically, it is present in the superficial layer; puncture can be performed safely, and hemostasis by manual compression from the body surface can be readily conducted when hemorrhagic complications develop during or after surgery. Therefore, when approaching by direct puncture, SI is targeted.[4]

When the SOV functions as a main drainage vein, it is swollen in many cases, as described above; therefore, the number of cases in which puncture is difficult is relatively small. In addition, direct puncture of the large-diameter SOV may not induce intraoperative venous congestion in comparison with the previously mentioned cut-down method in which a microcatheter is inserted into the surface veins such as the angular vein, superior root, and inferior root (**Fig. 6**). Therefore, the operative time could be shortened, being advantageous.

Concerning the cut-down method, one study suggested that when the SOV exists in a deep area, it is difficult to expose, increasing the risks of injury of the supraorbital nerve, levator palpebrae muscle or trochlear nerve, and infection.[13] In addition, skin incision has postoperative cosmetic problems.

However, when directly puncturing the SOV, the vascular diameter must be carefully evaluated. According to a previous study, a vascular diameter of 5 mm at minimum is necessary to safely insert a catheter.[7]

As the limitation of this study, for puncture, an 18-G needle was inserted along with an instrument tip, but this method may lead to a small giometrical error. In the future, a puncture needle that contains an instrument tip in the inner area, with a sharpness sufficient for soft tissue or SOV puncture, should be used. This facilitates simultaneous puncture under the use of an electromagnetic navigation system.

In the present case, a microcatheter was also placed on the arterial side for flow reduction in case of venous obstruction related to puncture failure. Embolization with ONYX is performed by approaching an area adjacent to a shunt via a transarterial access in some cases in many countries. A previous study demonstrated a high rate of shunt disappearance, whereas the incidence of cranial nerve disorder as a complication was 25%. This may have been associated with embolization involving a deep penetrating branch nourishing the cranial nerve or the neurotoxicity of ONYX.[14]

In addition, currently, transarterial embolization (TAE) of non-sinus-type dAVF with ONYX is sometimes performed through direct puncture of a dural branch adjacent to a shunt and catheter insertion to the puncture site.[15] In such cases, an electromagnetic navigation system may also be applied.

Conclusion

We reported a patient in whom the treatment of a cavernous sinus dAVF by direct puncture of the SOV was performed using an electromagnetic navigation system, leading to a favorable outcome.

Direct puncture of the SOV using an electromagnetic navigation system may be effective from the viewpoint of safety in the future.

Acknowledgment

This research was funded by Japanese Red Cross, Nagoya 1st. Hospital Research Grant NFRCH20-0020.

Disclosure Statement

The authors declare no conflict of interest.

References

1) Luo CB, Chang FC, Teng MM, et al: Transvenous embolization of cavernous sinus dural arteriovenous fistula via angiographic occlusive inferior petrous sinus. *J Chin Med Assoc* 2015; 78: 526–532.
2) Rhim JK, Cho YD, Park JJ, et al: Endovascular treatment of cavernous sinus dural arteriovenous fistula with ipsilateral inferior petrosal sinus occlusion: a single-center experience. *Neurosurgery* 2015; 77: 192–199; discussion 199.
3) Tang CL, Liao CH, Chen WH, et al: Endoscope-assisted transsphenoidal puncture of the cavernous sinus for embolization of carotid-cavernous fistula in a neurosurgical hybrid operating suite. *J Neurosurg* 2017; 127: 327–331.
4) Kurata A, Suzuki S, Iwamoto K, et al: Direct-puncture approach to the extraconal portion of the superior ophthalmic vein for carotid cavernous fistulae. *Neuroradiology* 2009; 51: 755–759.
5) Wakui D, Terada T, Oshima K et al: A case of carotid cavernous sinus fistula treated with a direct puncture to the thrombosed superior ophthalmic vein. *JNET J Neuroendovasc Surg* 2013; 7: 345–350.
6) Puffer RC, Lanzino G, Cloft HJ: Using XperGuide planning software to safely guide catheter access to the cavernous

sinus via transorbital puncture: a case report. *Neurosurgery* 2014; 10 Suppl 2: E370–373; discussion E373.
7) Fu ZY, Feng Y, Ma C, et al: Endovascular treatment of cavernous sinus dural arteriovenous fistulas via direct transorbital puncture using cone-beam computed tomography image guidance: report of 3 cases. *World Neurosurg* 2019; 130: 306–312.
8) White JB, Layton KF, Evans AJ, et al: Transorbital puncture for the treatment of cavernous sinus dural arteriovenous fistulas. *AJNR Am J Neuroradiol* 2007; 28: 1415–1417.
9) Loporchio D, Mukkamala L, Gorukanti K et al: Intraocular foreign bodies: a review. *Surv Ophthalmol* 2016; 61: 582–596.
10) Chronopoulos A, Ong JM, Thumann G, et al: Occult globe rupture: diagnostic and treatment challenge. *Surv Ophthalmol* 2018; 63: 694–699.
11) Li X, Zarbin MA, Bhagat N: Pediatric open globe injury: a review of the literature. *J Emerg Trauma Shock* 2015; 8: 216–223.
12) Reis CV, Gonzalez FL, Zabramski JM, et al: Anatomy of the superior ophthalmic vein approach for direct endovascular access to vascular lesions of the orbit and cavernous sinus. *Neurosurgery* 2009; 64: 318–323; discussion 323.
13) Thiex R, Gross BA, Gupta R, et al: Transvenous approach to carotid-cavernous fistula via facial vein cut down. *J Clin Neurosci* 2014; 21: 1238–1240.
14) Elhammady MS, Wolfe SQ, Farhat H, et al: Onyx embolization of carotid-cavernous fistulas. *J Neurosurg* 2010; 112: 589–594.
15) Oh JS, Yoon SM, Shim JJ, et al: Transcranial direct middle meningeal artery puncture for the onyx embolization of dural arteriovenous fistula involving the superior sagittal sinus. *J Korean Neurosurg Soc* 2015; 57: 54–57.