artifacts, diagnostic angiography was executed again from ECAs and accurate information was obtained regarding which branch of the ECA was involved. Also, a 6F guiding catheter was navigated to the ipsilateral internal jugular vein through the femoral vein, in which a 4F catheter was introduced coaxially.

After detection of the involved branches, a microcatheter was placed in one of the involved branches of the ECA, where superselective arteriography was performed to confirm the shunt segment.

The next step was performed in the venous side. Another microcatheter was introduced into the affected CS via the inferior petrosal sinus, which was approached by the 4F catheter regardless of its patency.[10, 11] In the affected CS, this venous-sided microcatheter was advanced to the major venous outlets, for instance, the superior ophthalmic vein, sphenoparietal sinus and superior petrosal sinus, to understand the structure of the affected sinus before reaching the shunt segment, and to secure accessibility of the major outlet even if SSSO failed to eliminate shunt flow.

On reaching the shunt segment, contrast was injected from the microcatheter in the feeding artery, followed by a contrast injection from the venous-sided microcatheter for superimposition. This maneuver, which we named "consecutive superselective arterio-venography", was performed to confirm the microcatheter on the venous side located in the shunt segment.

Finally, the shunt segment was obliterated with soft, electrically detachable coils.

Results

The characteristics of the cases in this series are summarized in Table 1. Among the 20 patients in this study, 15 were female and the mean age was 67.5 years old. Initial symptoms were ocular symptoms (chemosis and/or exophthalmos) in 13 and cranial nerve palsy in 11. The location of the shunt was clearly identified in 14 cases, and the shunt point was located outside the CS in 7 cases.

In all cases, the shunt was diminished by transvenous coil placement, and SSSO was defined as a coil mass not exceeding more than one compartment of the CS.

SSSO was achieved in 12 of 14 cases (85.7%) with shunts restricted to the small compartment. In two cases, SSSO was tried in vain; dislocation of the microcatheter out of the shunt segment before placement of sufficient coils for obliteration occurred in one case (case 7), and navigation of the microcatheter to one of the two shunt segments was failed in the other (case 18). Entire sinus packing was performed instead to eliminate the shunt in these two cases, in the same way as the remaining six cases with diffuse shunts.

Clinical follow-up was obtained in all cases with a mean of 40 (6 to 69) months. All patients were examined by an ophthalmologist before and after the procedure. During the follow-up period, referral to the ophthalmologist was performed whenever the patient complained of visual symptoms or the external ocular movement of the patient looked abnormal.

In cases treated by SSSO, whose mean follow-up period was 48 months, transient abducens nerve palsy occurred in 3 of 12 cases (25%) which was resolved within one month, whereas permanent cranial nerve palsy occurred in 2 cases (25%) with sinus packing.

Radiological follow-up was done by conventional angiography at three to six months after the procedure in eleven cases and by MRA in all cases annually, and no recurrence was detected in cases with SSSO. In two cases with sinus packing, however, recurrences of the shunts were detected and additional coil placement was executed.

Illustrative Cases

Case 5

This 76-year-old woman presented with right chemosis and abducens palsy. Cerebral angiography revealed a Barrow type D CSdAVF (Figs. 1A-B). At the time of the procedure, a microcatheter was advanced into the shunt segment by the transvenous approach. After the location of the microcatheter was confirmed by consecutive superselective arterio-venography (Figs. 1C-D), the shunt segment was obliterated with five bare platinum coils (Fig. 1E). Her symptoms disappeared immediately and she remained asymptomatic for 5 years without recurrence of the shunts.

Case 19

This 71-year-old man suffered from left abducens palsy and tinnitus. Cerebral digital subtraction angiography revealed a CSdAVF whose feeders were bilateral ascending pharyngeal arteries (Figs. 2A-B). A 3-D RA revealed two distinct shunt segments located just outside the medial compartment of the left CS (Figs. 2C-D). At the time of the procedure, a microcatheter was advanced to the shunt segment, with proper working angles obtained by 3-D RA. Shunt segments were obliterated with eight bare platinum coils following the confirmation step, resulting in the disappearance of the shunt and prompt resolution of his symptoms (Fig. 3).

Discussion

In treating CSdAVFs, TVE has been used for decades since the prevalence of neuroendovascular procedures, and obliteration of the cavernous sinus itself has been the standard procedure for years.[1, 2, 10, 12] This entire sinus packing, however, requires a certain amount of coils to eliminate shunt flow, and the mass effect of the coils in the sinus may result in subsequent cranial nerve palsy (CNP). Nishino et al. described that when the coil volume was >0.2cm^3, the occurrence of CNP was 77.8% in their series, and overpacking appeared to be the predominant cause of CNP.[3] Another report by Bink et al. reported that the incidence of persistent CNP was up to 44% with a mean follow-up period of 4.4 years.[4]

Recently, transarterial or transvenous embolization using Onyx, a liquid material, has also been reported by several authors. A complete cure for dural AVFs could be achieved with the use of this non-adhesive agent. However, unfavorable complications such as bradycardia, cranial nerve palsy, and gluing of the microcatheter, could not be ignored.[13, 14, 15] On the other hand, TVE enables the direct interruption of abnormal drainage to the orbit and cerebrum without damaging the branches of external carotid arteries that may supply the cranial nerves. Thus, we chose transvenous embolization as the first line therapy in this study. Unavailability of Onyx for treating dural AVFs in Japan was another reason.

Our data demonstrated the excellent results of SSSO in CSdAVFs. In all 12 cases with SSSO, initial symptoms were resolved within one month; only 3 patients (25%) had postprocedural transient abducens palsy and permanent deficits were reported in none. The possible cause of transient symptoms may be due to the inflammatory effect of the rather small coil mass to the abducens nerve, which only lasted for a short period. Clinical and radiographic follow-up showed no recurrence over three years.

This idea has already been reported in several articles. Nakamura et al. first reported three cases of selective venous embolization, in which many coils were placed in more than two compartments of the CS.[6] Piske et al. reported twelve cases of superselective transvenous sinus occlusion, in which only two cases were CSdAVFs.[7] Agid et al. also reported two cases, in which transvenous approaches via the facial vein were focused on.[8] Although they showed cases with CSdAVFs treated by selective venous embolization, none of them depicted details of this procedure. To our knowledge, this is the first detailed description of the technical tips for this method.

There are four indispensable steps to achieve SSSO: (1) identification of the shunt point, (2) navigation of the microcatheter to the shunt segment (including shunt point and the adjacent venous component), (3) confirmation of the microcatheter (from the venous side) located at the targeted shunt segment, and (4) obliteration of the shunt segment.

Identification of the shunt is mainly done by diagnostic angiography with fast sequences of 4 to 6 frames/seconds. Instead of selective venography in the CS, superposing the early arterial phase with full venous phases, and using oblique views as reported in previous reports[6, 7], we preferentially used 3-D RA to clarify the location of shunts. 3-D RA usually showed the arterial segment as denser than the venous component in fistulous lesions, thus allowing comprehensive visualization of the fistulas. Furthermore, the working angles at the time of the procedure could be easily obtained. If available, a 3-D C-arm mounted FPD cone-beam CT system may also be useful in this identifying step as reported by Hiu et al.[16]

Navigation of the microcatheter to the shunt segment was easy when the angioarchitecture of the affected CS was clearly demonstrated by angiograms with appropriate working angles obtained by 3-D RA.

Exploring the CS with the microcatheter before reaching the shunt segment is important to understand the structure of the CS. Access to the major venous outlets such as the superior orbital vein or sphenoparietal sinus should be assessed and assured in case SSSO failed to eliminate the shunt. SSSO failed in two cases in this series, in which sinus packing was performed subsequently with ease due to this exploration before starting SSSO.

Confirmation of the position of the microcatheter is usually achieved by consecutive superselective arterio-venography. This method is superior to superselective venography, as it clearly visualizes shunt flow exclusively to assure proper positioning of the microcatheter located in the venous side.

Obliteration of the shunt segment was performed with soft coils, as the shunt segment in each case was a small space, and also to prevent dislocation of the microcatheter from the segment.

As to the location of the shunt, we report an interesting finding in the present study. In 7 of 12 cases with SSSO, the shunt segment was found outside the CS. This para-cavernous venous plexus is reported to exist frequently.[17] The reason why shunts were located in these para-cavernous structures still remains unknown, as para-cavernous structures are constructed in the fetal stage, whereas dural AVFs are known to be an acquired disease.[18, 19] A possible explanation for this question is that inflammation, which is considered to be the cause of the occurrence of dural arteriovenous shunts, may be more prone to take place in these restricted small structures than the vast sinus wall itself.[20]

There are several limitations to this study. This is a retrospective study from a single center experience. And the total number of patients is rather small, thus the success rate of SSSO may vary with the accumulation of cases. Furthermore, longer follow-up may be required to ensure that there is no clinical or radiological recurrence.

Nevertheless, the technical details described here are very comprehensive and should be considered useful to physicians who deal with neuroendovascular therapy.

Conclusion

In treating CSdAVFs, superselective shunt occlusion could be achieved in considerable cases with excellent long-term results. The appropriate use of 3-D RA and consecutive superselective arterio-venography provides enough information to perform this method, which should be considered before sinus packing or mere obliteration of dangerous venous outlets.

References

1. Lucas C, Zabramski JM, Spetzler RF, Jacobowitz R.Treatment for intracranial dural arteriovenous malformations: a meta-analysis from the English language literature. Neurosurgery. 1997;40(6):1119-1130.
2. Kirsch M, Henkes H, Liebig T, et al. Endovascular management of dural carotid-cavernous sinus fistulas in 141 patients. Neuroradiology. 2006;48(7):486-490.
3. Nishino K, Ito Y, Hasegawa H, et al. Cranial nerve palsy following transvenous embolization for a cavernous sinus dural arteriovenous fistula: association with the volume and location of detachable coils. J Neurosurg. 2008;109(2):208-214.
4. Bink A, Goller K, Lüchtenberg M, et al. Long-term outcome after coil embolization of cavernous sinus arteriovenous fistulas. AJNR Am J Neuroradiol. 2010;31(7):1216-21.
5. Yoshida K, Melake M, Oishi H, Yamamoto M, Arai H. Transvenous embolization of

dural carotid cavernous fistulas: a series of 44 consecutive patients. AJNR Am J Neuroradiol. 2010;31(4),651-655.

6. Nakamura M, Tamaki N, Kawaguchi T, Fujita S. Selective transvenous embolization of dural carotid-cavernous sinus fistulas with preservation of sylvian venous outflow. Report of three cases. J Neurosurg. 1998;89(5):825-829.

7. Piske RL, Campos CM, Chaves JB, et al. Dural sinus compartment in dural arteriovenous shunts: a new angioarchitectural feature allowing superselective transvenous dural sinus occlusion treatment. AJNR Am J Neuroradiol. 2005;26(7):1715-1722.

8. Agid R, Willinsky RA, Haw C, Souza MP, Vanek IJ, terBrugge KG. Targeted compartmental embolization of cavernous sinus dural arteriovenous fistulae using transfemoral medial and lateral facial vein approaches. Neuroradiology. 2004;46(2):156-160.

9. Debrun GM. Angiographic workup of a carotid cavernous sinus fistula (CCF) or what information does the interventionalist need for treatment? Surg Neurol 1995;44:75-79.

10. Yamashita K, Taki W, Nishi S, et al. Transvenous embolization of dural caroticocavernous fistulae: technical considerations. Neuroradiology. 1993;35(6),475-479.

11. Benndorf G, Bender A, Lehmann R, Lanksch W. Transvenous occlusion of dural cavernous sinus fistulas through the thrombosed inferior petrosal sinus: report of four cases and review of the literature. Surg Neurol. 2000;54(1):42-54.

12. Theaudin M, Saint-Maurice JP, Chapot R, et al. Diagnosis and treatment of dural carotid-cavernous fistulas: a consecutive series of 27 patients. J NeurolNeurosurg Psychiatry. 2007;78(2):174-179.

13. Elhammady MS, Wolfe SQ, Farhat H, Moftakhar R, Aziz-Sultan MA. Onyx

embolization of carotid-cavernous fistulas. J Neurosurg. 2010;112(3):589-594.

14. Lv X, Jiang C, Zhang J, Li Y, Wu Z. Complications related to percutaneous transarterial embolization of intracranial dural arteriovenous fistulas in 40 patients. AJNR Am J Neuroradiol. 2009;30(3):462-468.

15. Natarajan SK, Ghodke B, Kim LJ, Hallam DK, Britz GW, Sekhar LN. Multimodality treatment of intracranial dural arteriovenous fistulas in the Onyx era: a single center experience. World Neurosurg. 2010;73(4):365-79.

16. Hiu T, Kitagawa N, Morikawa M, et al. Efficacy of DynaCT digital angiography in the detection of the fistulous point of dural arteriovenous fistulas. AJNR Am J Neuroradiol. 2009;30(3):487-491.

17. Tanoue S, Kiyosue H, Okahara M, et al. Para-cavernous sinus venous structures: anatomic variations and pathologic conditions evaluated on fat-suppressed 3D fast gradient-echo MR images. AJNR Am J Neuroradiol. 2006;27(5):1083-1089.

18. Mironov A. Pathogenetical consideration of spontaneous dural arteriovenous fistulas (DAVFs). ActaNeurochir (Wien). 1994;131(1-2):45-58.

19. Chaudhary MY, Sachdev VP, Cho SH. et al. Dural arteriovenous malformation of the major venous sinuses: an acquired lesion. AJNR Am J Neuroradiol 1982;3(1):13-19.

20. Miyachi S, Izumi T, Matsubara N, Naito T, Haraguchi K, Wakabayashi T. Mechanism of the formation of dural arteriovenous fistula: the role of the emissary vein. Interv Neuroradiol. 2011;17(2):195-202.

Figure Legends

Figure 1: Case 5. Branches of both the right ICA (lateral view, A) and ECA (lateral view, B) were involved and diagnosed as a Barrow type D CSdAVF. The middle meningeal artery and the artery of foramen rotundum were the feeding arteries from right ECA. During the procedure, a microcatheter was located in right MMA and another microcatheter was in the

para-cavernous vein. The shunt and CS were visualized by arterial injection (C), followed by venous injection (D) to confirm the tip of the venous-sided microcatheter in the shunt segment. The tip of the venous-sided microcatheter is indicated by an arrow, and the course of the microcatheter is indicated by arrowheads. The shunt segment was obliterated with five bare platinum coils.

Postprocedural angiograms of the right CCA (lateral view, E) showed the extirpation of the shunt. Note the small size of the coil mass that was located inferior to the right ICA.

Figure 2: Case 19. Angiograms of the right (A) and left (B) ECA showed the involvement of bilateral ascending pharyngeal arteries (APhA) as feeders, and the shunt flow was draining into the left superficial middle cerebral vein. 3-D rotational angiograms from the right APhA and left ECA were shown in 2C and 2D, respectively. The shunt point from the right APhA was encircled with white dots (C), while the shunt from the left APhA was encircled with white line (C, D). By synchronizing the angles of 3-D angiograms, shunt points were found to be distinct although connected.

Figure 3: Intraprocedural angiograms of case 19. The shunt from the right APhA was treated first. The confirmation step was executed by consecutive superselective arterio-venography (A: injected from the right APhA, B: injected from the microcatheter at the venous side) to assure the location of the microcatheter. The tip of the microcatheter is indicated by black arrows in 3A and 3B. After successful coil placement in the shunt segment from the right APhA, the same procedure was performed for the shunt from the left APhA. The shunt segments were obliterated with a total of eight bare platinum coils (C). Postprocedural angiograms of the right (D) and the left CCA (E) showed extirpation of the shunt.

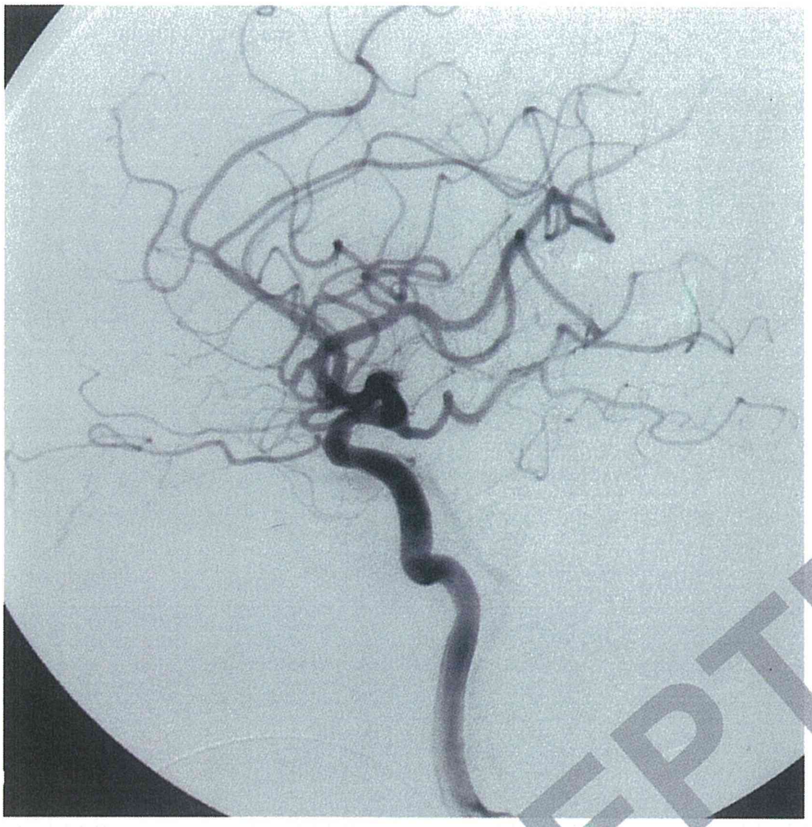
Table 1 **Profiles and characteristics of the cases in this study**

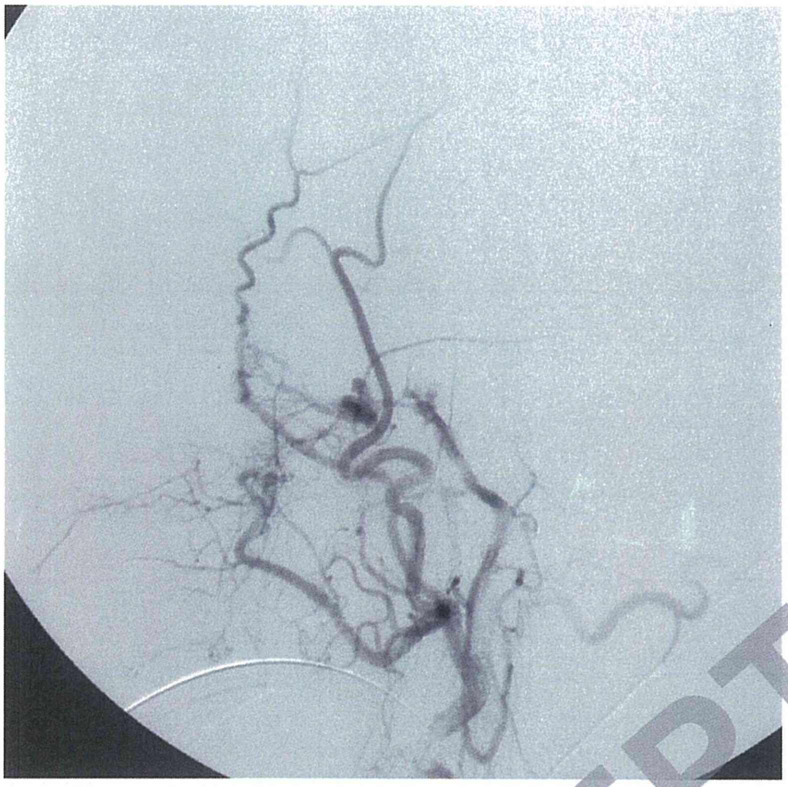
Case No.	age	sex	side	Barrow type	Initial symptoms	shunt location	SSSO	worsening of symptoms post IVR	persistent or newly developed symptoms	duration (days)	FU period (months)
1	62	F	R	D	C, VI	AI*	Yes	Yes	VI	7	59
2	50	F	L	C	C, E	PS	Yes	No	none		69
3	75	F	R	D	C, VI	AI*	Yes	No	none		60
4	76	F	R	C	C, E, VI	AI*	Yes	No	none		65
5	58	M	L	D	C, E, VI	AI*	Yes	No	none		59
6	73	F	R	D	C, E	diffuse	No	Yes	C	8	54
7	22	F	L	D	V	AI	No	Yes	VI	1	52
8	68	M	R	D	C, E, VI	diffuse	No	Yes	III, VI	permanent	52
9	64	F	R	D	C, E	PS†	Yes	Yes	VI	2	52
10	67	M	R	D	VI	PS	Yes	Yes	VI	30	44

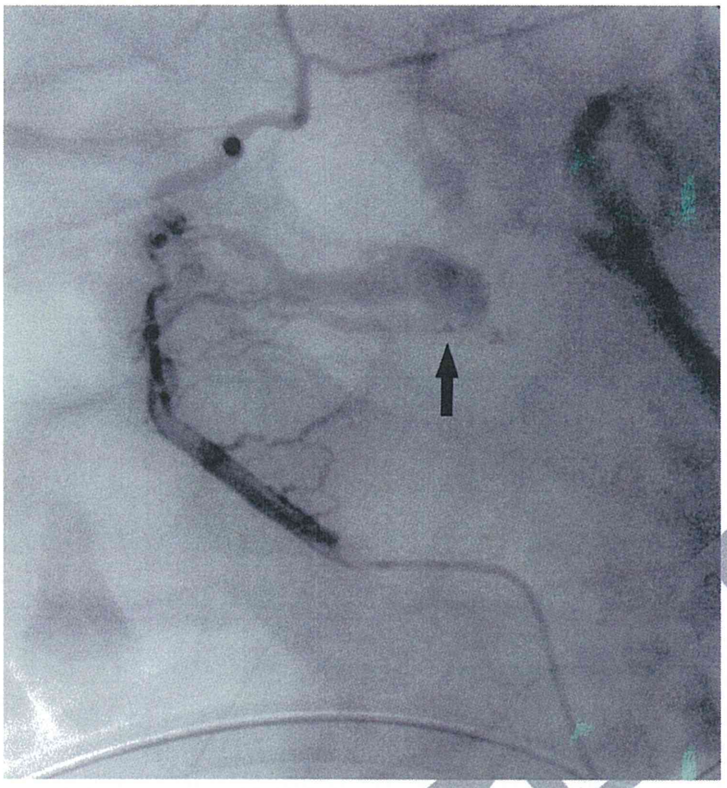
11	74	F	L	D	E	PS	Yes	No	none		36
12	76	F	B	D	C, E	diffuse	No	Yes	VI	90	24
13	70	F	R	D	C, VI	PS	Yes	No	none		33
14	83	F	L	D	C, VI	PS	Yes	No	none		24
15	42	F	R	D	V	diffuse	No	Yes	III, VI	permanent	24
16	63	F	R	D	none	diffuse	No	No	none		20
17	63	F	L	D	C, VI	diffuse	No	No	none		18
18	53	M	R	D	VI	PS, M	No	Yes	III, VI	7	12
19	71	M	L	C	VI	PS†	Yes	No	none		6
20	76	F	R	B	C, E	M*	Yes	No	none		6

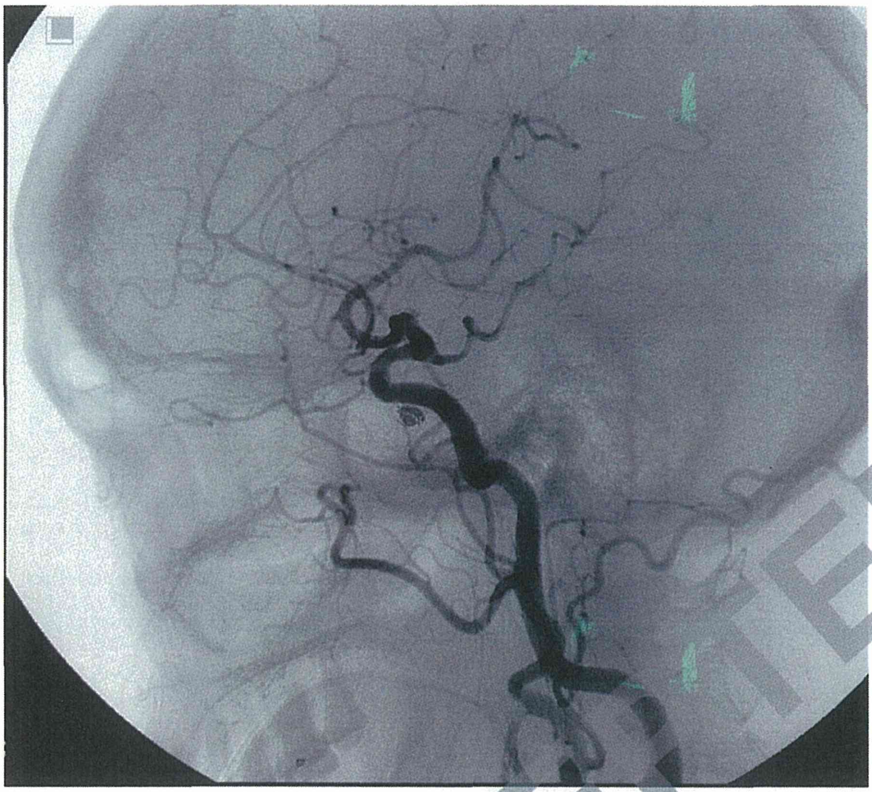
Abbreviations:

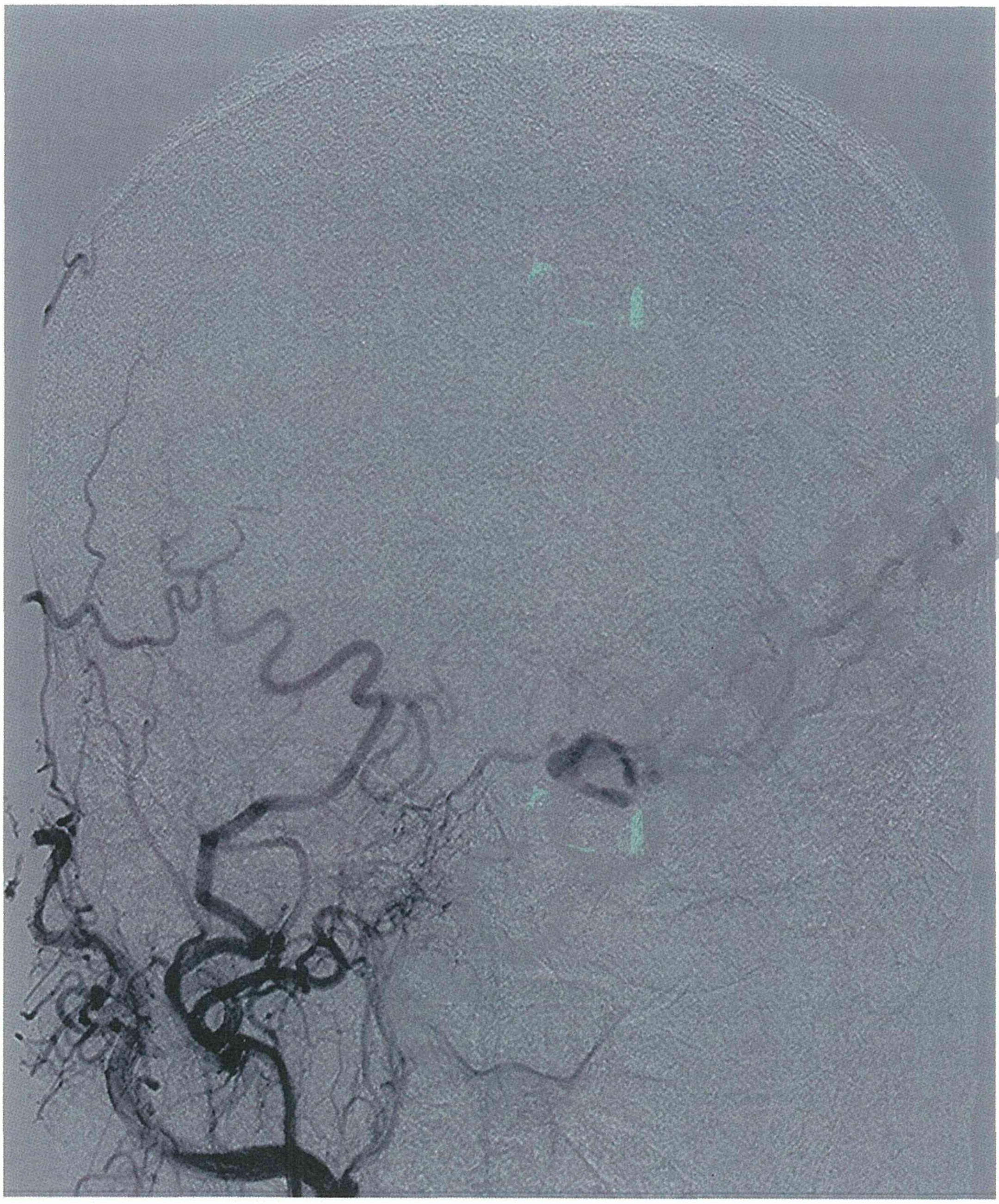
IVR: interventional radiology, FU: follow-up, C: chemosis, E: exophthalmos, III: oculomotor palsy, V: trigeminal dysesthesia in V1 lesion, VI: abducens palsy, AI: anteroinferior compartment, M: medial compartment, PS: posterosuperior compartment, * indicates the shunt located in para-cavernous region, † indicates two distinct shunts located in para-cavernous region.



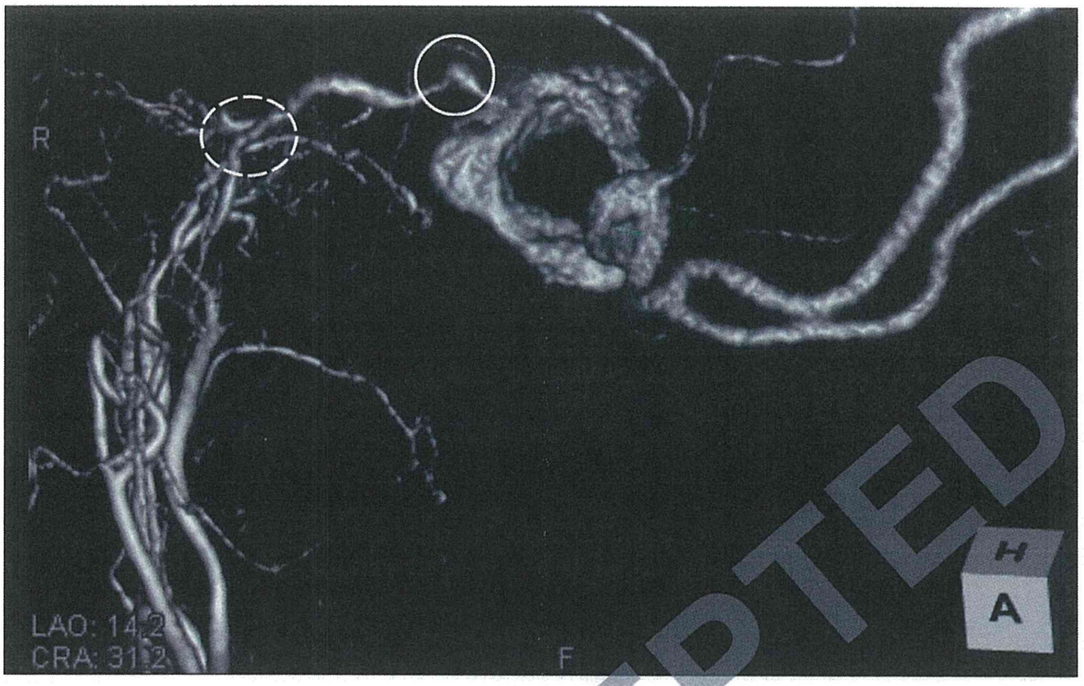


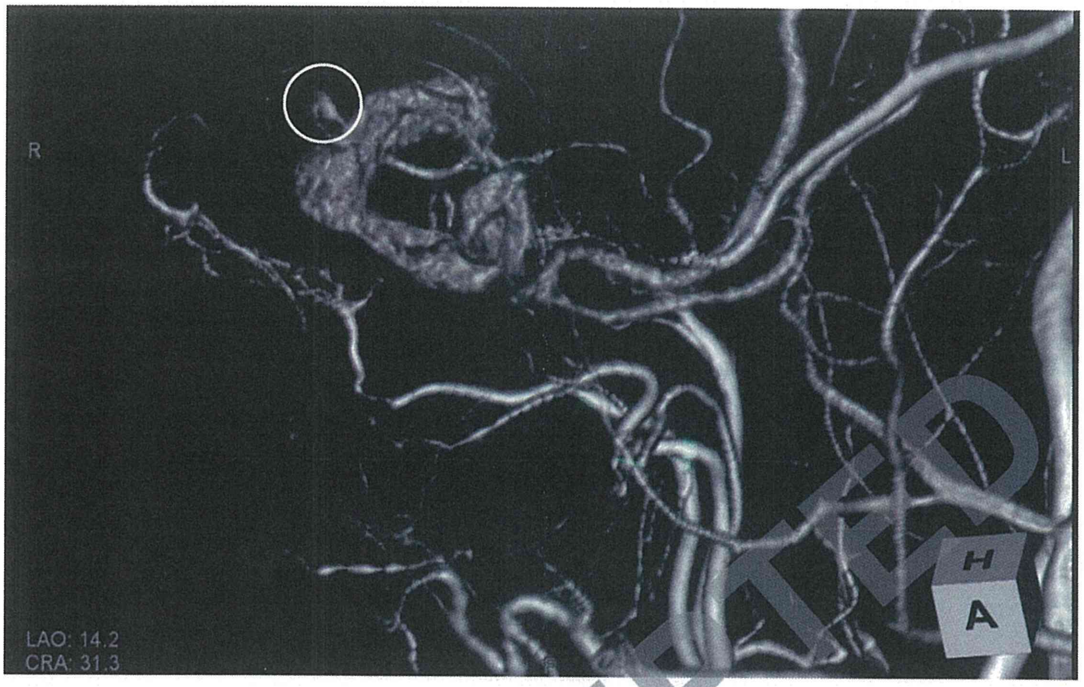







ACCEPTED


R
LAO: 14.2
CRA: 31.2
F
H
A


R
L
LAO: 14.2
CRA: 31.3
H
A