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Endovascular Approaches to the Carotid Cavernous Sinus for Endovascular Treatment of Carotid Cavernous Fistulas and Hormone Sampling

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1. Introduction

1.1 Venous morphology of the cavernous sinus

A precise knowledge of the venous morphology of the carotid cavernous sinus is essential in order to choose the appropriate access routes to the cavernous sinus. The sinus is trabeculated and subdivided in compartments. Newton and Potts [1] mentioned two parts, the anterior and posterior part. The anterior receives blood from the superior ophthalmic vein (SOV), inferior ophthalmic vein (IOV), sphenoparietal sinus and superficial middle cerebral vein (sylvian vein). We prospectively investigated the morphology of the cavernous sinus in recent ten consecutive dural carotid cavernous fistula (CCF) patients treated using three dimensional (3D) coils. All CCFs of our series except two were mainly under the internal carotid artery. According to our findings, we divided all cavernous sinuses into three compartments: the antero-lateral; intermediate; and postero-medial (Fig 1). The antero-lateral compartment combined with the postero-medial compartment make up the anterior part of Newton and Potts [1]. The antero-lateral compartment receives blood as mentioned above and sometimes from the olfactory vein and deep middle cerebral veins. The intermediate compartment receives blood from the pterigoid plexus. The postero-medial compartment corresponds to the posterior part of Newton and Potts [1]. The postero-medial compartment mainly receives blood from the inferior petrosal sinus (IPS). The two cavernous sinuses communicate with each other by way of coronary (anterior and posterior intercavernous) sinuses anteriorly and occipital transverse sinus posteriorly.

1.2 Transvenous approaches to the CS

Transvenous approaches to the carotid cavernous sinus are used for endovascular treatment of carotid cavernous fistulas (CCFs) and venous hormone sampling [2,3]. Various kinds of venous approaches have been reported: the inferior petrosal sinus (IPS) route was the first established and most commonly used [4-6], especially for venous hormone sampling[2,3]. When the ophthalmic vein [7-20], superior petrosal sinus (SPS) [21] and pterigoid plexus (PP) [22] are involved in venous drainages of CCFs, each venous channel may become an appropriate access route.
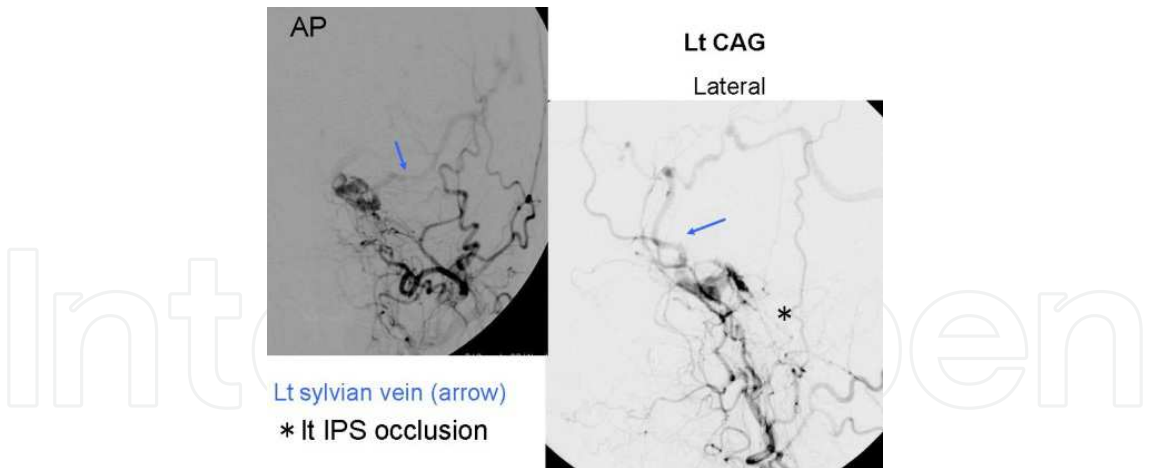
Fig. 1A. Left carotid angiogram (lt CAG) (AP: anteroposterior view, lateral: lateral view) showing a dural CCF draining into the sylvian vein only (arrow) and occlusion of the left inferior petrosal sinus (IPS) (∗)
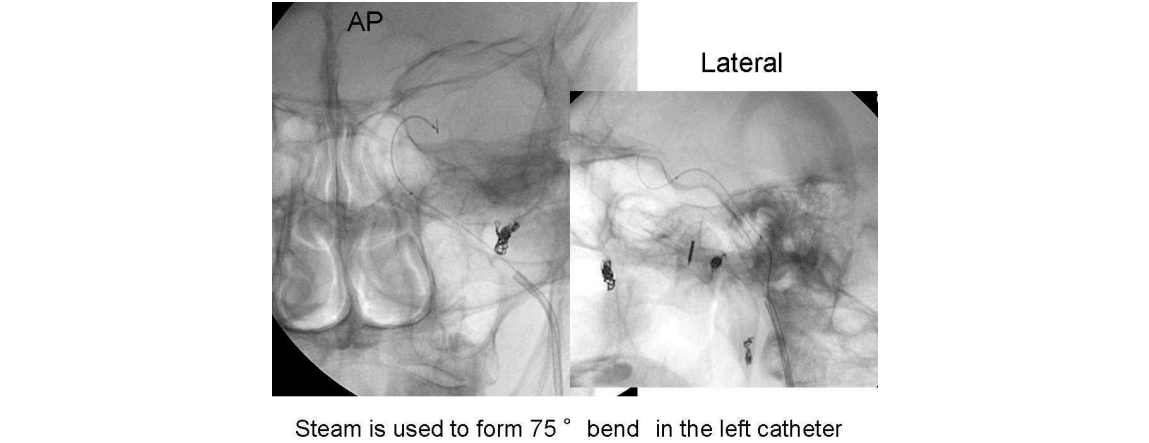

Fig. 1B. Skull radiograph (AP: anteroposterior view, lateral: lateral view) showing the running of the inferior petrosal sinus (IPS) with the aid of a microcatheter and catheter.
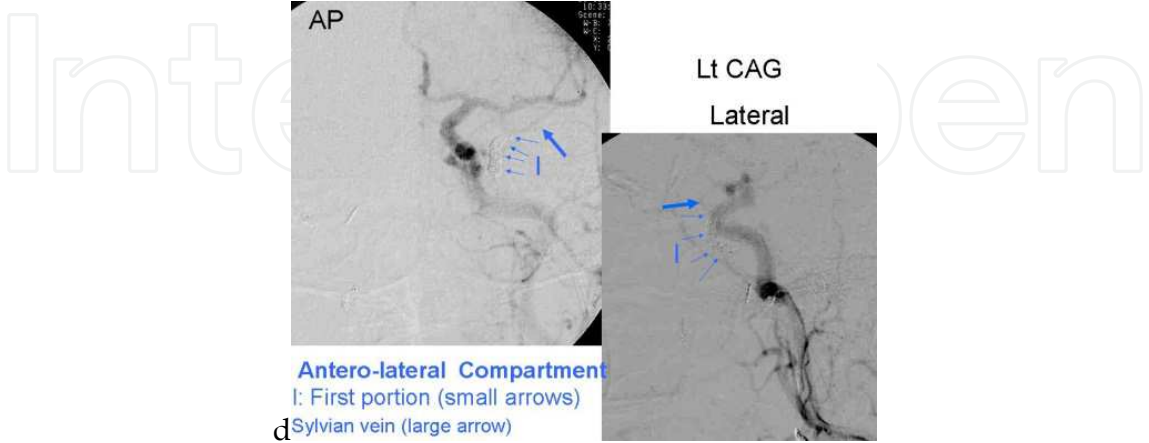

Fig. 1C. Left carotid angiogram (CAG)(AP: anteroposterior view, lateral: lateral view) showing the antero-lateral compartment(I: First portion) of the cavernous sinus (4 small arrows) and sylvian vein (large arrow)

Endovascular Approaches to the Carotid Cavernous Sinus for
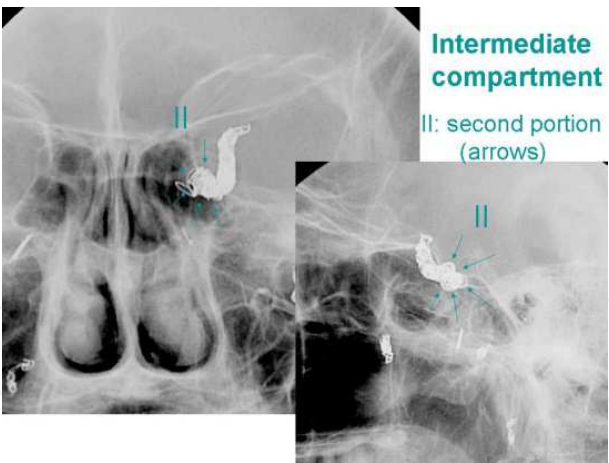Endovascular Treatment of Carotid Cavernous Fistulas and Hormone Sampling

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Fig. 1D. Skull radiograph (left: anteroposterior view, right: lateral view) showing the intermediate compartment (II: second portion) (arrows) of the cavernous sinus.
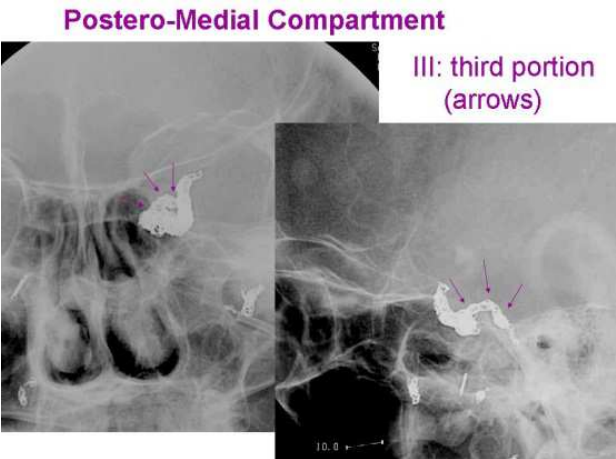

Fig. 1E. Skull radiograph (left: anteroposterior view, right: lateral view) showing the posteromedial compartment (III: third portion) (arrows) of the cavernous sinus
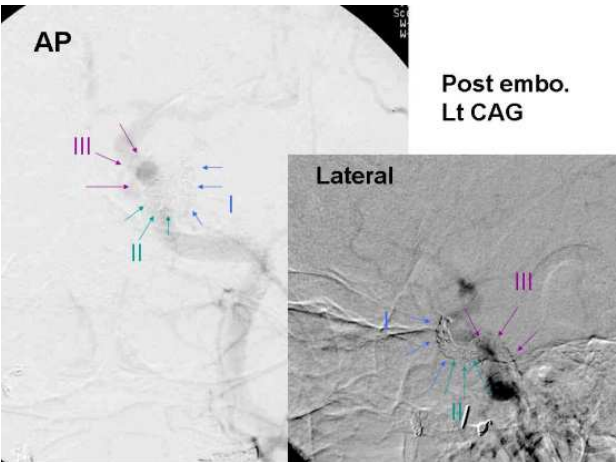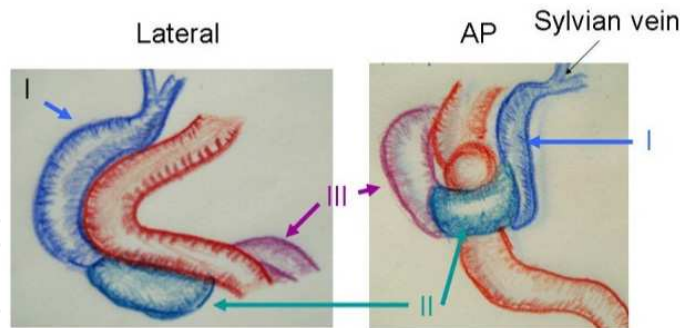

Fig. 1F. Left carotid angiogram (CAG)(AP: anteroposterior view, lateral: lateralview) showing the three compartments of the cavernous sinus(I: first portion=antero-lateral compartment, II: second portion=intermediate compartment, III: third portion=postero-medial compartment)

Schematic drawing of the left cavernous sinus

I: first portion(antero-lateral compartment)
II: second portion (intermediate compartment)
III: third portion (postero-medial compartment)

Fig. 1G.

2. Alternative approaches

1. Transvenous approach to the carotid-cavernous via the inferior petrooccipital vein
2. Direct puncture approach to the extraconal portion of the superior ophthalmic vein

3. Indications and contraindications of each procedure

The transvenous approach via the IPS [4-6] for dural CCF and hormone sampling [2,3] from the cavernous sinus is the standard access route. However, when there is obstruction of the IPS or other problem such as non-communication with the jugular vein, other venous drainage routes should be attempted. Benndorf G, et al [5] described that a thrombosed IPS may also become an alternative transvenous approach route for dural CCFs, reporting four cases and a review of the literature. Obstructions caused by secondarily formed thrombi which are not organized or old may allow introduction of a microcatheter preceded by a guide wire.

However, when the obstruction of the IPS is stiff with an organized old thrombus [11], the another access route to the cavernous sinus is needed. In our series, with two (cases 1 and 2) (11%) of 18 dural CCF patients the conventional venous approach via the IPS failed [23]. These two patients were referred to our institute more than 1 year after development of initial symptoms, which may have contributed to obstruction of the IPS with an organized old thrombus.

Shiu et al.[24] described that the IPS does not join the IJV, sometimes emptying directly into the anterior condylar vein (7%). Mitsuhashi et al. [25] demonstrated the IPS drainage directly into the vertebral plexus with no connection to the IJV in 3/83 sides (3.6%) and the IPS was absent in 14/ 83 sides (16.9%). In our series also, absence of connection with the IJV was noted in one (10%) of 10 venous sampling procedures from the cavernous sinus in five patients [23].

Yamashita et al [6] reported complications occurring in 7 of 16 patients with TVE. One was epidural extravasation from perforation of the inferior petrosal sinus. Major complications especially will occur in cases with cortical venous reflux. Araki et al.[26] reported such a case featuring extravasation from the uncal vein during TVE for SOV and IOV via the IPS. They emphasized that it is important to obliterate the cortical venous drainage as early as

possible, even if the reflux is small. Watanabe et al [27] reported a patient with a dural CCF in whom the cavernous sinus received normal cortical venous drainage from the insular vein. Nakamura et al.[28] emphasized preservation of sylvian venous flow because the affected cavernous sinus received not only the shunted flow but also sylvian venous drainage in three cases (12%) of 26 dural CCFs.

Targeting TVE using minimum coils may become an ultimate treatment after being first established by TAE useful to reduce the arterial inflow and the affected lesions. In dural CCF patients, bilateral cavernous sinuses and also ICS are often widely involved [29] which is important to chose the right treatment strategy. In dural CCF patients with wide involvement of the sinuses (bilateral CS and bilateral CS &ICS types), especially with a cortical venous reflux, TAE for initial reduction of inflow has been recommended as a reasonable approach to avoid serious complications because of the comparative non-aggressive nature of the disease. Kupersmith et al [30] reported complications in 5 of 38 cases with dural CCF by TAE, but four of these were due to IBCA treatment. Particles provides safer emboli compared with liquid material. In our series of TAE using only particles, no complications were encountered [31]. Repeated provocative testing and care of dangerous anastomoses are also important to avoid untoward outcome.

When the SOV route is accessible it may be the first choice. However, the distal roots of the SOV often show focal narrowing and tortuosity, which make difficulty in the conventional transvenous approach via the SOV difficult. Direct exposure of the SOV roots under general anesthesia is widely used [7-14,] but may be complicated. Direct exposure may damage the superior root of the fifth nerve resulting in numbness of the forehead [17]. Furthermore, it may also cause palsy of the superior levator muscle resulting in palpebral ptosis

Direct-puncture approach to the intraconal portion of the SOV has been reported in the literature [13, 15-20]. This method is a useful in cases with a dilated SOV only within the intraconal segment, according to the thrombosed branches of the SOV [17]. However, the possibility of damage to the optic nerve, cranial nerves III-VI and ophthalmic arterial divisions needs to be taken into account. With deep-puncture (the posterior third of the SOV [17], the posterior half of the SOV [18], the superior orbital fissure [19] to the SOV) precise access and prevention of bleeding from the puncture point is usually difficult. Massive retro-orbital bleeding may occur and result in an untoward increase of orbital pressure [13].

It is recommended that dural CCF patients without aggressive symptoms, aged more than 70 years, classified as Barrow type B [32], and/or with slow flow and mild inflow into the cavernous sinus be conservatively treated because spontaneous cure is not rare. In our series, eleven out of 76 dural CCF patients were selected for this option, three being aged more than 70 years old. Five others were classified as Barrow type B and the remaining three demonstrated slow and mild inflow. All lacked aggressive symptoms like decrease of visual acuity, severe retro-orbital pain or cranial nerve palsies. Radiological findings revealed no cortical venous reflux. In 9 of the 11, all except one fistulas were completely occluded on MRA after 1months to 13 years 5 months (average: 5 years 3 months). One patient was still exhibited a residual fistula on follow-up angiography 1 year after the initial symptoms. Another was complicated with central retinal thrombosis during follow-up period and the other 2 patients were lost to follow-up.

Dural CCF patients with aggressive symptoms and or cortical venous reflux on angiography are indicated for reduction of arterial inflow first by TAE followed by TVE.

For the high flow CCF patients with a traumatic and/or aneurysmal nature, urgent treatment with TVE or TAE via the internal carotid artery [33] is recommended because hemorrhage and /or congestive infarction may occur frequently in the early clinical course.

4. Key steps for each procedure

i.   **IPS approach** [4-6]

The IPS enters the anteromedial aspect of the internal jugular vein (IJV), approximately 2mm in diameter, about 6mm inferior to the level of the entrance of the jugular foramen. It courses just lateral to the clivus, along the posterior inferior edge of the petrous ridge. The right IPS runs at an acute angle and left at an obtuse angle. Steam is used to form 95 °bend in a right catheter (Fig 1B) and 75 °bend in a left catheter 2. Shiu et al. 24 described four types of variation of the junction between the IPS and the internal jugular vein (IJV), on the basis of their experience with cavernous sinus venography. In type I, the IPS anastomosis with the IJV and the anterior condylar vein is small or absent (45%). In type II, the anterior condylar vein is large and there is a prominent anastomosis of this vessel with the IPS (24%). In type III, the IPS exists as several small channels, which may form a plexus (24%). In type IV, the IPS does not join the IJV, emptying directly into the anterior condylar vein (7%) (Fig 2). Mitsuhashi et al 25 evaluated morphological aspects of the caudal end of the IPS using 3D rotational venography and described IPS drainage into the jugular bulb in only one /83 sides (1.2%), the remainder draining into the IJV below the jugular bulb. The IPS was found to drain directly into the vertebral plexus with no connection to the IJV in 3/83 sides (3.6%) and the IPS was absent in 14/ 83 sides (16.9%).
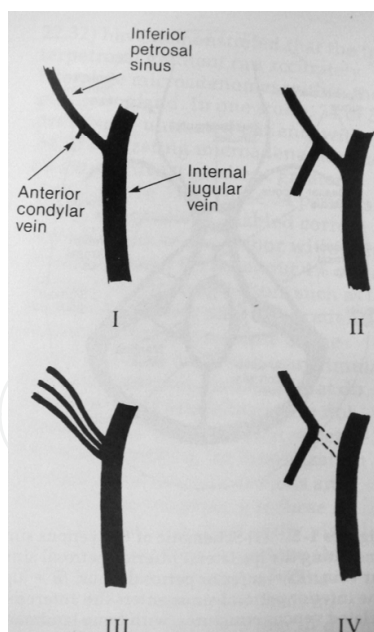
Type I : 45%,
Type II: 24%
Type III: 24%
Type IV: 7%

Fig. 2A. Schematic drawing of the four variation of the junction between the IPS and the IJV (Shiu et al.[7])

ii.   **SPS approach** [21]

For the CCF patients mainly draining into the SPS, this approach will become useful. However, the SPS receives the petrosal vein, so that with advancement of the microcatheter attention should be paid not to disturb this fragile vein. In the majority of the cases with hemorrhage in the posterior fossa, cortical venous drainages from the petrosal vein through the SPS is recognized. Coaxial navigation of the microcatheter through a 4F catheter (Cerulean 4F catheter, Medikit Co.ltd., Japan) may be useful for dvancement to the cavernous sinus (mentioned in detail as Explicative case).

iii.   **Contralateral cavernous sinus approach**

This is available approach for bilateral or the type of dural CCFs with drainage mainly into the contralateral IPS, SPS or pterigoid plexus [22].

iv.   **SOV, IOV approach**[7-20]

Approaches via direct puncture approach to the SOV and IOV and through the SOV from the dilated superficial temporal vein or division of external jugular vein are limited to CCF patients with comparative high flow drainages mainly inflowing into the SOV and/ or the inferior ophthalmic vein (IOV).

Initially the IPS approach should be tried as the most appropriate approach because it is comparative large and stiff with no division of the fragile branches. However, if a venous approach route may also attempted, but if neither of these are successful, our new IPOV approach should be explored as an alternative. If the apparent venous drainage route is SOV, direct puncture of the extraconic portion of the SOV is recommended because the anterior apsidal vein is a good landmark, located in the junction of the first and second segment.of intra-conal portion with a possibility of damage to the eloquent structures of the optic nerve, cranial nerves III-VI and ophthalmic arterial divisions.of the SOV.

v.   **Transvenous approach to the carotid-cavernous via the inferior petrooccipital vein** [23]

The transvenous approach via the inferior perusal sinus (IPS) is commonly used as the most appropriate for carotid cavernous fistula (CCF) or cavernous sinus sampling. However, it may be that the IPS is not accessible because of anatomical problems and/or complications, so that an alternative route is needed. In this paper, we have presented and discussed the utility of a transvenous approach to the cavernous sinus via the inferior petrooccipital vein (IPOV) [23].

Trolard [34] initially named this small vein differing from the IPS as the IPOV. San Millan ruiz et al [35] reported venous plexus of Rektorzik, corresponding to Trolard's inferior petrooccipital vein found coursing exracranially along the petrooccipital suture, which regularly contributes in forming the anterior condylar confluent.

Katsuta et al. [36] stressed the utility of the IPOV a small vein running in the extracranial groove (Fig. 3A) of the petrooccipital fissure, pouring into the petrosal confluens (anterior condylar confluent) and acting like a mirror image of the inferior petrosal sinus (Fig 3B). To our knowledge there have been no previous reports of its use as an actual access route to the cavernous sinus through the IPOV. The IPOV might be mistaken as the IPS because their running courses resemble each other.
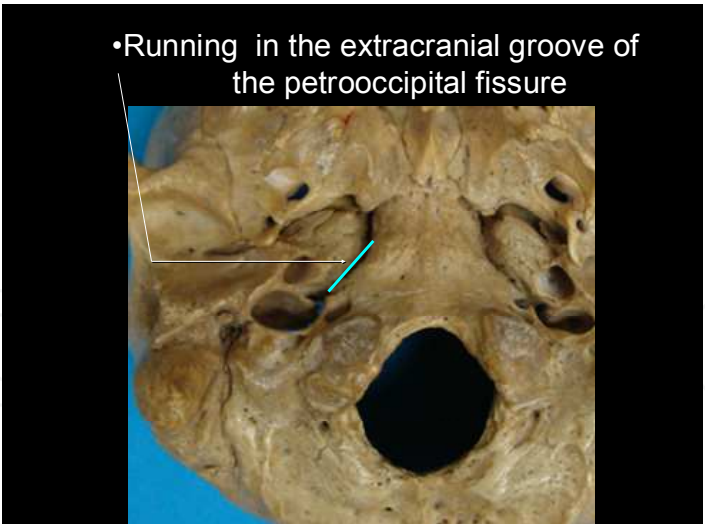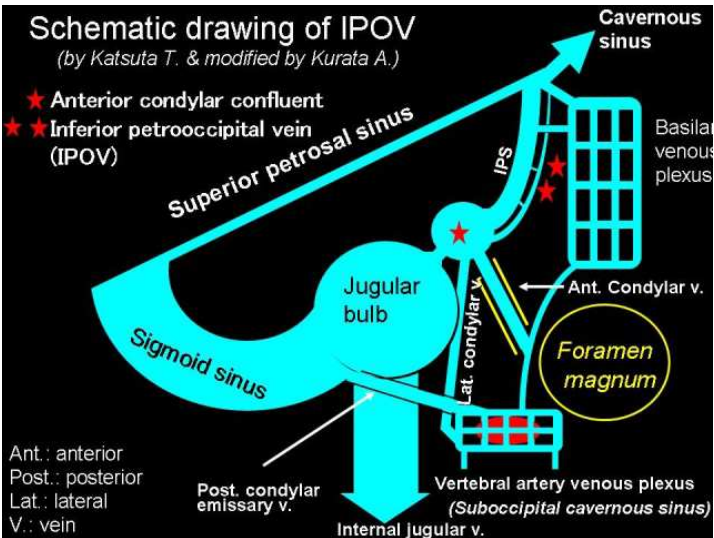
Fig. 3A. Inferior petrooccipital vein

Fig. 3B. Schematic drawing of the inferior petrooccipital vein

Techniqes to navigate a microcather into the cavernous sinus through the IPOV

To navigate a small diameter and soft tip microcather into the IPOV, use of a preceding small soft guide wire is essential because of the small size of the vein, even if it is dilated. The microcatheter should be advanced considering the running course. Initially the IPOV originating from the medial part of the petrosal confluence runs in parallel and slightly deeper with the IPS (mirror image), finally changes course to become lateral

vi.   Direct puncture approach to the extraconal portion of the superior ophthalmic vein[37]

The transvenous approach via the superior ophthalmic vein (SOV) is available approach for carotid cavernous fistula (CCF), where no other suitable approach route exists. Surgical exposure of the peripheral roots of the SOV is commonly used, but the SOV is often not accessible because the distal roots may show focal narrowing and tortuosity. We therefore here present our original direct-puncture approach to the extraconal portion of the SOV. The efficacy and safety of this approach have already been documented [37].

Anatomy of the SOV (Fig. 8A -C) 38

The SOV originates at its superior and inferior tributaries (roots). The junction of these roots is situated approximately 4-5 mm behind the tendon of the superior oblique muscle through the trochlea. The SOV is divided into three segments. The first segment, which courses obliquely upward and laterally, extends from the trochlea to the roof of the orbit (the extraconal portion). The second segment enters the muscle cone to course posterolaterally along the undersurface of the superior rectus muscle (Fig. 4). The anterior (medial) apsidal vein drains the internal rectus muscle and empties into the posterior aspect of the first segment of the SOV near the junction of the first and second segments. This vein is a good marker to distinguish the junction of the segments. The posterior (external) apsidal vein drains the lateral rectal muscle and enters the third segment. The second and third segments (the intraconal portion) are close to the optic nerve and the orbicular motor nerves.
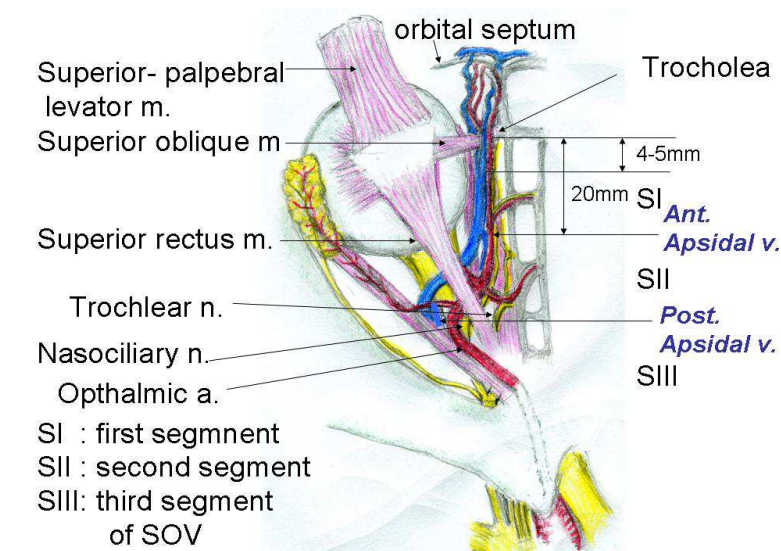

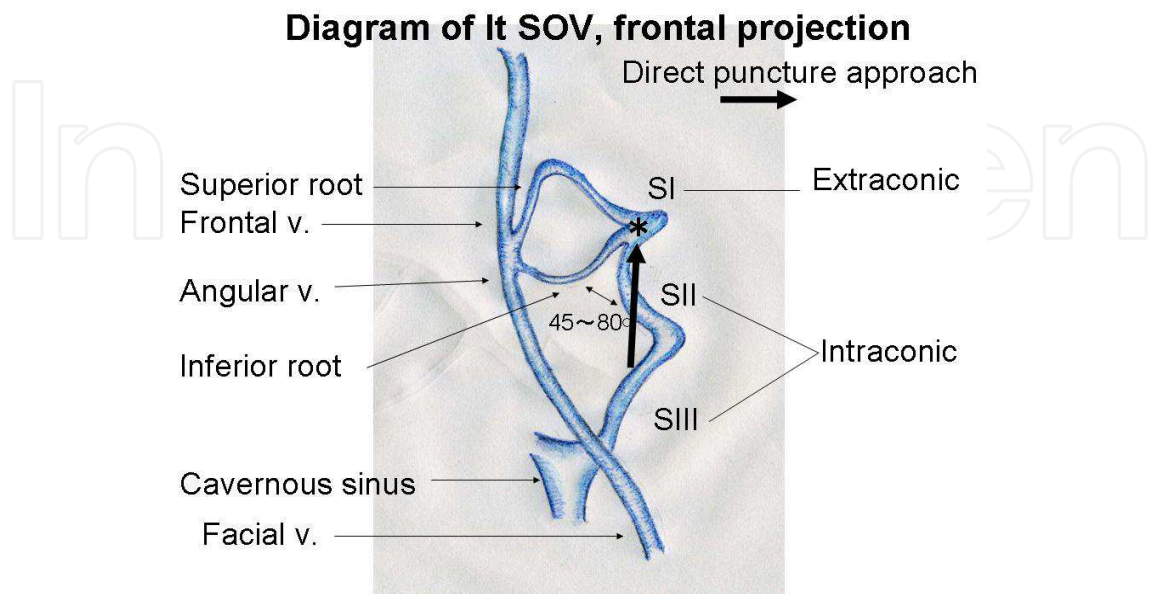Fig. 4A. Schematic drawing of the upper view of the orbita and SOV.

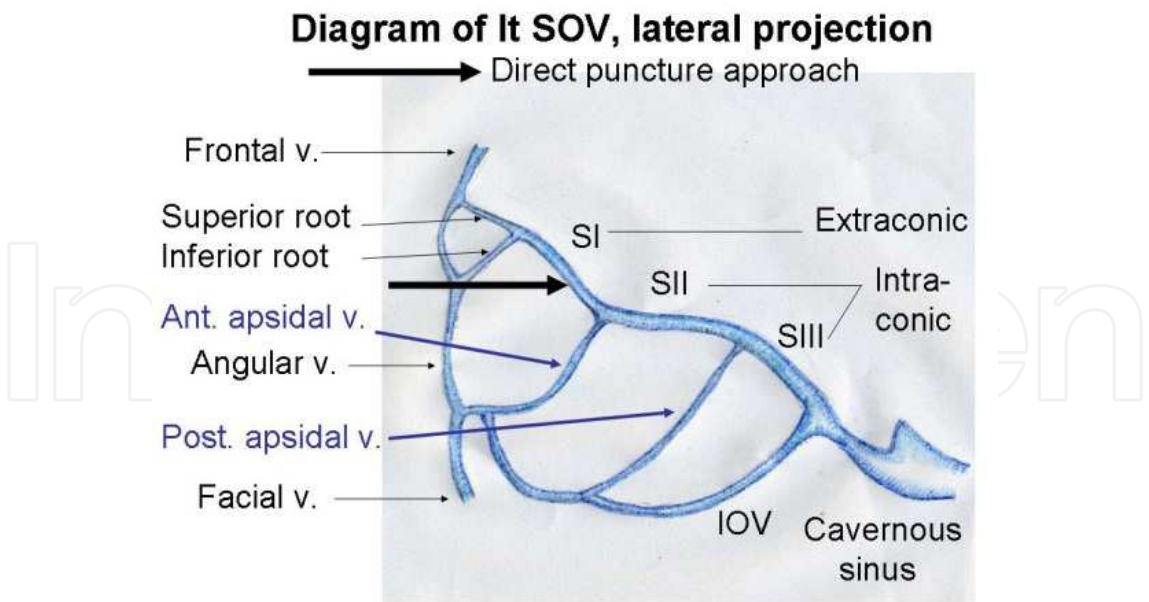Fig. 4B. Schematic drawing of the SOV (Anterior-posterior view).

Fig. 4C. Schematic drawing of the SOV (lateral view).

Direct exposure of the SOV roots under general anesthesia is widely used [7-14] (Fig 4D), but may be complicated and damage may occur to the superior root of the fifth nerve resulting in numbness of the forehead [15]. Furtheremore, it may also cause palsy of the superior levator muscle and palpebral ptosis.
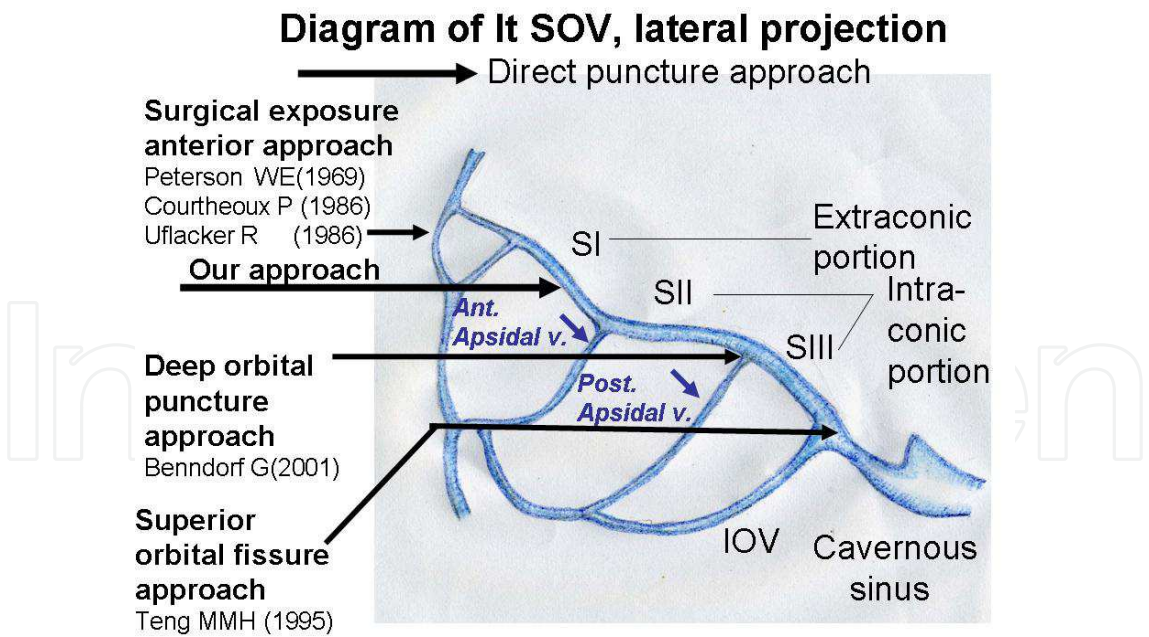

Fig. 4D.

The direct-puncture approach to the intraconal portion of the SOV has been reported in the literature [13,16-20] (Fig 4D). It is particularly useful in cases with a SOV dilated only within the intraconal segment, with thrombosed branches of the SOV [16]. However, there is a possibility

of damage to the eloquent structures of the optic nerve, cranial nerves III-VI and ophthalmic arterial divisions. Using the deep-puncture approach (the posterior third of the SOV [17], the posterior half of the SOV [18], the superior orbital fissure [19] to the SOV usually results in difficulty in making an exact access and in preventing bleeding from the puncture point. Massive retro-orbital bleeding may occur and result in an inadequate increase of orbital pressure [13] Recently, the direct percutaneous approach to the cavernous sinus by the way of the inferior ophthalmic vein (IOV) was reported [20]. This method will be of assistance in cases with dilatation of the IOV. However, the IOV is less often found as the main drainage route than the SOV. In the present series as well, the main drainage route was the SOV in all three patients without dilatation of the IOV.

Our direct-puncture approach (Fig 4C,D) has particular advantages. One is that the extra-conal portion of the SOV is anatomically thick and less prone to damage than the intraconal portion. When the SOV is the draining vein of the CCF, the SOV will become dilated more and thicker during the time course, which facilitates easy puncture and makes the technique safer. When bleeding occurs, hematomas can be minimized because the extraconal portion of the SOV is relatively shallow and therefore hemostasis can be achieved by direct compression with a finger. The anterior apsidal vein is a good landmark for this approach because it originates from between the extraconal and the intraconal portions of the SOV.

Initially the IPS approach should be tried as the most apparent approach because it is comparative large and stiff with no division of the fragile branches. However, if the IPS is not successful, our new IPOV approach should be explored as an alternative. If apparent venous drainage route is SOV, direct puncture of the extraconic portion of the SOV is recommended because the anterior apsidal vein is a good landmark, located in the junction of the first and second segment of intra-conal portion and risk of damage to the eloquent structures of the optic nerve, cranial nerves III-VI and ophthalmic arterial divisions is low.

5. Postoperative care

In pre- as well as in postoperative care, it is essential to improve the venous outflow and reduce the venous congestion in order to avoid worsening of symptoms and prevent venous infarction and/or hemorrhagic complication, especially in the patients featuring high flow CCF with cortical venous drainage. Patients usually show an aggravation of the symptoms when getting up in the morning. Therefore, the upper part of the body should be elevated up to 30 degrees during sleeping before and immediately after treatment. It is recommended to avoid increase in venous pressure in the day time. Newton et al [39] detailed 5 of 11 dural AVF patients, which fistula onset may have been related to straining or heavy lifting. Especially in patients undergoing TVE, venous pressure may readily become raised, so that they should be guided to avoid straining actions such as with constipation, coughing, head standing and also lifting heavy weights. A posture to keep up the head should be recommended to improve the venous circulation. These precautions should be observed after diagnosis of CCF and until disappearance of CCF. TVE may be an effective treatment for dural AVFs localized in the sinus, particularly with regard to aggressive lesions with cortical venous reflux, but for patient with complete occlusion defined by angiography, insufficient attention may be paid to venous pressure. New development of dural AVF after TVE for dural AVF has been reported [40-47,

sometimes in sites distant from the primary lesion [45], with time after sinus packing ranging from 4 months to 30 months (average: 10 months).Tearing of the vessels may be a feature [45]. Terada et al [48] from an experimental study, concluded that chronic venous hypertension of 2 to 3 months' duration, without associated venous or sinus thrombosis, can induce new AVF's affecting the dural sinuses. For dural AVF patients with complete occlusion defined by angiography careful attention should thus be paid to venous pressure as well as radiological and clinical examination over the long term.

During the postoperative course, in our experience [29], 4 of eighteen patients treated by TVE, a VIth cranial nerve palsy developed between two and four days after the treatment. It resolved within one year in two cases and in the other two persisted longer. Aihara et al.[49] reported two patients featuring deterioration of oculo-motor dysfunction out of 9 patients with dural AVF involving the cavernous sinus after treatments of the TVE. Two different mechanisms were put forward: high intra-sinus pressure caused by the obliteration of the drainage pathway resulting in cranial nerve palsy in one and direct compression of the cranial nerve by implanted coils in the other. In our series, the VIth cranial nerve palsy was caused by thrombosis developing around the platinum coils inserted into the postero-medial part of the cavernous sinus appeared to contribute. Minimum insertion of the coils is therefore a point in order to avoid such complications and anticoagulation agents such as warfarin is also indicated. The international ratio of prothrombin time (PT-INR) should be controlled around 2.0~3.0 until disappearance of symptoms.

6. Complications

Recently, TVE has been proposed as a more curative treatment for CCFs compared with trans-arterial embolization (TAE). However, it may induce serious complications. Embolic stroke was reported by Halbach et al [4], especially if it is performed at first without previous arterial supply reduction by TAE. Yamashita et al [6] reported complication occurred in 7 of 16 patients by TVE. One was epidural extravasation from perforation of the IPS, and the other 6 were transient aggravation of symptoms (chemosis and VIth/IIIrd cranial nerve palsy in each 3). To navigate a small diameter and soft tip microcather into the cavernous sinus via venous sinus and vein, use of a preceding small soft guide wire is essential because of the fragile nature of venous channels.

 Major complication especially will occur in the cases with cortical venous reflux. Araki et al.[24] reported such a case of extravasation from uncal vein during TVE for SOV and IOV via IPS. To avoid such serious complications, reduction of the arterial inflow into the cortical vein by TAE before TVE will is of help.

7. Outcomes (including results of the authors' own series)

Time of flight 3D-MRA is useful for long-term clinical follow-up of CCF cases [29]. In 47 dural CCF patients treated with only TAE in our series [34], all except two were followed using this modality. In 43 (90 %) of 45, complete obliteration was established on MRA in periods ranging from 1 month to 13 years 8 months (average: 4 years 6 months). Two patients with residual fistulas were still recognized on follow-up MRA (6 years 2 months, and 2 years) after TAE, but both refused additional treatments because of the lack of any symptoms.

In all of 18 patients undergoing TAE followed by TVE, fistulas were completely occluded on follow-up MRA ranged from 1month to 3 years 6 months (average: 2 years 3 months) after the treatment. In one patient receiving TAE, TVE and SRS, follow-up MRA 10 years and 8 months after the treatment confirmed the disappearance of the fistula.

8. Expert suggestions

In dural CCF patients with wide involvement of the sinuses (type of bilateral CS and bilateral CS &ICS: 39%), especially with a cortical venous reflux, TAE for initial reduction of inflow has been recommended as a reasonable treatment strategy to avoid serious complications because of the comparatively non-aggressive nature of the disease. Onyx-is a newly developed liquid embolic agent, effective in the treatment of CCFs but not without hazards [50]. Particles may be safer than liquid emboli and in our series of TAE using only particles, no complications occurred. Repeated provocative testing and care of dangerous anastomosis are also important. Repeated TAE will establish targeting TVE because of diminishing the fistulas point.

A relative long follow-up by MRA (average: 4 years 6 months) showed complete obliteration in 93% [29] . Additional TVE is needed for residual fistulas, especially for the ones with residual cortical venous drainages. TVE can cure the fistulas as evidenced by their complete occlusion of fistulas in all 18 of our patients treated with TAE followed by TVE. Hydro-coil (Terumo Co, Japan) is the ultimate embolic material for TVE because of the small mass effect. Stereotactic radiosurgery (SRS) can be recommended for limited residual lesion after TAE and TVE. One last CCF of our series received stereotactic radiosurgery as reported earlier [51]. Stereotactic radiosurgery is an appropriate treatment for cavernous sinus dural AVFs resistant to endovascular treatment, especially with small, slow flow.

9. Explicative cases

9.1 Transvenous approach to the cavernous sinus via the inferior petorooccipital vein (case 1-4)

Case 1

A 72-year-old man suddenly developed diplopia, and was followed up conservatively in an outpatient clinic because the symptoms caused by left IIIrd cranial nerve palsy gradually improved with time. Six months later, the diplopia disappeared. However, after one year, left pulsating exophthalmos, conjunctival chemosis and pulsatile- tinnitus developed. The patient was examined by magnetic resonance imaging (MRI) in another hospital and referred to our institution. Magnetic resonance angiography (MRA) showed increase of the vascular structure in the left cavernous sinus communicating with a dilated cortical vein. Angiography showed a dural CCF in the left cavernous sinus draining into the cortical veins (the superficial middle cerebral vein and the deep middle cerebral vein), SOV and IOV (Fig 5A). Initially, transarterial embolization using platinum coils for the inflowing external carotid arteries (bilateral middle menigeal arteries and sphenopalatine arteries) was performed to decrease arterial inflow. Next, the transvenous approach via the IPS was tried, but this failed because of an obstruction. The peripheral roots of SOV and IOV showed lack of dilatation. The left inferior petrooccipital vein (IPOV) route was then attempted (Fig. 5B, C), and this proved successful without any complications. Angiography after the endovascular surgery showed no residual fistula and no cortical venous drainage (Fig. 5D).

Although, postoperative new left VIth cranial nerve palsy worsened two days later, this had disappeared by 3 months after the treatment. Follow-up MRA three months after the treatment showed no recurrence of the CCF.
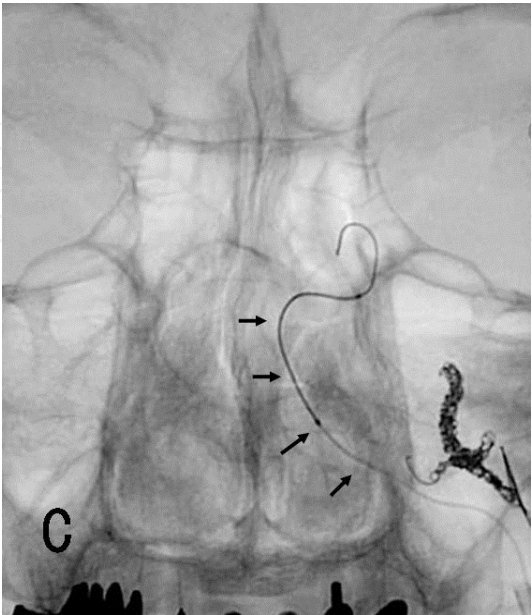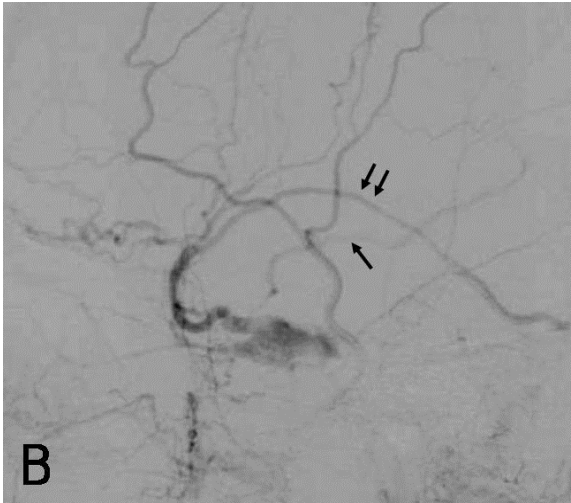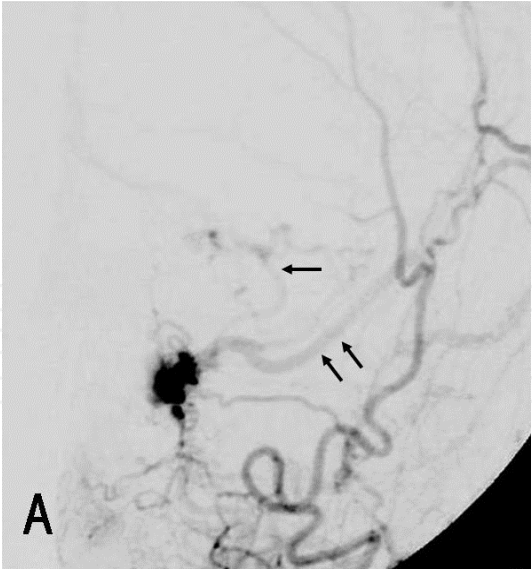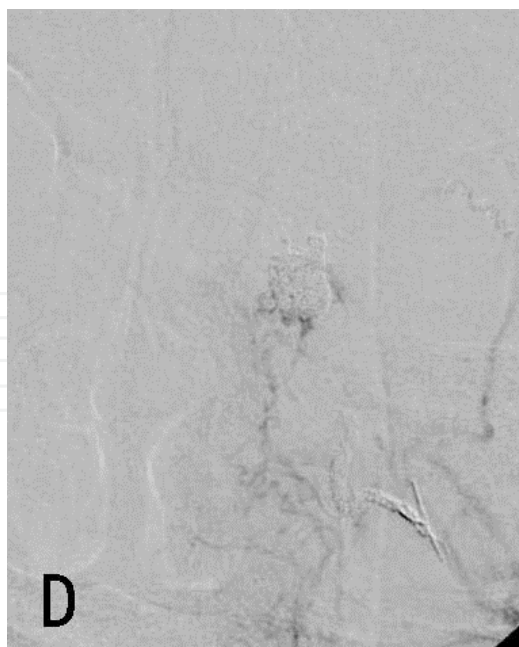
Fig. 5. Left carotid angiogram, lateral view(A) ,showing a carotid cavernous fistula (CCF) supplied by sphenopalatine and middle meningeal arteries with drainage into the superficial middle cerebral vein (SMCV) (double arrows), th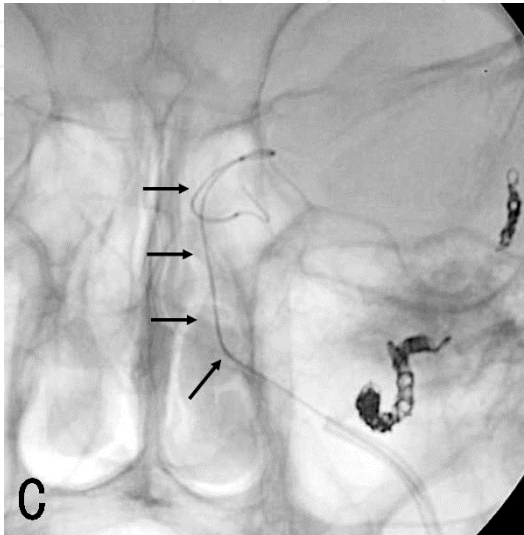e deep middle cerebral vein (DMCV) (single arrow), the superior ophthalmic vein (SOV) and the inferior ophthalmic vein (IOV). The peripheral roots of the SOV and IOV lack any dilatation. Digital subtraction angiography, anteroposterior view (B), and skull radiograph, anteroposterior view (C), showing venography from the microcatheter into the left cavernous sinus via the inferior petrooccipital vein (arrows). SMCV: double arrows, DMCV: arrow. Left carotid angiogram, anteroposterior view (D) after endovascular surgery showing complete obliteration of the fistula and no cortical venous reflux.

Case 2

A 76-year-old woman suddenly developed diplopia and was followed up conservatively in an outpatient clinic because the symptoms caused by the left VIth cranial nerve palsy gradually improved with time. Six months later, the diplopia disappeared. However, after two years, the patient developed symptoms and was examined by MRI in another hospital and referred to our institution. MRA showed increase of the vascular structure in the left cavernous sinus communicating with a dilated cortical vein. Angiography showed a dural CCF in the left cavernous sinus draining into the superficial middle cerebral vein and the deep middle cerebral vein only (Fig 6A, B). Initially, transarterial embolization of the inflowing external carotid arteries (left sphenopalatine, accessory menigeal and middle meningeal arteries) was performed to decrease the inflow. Next, the transvenous approach via the IPS was tried, but this failed because of an obstruction of the IPS. The left IPOV route was then attempted (Fig. 6C), and this proved successfully without any complications. Angiography after the endovascular surgery showed no residual fistula and no cortical venous drainage (Fig. 6D). Although left VIth cranial nerve palsy worsened two days later, this had disappeared by 3 months after the treatment. Follow-up MRA two months after the treatment showed no recurrence of the CCF.

Skull radiograph, anteroposterior view (C) showing the microcatheter with microguide wire introduced into the left cavernous sinus via the inferior petroccpital vein (arrows). Left external carotid angiogram, anteroposterior view (D), after endovascular surgery showing complete obliteration of the fistula and no cortical venous reflux.

Fig. 6. Left carotid angiogram, anteroposterior view (A) and lateral view (B) showing a carotid cavernous fistula (CCF) supplied by sphenopalatine, accessory menigeal and middle meningeal arteries with drainage limited to the superficial middle cerebral vein (double arrows) and the deep middle cerebral vein (single arrow).
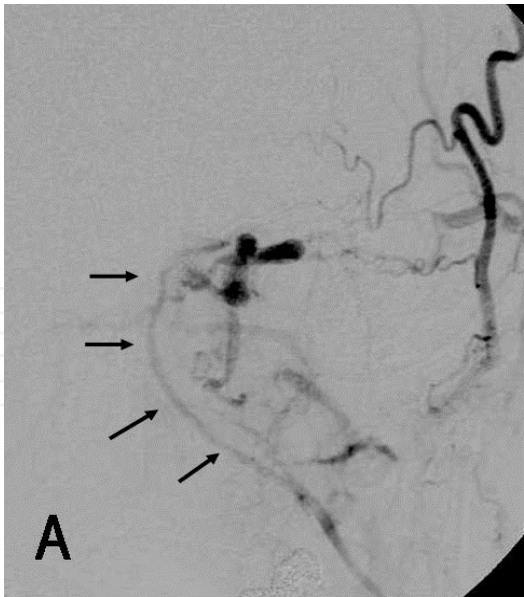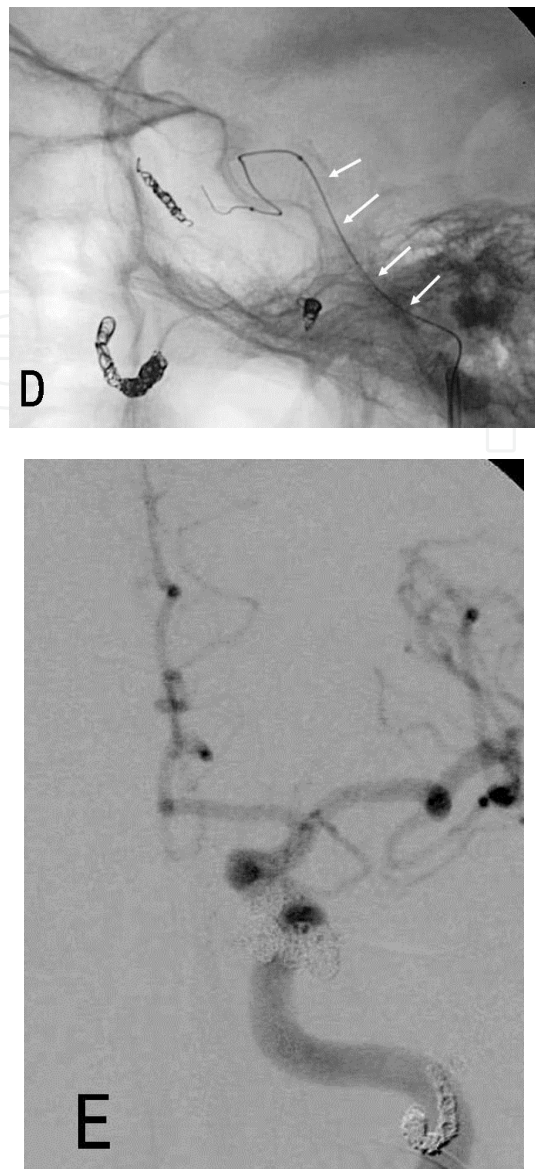
Case 3

A 77-year-old woman developed left chemosis and was followed up conservatively in an outpatient clinic. The symptoms worsened with time and proptosis also appeared. One month later, the patient was examined by MRI in another hospital and referred to our institution. MRA showed increase of the vascular structure in the left cavernous sinus. Angiography showed a dural CCF in the left cavernous sinus, supplied by sphenopalatine , middle meningeal and ascending pharyngeal artery, draining into the SOV, the IOV and the IPOV (Fig. 7A, B). Initially, transarterial embolization of the inflowing external carotid arteries was performed to decrease the inflow. Next, the transvenous approach via the left IPOV route was attempted (Fig. 7C, D), and this proved successful without any complications. Angiography after the endovascular surgery showed no residual fistula and no cortical venous drainage (Fig. 7E). Three months after the treatment, the symptoms had completely disappeared and follow-up MRA 8 month after the treatment showed no recurrence of the CCF.

Case 4

A 67-year-old woman was referred to our department for cavernous venous sampling to distinguish between Cushing disease and the ectopic adrenocorticotrophic hormone (ACTH) syndrome because the patient showed no suppression by means of a high -dose dexamethasone suppression test (Liddle test), but a micro-pituitary adenoma was suspected

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Skull radiograph, anteroposterior view(C) and lateral view (D)showing a microcatheter with a micro-guide wire introduced into the left cavernous sinus via the IPOV (arrows). Left carotid angiogram (E: anteroposterior view) after endovascular surgery showing complete obliteration of the fistula and no cortical venous reflux.

Fig. 7. Left carotid angiogram, anteroposterior view (A) and lateral view (B), showing a carotid cavernous fistula (CCF) supplied by sphenopalatine , middle meningeal and ascending pharyngeal arteries with drainage into the superior ophthalmic vein, the inferior ophthalmic vein and the inferior petroccipital vein (IPOV) (arrows).

on MRI. A transvenous approach to the right cavernous sinus via the right IPS was initially attempted, but failed because of an obstruction. Next, the right IPOV route was attempted , which was successful. The left transvenous approach to the left cavernous sinus via the left IPS was conventionally performed (Fig 8). Venous sampling from the bilateral cavernous sinuses and femoral veins was possible and resulted in diagnosis of Cushing disease caused by a micro-pituitary adenoma in the left side of the pituitary gland, which was successfully removed by a trans-sphenoidal approach.

The transvenous approach to the cavernous sinus via the OPOV should be considered as an alternate in cases when use of the IPS is precluded by an anatomical problem and there are no other suitable venous approach routes.
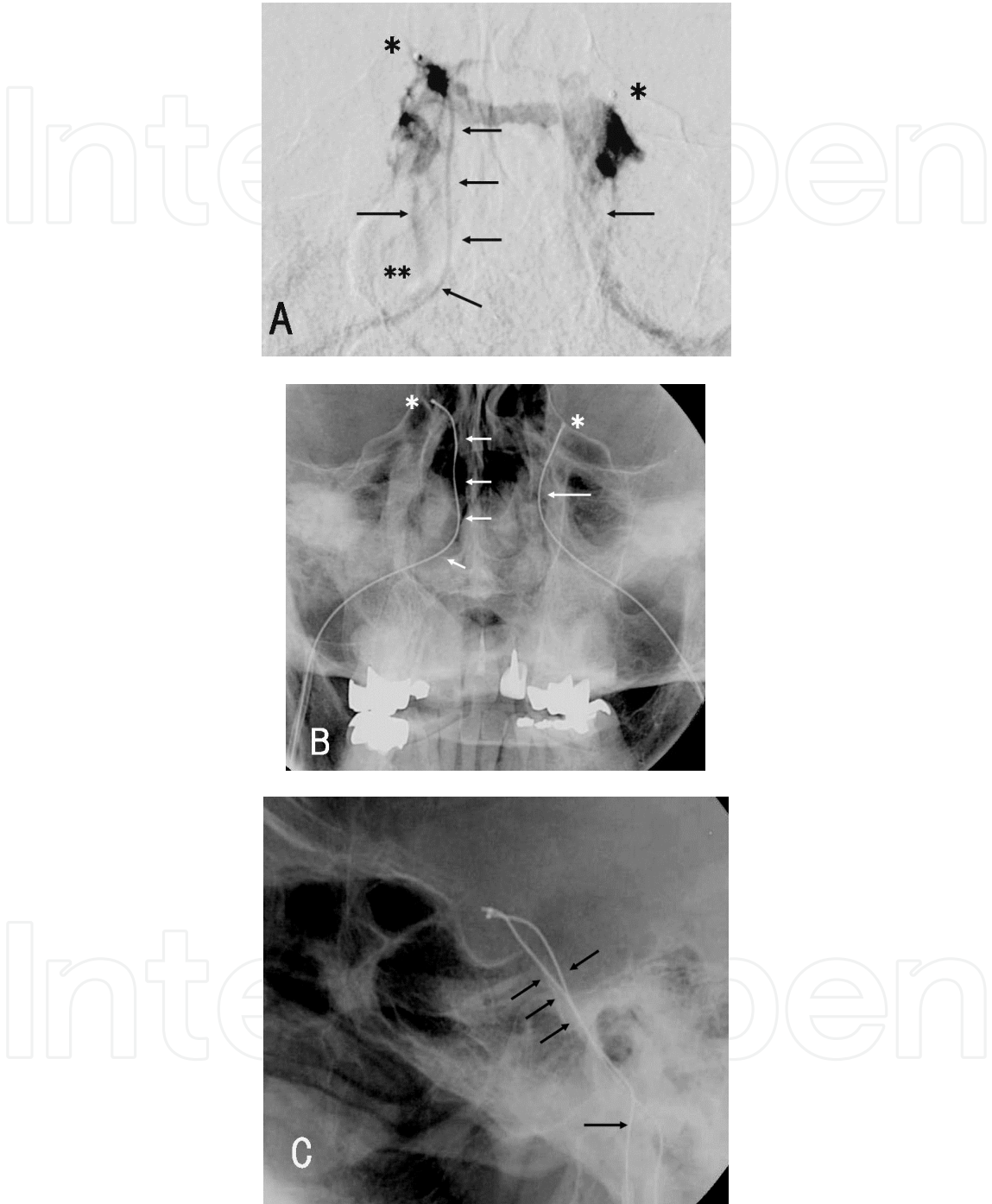

Fig. 8. Venography, anteroposterior view (A) from a microcather in the right cavernous sinusInferior petrosal sinus (IPS)= single arrow, IPOV(inferior petrooccipital vein)=.four arrows. tip of the microcatheters=asterisk, obstruction of the right IPS= double asterisks. Skull radiograph, anteroposterior view (B) and lateral view (C) showing a microcatheter introduced into the left cavernous sinus via the left IPS (single arrow) and a microcatheter introduced into the right cavernous sinus via the IPOV(arrows).

### 9.2 Direct puncture approach to the extraconal portion of the SOV (case 5)

Case 5

A 40-year-old man was injured in a traffic accident resulting in a left cerebellar and frontal contusion, fracture of the left optic canal and skull base. The patient was followed up conservatively. Consciousness gradually improved, but the loss of the left visual acuity unfortunately did not show any improvement. Two months later, left chemosis and pulsatile proptosis developed and worsened with time and after four months the patient was admitted to our hospital. when an angiogram showed a left CCF. Collateral flow from the right carotid system and the vertebro-basilar system were poor. Drainage routes of the left superior petrosal sinus and inferior sinus were obliterated (Fig. 9A). Remarkable cortical venous refluxes to the cerebellar hemisphere were evident. A collateral flow to the affected left internal carotid artery was poor because of hypoplastic left A1portion. The transvenous approach was determined to be a more suitable approach than the transarterial approach because of the occlusion time for the balloon protection so as not to permit migration of embolic material into the internal carotid artery. The transvenous approach via the femoral vein was attempted, but failed because of an obstruction in the left internal jugular vein (Fig. 9B). The only residual drainage route was via the SOV, but its distal divisions were tortuous and narrowed. The direct-puncture approach to the extraconal portion of the SOV was therefore selected as the only available residual transvenous approach route. Transvenous embolization for closure of the fistula using 18 platinum coils through the direct-puncture approach to the extraconal portion using 2D road mapping was successfully performed without any complications (Fig. 9C). Angiography after the endovascular surgery showed no residual fistula and no cortical venous refluxes (Fig. 9D, 9E). The patient's symptoms immediately improved after the procedure and he could be discharged 7 days later without any new neurological deficits. Follow-up MRA 1year after the treatment showed no recurrence of the CCF (Fig. 9F).
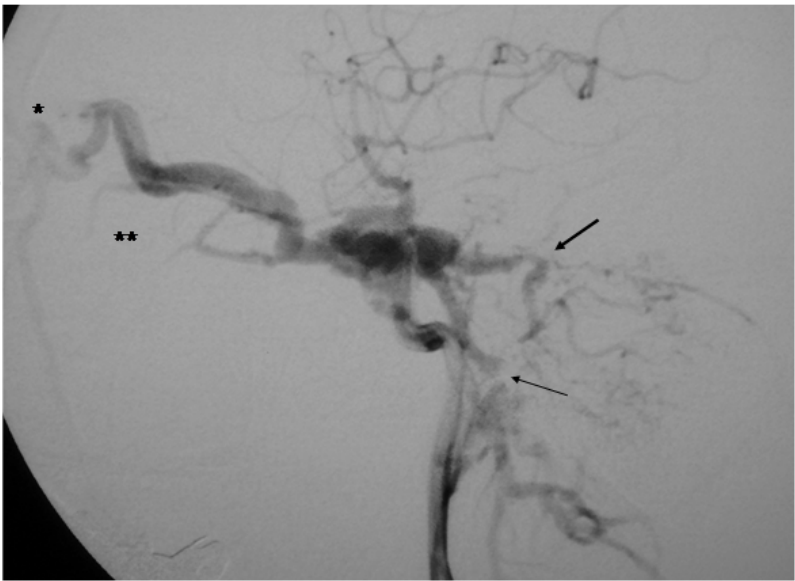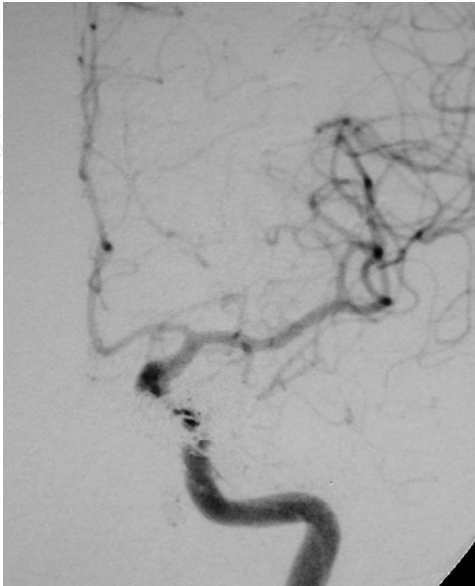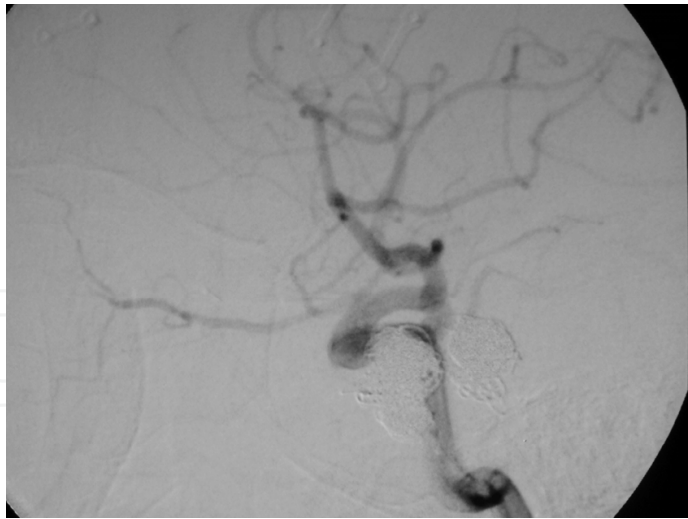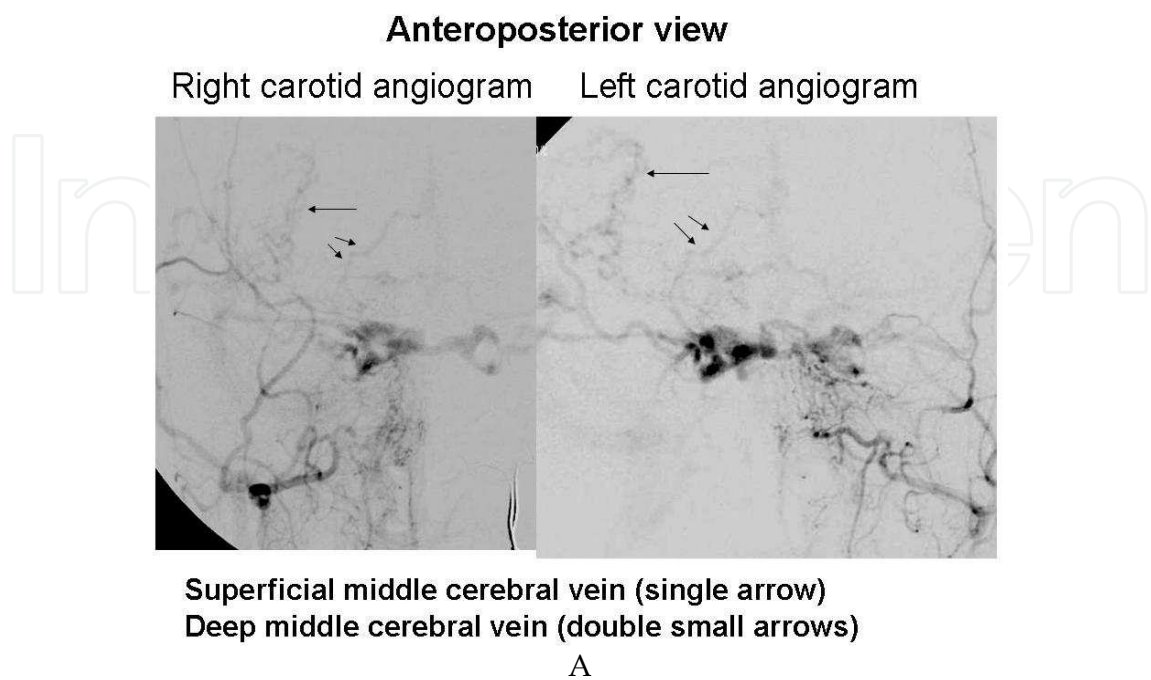

A
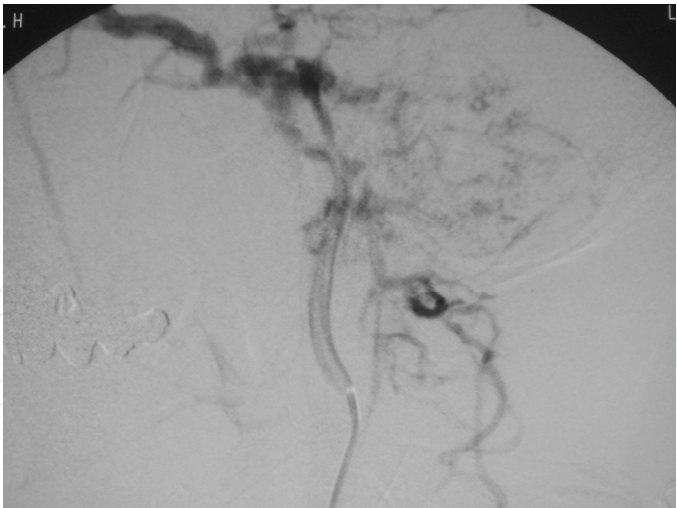
B

C

D

E

F

Fig. 9. Left carotid angiogram, lateral view (A) showing a carotid cavernous fistula (CCF) and the anterior apsidal vein (double asterisks). Drainage routs were the SOV, the superior petrosal sinus (SPS), and the inferior petrosal sinus (IPS). The SPS and IPS were obstructed (arrows) resulting in remarkable cortical venous reflux into the cerebellar hemisphere. Distal divisions of the SOV were tortuous and narrowed (asterisk). Left carotid angiogram, late arterial phase, lateral view (B) showing obstruction in the left internal jugular vein (arrow). Road mapping image of the magnified left carotid angiogram (C) during endovascular surgery showing a microcatheter (arrow) introduced via the direct-puncture approach into the extraconal portion of the SOV. The left carotid angiogram, left anteroposterior view (D) and lateral view (E) after endovascular surgery showing complete obliteration of the fistula and no cortical venous reflux. Follow-up magnetic resonance angiography (F) 1 year after the endovascular surgery showing no recurrence of the fistula.
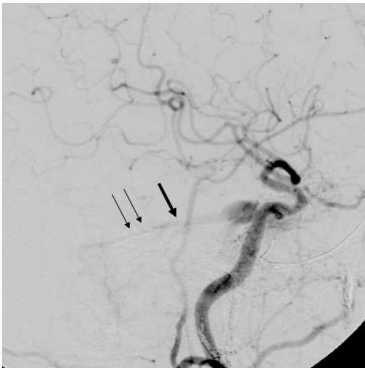
10. Transvenous approach to the cavernous sinus via SPS (case 6)

Case 6

A 71-year-old women suffered sudden onset of diplopia and three weeks later the patient was admitted to our hospital. Physiological and neurological and examination on admission showed right chemosis, right bruit, bilateral VIth cranial nerve palsies and left IIIrd nerve palsy. Angiography showed a bilateral CCF type D by Barrow's classification. Bilateral middle meningeal , accessory meningeal, sphenoparatine and ascending pharyngeal arteries all extensively supplied a CCF into the bilateral CS and ICS. Drainage routes were the right SPS, SOV and cortical vein (superficial middle cerebral vein) (Fig 10A). Remarkable cortical venous reflux to the right fronto-temporal lobe was evident. Repeated TAEs for reducing bilateral external carotid supply were initially before TVE. After three procedures, the dural fistula was located only in the right cavernous sinus with slight cortical venous reflux (Fig 10B). Initially, the transvenous approach via the IPS route was attempted, but this failed because of obstruction of the left IPS and lack of communication of the right IPS with the CS. The residual drainage route was via the right SPS. TVE via the right SPS was aimed to occlude the antero-lateral compartment of the right CS and reducing cortical venous reflux, but the SPS was partially narrowed (Fig. 10B). A 1.7F microcatheter (Excelsior SL- 10, Stryker, USA) assisted with a 4F catheter (Cerulean 4F catheter, Medikit Co., Japan) was successfully advanced through a 6F catheter (Envoy, Cordis/Johnson&Johnson, USA) into the antero-lateral compartment of the right CS (Fig. 10C) via the SPS. Transvenous embolization using 25 platinum coils was successfully performed without any complications (Fig. 10D). Angiography after the endovascular surgery showed no residual fistula and no cortical venous refluxes (Fig. 10E). The patient's symptoms immediately improved after the procedure, but two days later right VIth cranial nerve palsy once again worsened. However, the patient could be discharged 5 days later and the right VIth cranial nerve palsy gradually improved and completely disappeared within 1 year. Follow-up MRA 1year after the treatment showed no recurrence of the CCF (Fig.10F).

Anteroposterior view

Right carotid angiogram   Left carotid angiogram

Superficial middle cerebral vein (single arrow)
Deep middle cerebral vein (double small arrows)
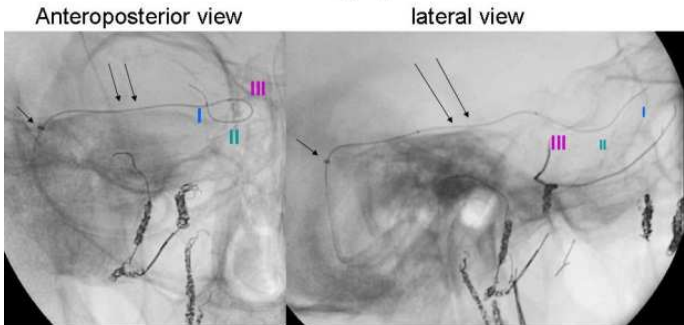
A

Right carotid angiogram
(lateral view)

Superior petrosal sinus (single arrow)
Stenosis(double arrows)

B

Right carotid angiogram, lateral view showing CCF mainly draining into the SPS (single
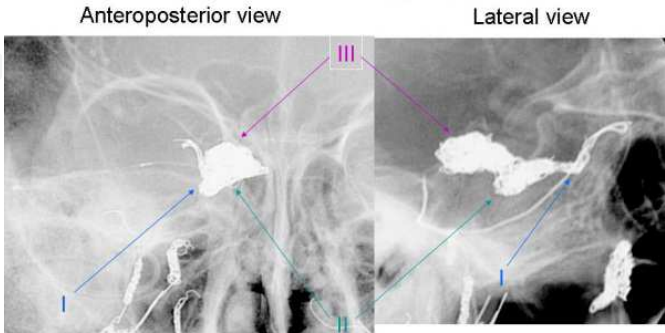arrow) with stenosis (double small arrows)

Skull radiograph

Tip of the Cerurian 4F catheter (single arrow)
Microcatheter (double arrows)
I=first portion (anterolateral compartment)
II=second portion (intermediate compartment)
III=third portion (posteromedial compartment)

C

Skull radiograph

I=first portion (anterolateral compartment)
II=second portion (intermediated compartment)
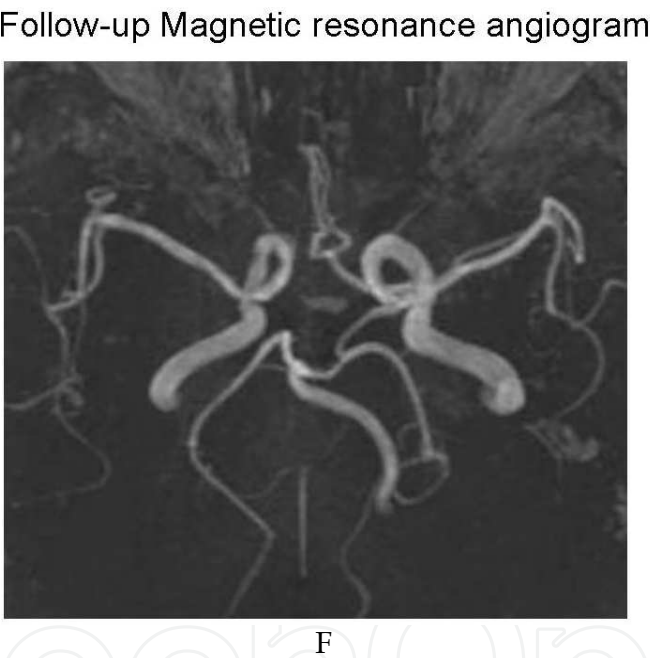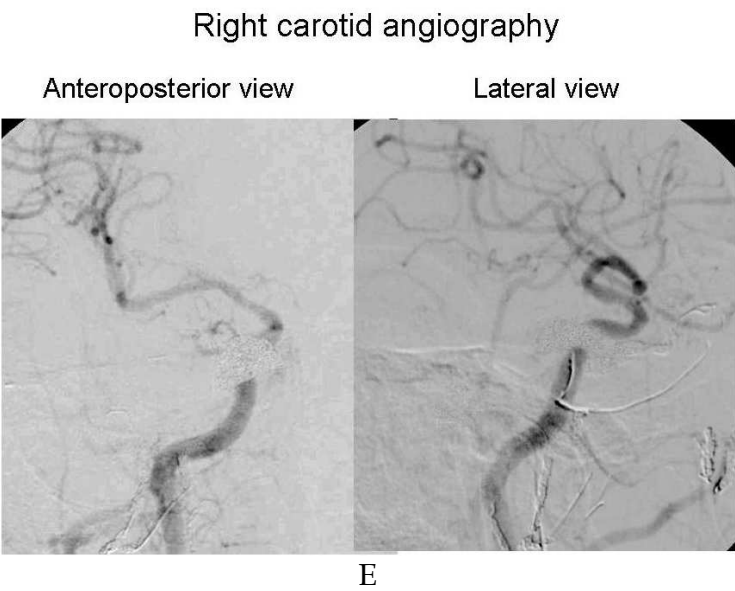III=third portion (posteromedial compartment)

D

Right carotid angiography

| Anteroposterior view | Lateral view |

E

Follow-up Magnetic resonance angiogram

F

Fig. 10. Right carotid angiogram (left) and left carotid angiogram (right) (A)showing CCF supplied by bilateral middle meningeal, accessory meningeal, sphenoparatine and ascending pharyngeal arteries draining into the right SPS, SOV, superficial middle cerebral vein (single arrow) and deep middle cerebral vein (double arrows)Right carotid angiogram, lateral view (B) showing CCF mainly draining into the SPS (single arrow) with stenosis (double small arrows)

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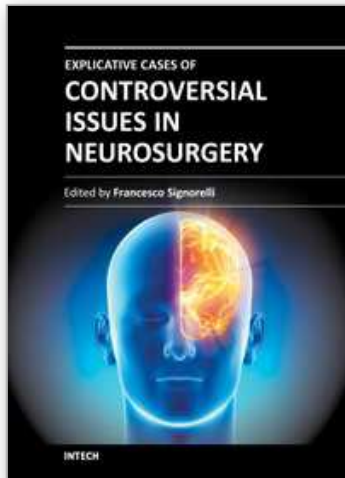
Explicative Cases of Controversial Issues in Neurosurgery

Edited by Dr. Francesco Signorelli

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