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Original Article

Transvenous embolization of cavernous sinus dural arteriovenous fistula via angiographic occlusive inferior petrous sinus

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Abstract

Background: Trans-inferior petrous sinus (IPS) coil embolization is an efficient and safe method to manage cavernous sinus dural arteriovenous fistulas (CSDAVFs). However, some CSDAVFs may be associated with angiographic occlusive IPS making access difficult. The purpose of this study was to report our experience of transvenous embolization of the CSDAVF via angiographic occlusive IPS.
Methods: We reviewed the cases of 20 patients who underwent transvenous embolization via angiographic occlusive IPS over a 6 year period. The study consisted of seven men and 13 women, ranging from 46 years to 78 years of age (mean, 60 years). We retrospectively analyzed the angioarchitecture of the CSDAVFs, the procedural time and the angiographic as well as the clinical outcomes after embolization.
Results: True occlusive IPS was found in 13 of the patients, while patent IPS with compartment of the IPS-CS was demonstrated in the remaining seven patients. The microcatheter was successfully navigated to the fistula site of the CS in 16 patients (80%), while such navigation failed in four patients following numerous attempts. The mean procedural times for truly occlusive IPS and for compartment of the IPS-CS were 111 minutes and 129 minutes, respectively. No recurrent fistula was observed on follow-up neuroimages. Three patients had transient third or sixth cranial nerve palsy, and one patient had perforation of the IPS leading to temporary headache. The mean clinical follow-up period was 18 months.
Conclusion: Angiographic occlusive IPS of CSDAVF may be related to true occlusion of IPS or patent IPS with compartment of the IPS-CS. There is no statistically significant difference in procedural times for these two different fistula anatomies. Transvenous embolization via angiographic occlusive IPS is a safe and effective method to manage CSDAVFs.

Keywords: cavernous sinus; dural arteriovenous fistula; embolization; inferior petrous sinus

1. Introduction

Cavernous sinus dural arteriovenous fistulas (CSDAVFs) are arteriovenous fistulas of the cavernous sinus (CS), fed by dural branches of internal and/or external carotid arteries. Most CSDAVFs are low-flow shunts presenting with benign neuro-ophthalmic symptoms such as ocular-orbital venous congestion, cephalic bruit and/or impairment of visual acuity.[1–6] However, certain CSDAVFs with insufficient venous drains may have pial venous reflux associated with the potential risk of hemorrhagic or nonhemorrhagic neurologic deficit.[2,3] Trans-inferior petrous sinus (IPS) coil embolization is a safe and effective method to manage CSDAVFs that require treatment.[4–6] Nevertheless, this access route may become difficult in CSDAVFs due to angiographic occlusive IPSs.

Conflicts of interest: The authors declare that they have no conflicting interests related to the subject matter or materials discussed in this article.

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The purpose of this study was to evaluate the angioarchitecture of CSDAVFs with angiographic occlusive IPS, and to report our experience and outcomes using transvenous coil embolization.

2. Methods

From May 2008 to April 2014, a total of 67 patients with 71 CSDAVFs were referred to our institute for endovascular embolization because of progressive neuro-ophthalmic symptoms. From available records, we enrolled 57 patients with CSDAVFs undergoing trans-IPS coil embolization via the IPS. Of these 57 CSDAVF patients, 20 underwent transvenous embolization via angiographic occlusive IPS. Before this article was initiated, informed consent was obtained from all 20 patients. The clinical data of the 20 patients are summarized in Table 1. These patients comprised seven men and 13 women with ages ranging from 46 years to 78 years (mean, 60 years). Transvenous embolization via occlusive IPS was performed under general anesthesia using bilateral femoral approaches with 5 French (F) and 6F femoral sheath (Prelude, Merit Medical system, Inc., South Jordan, Utah, USA) placements to the left femoral artery and right femoral vein, respectively. Activated clotting time was monitored and maintained at a value of twice the baseline value by intravenous administration of heparin. A 4 F diagnostic catheter was positioned in the feeding carotid artery as a guide for subsequent transvenous embolization. A 6 F guiding catheter (Envoy; Codman & Shurtleff, Rayhnam, MA, USA) was placed into the internal jugular vein (IJV) for the retrograde catheterization of angiographic occlusive IPS. CSDAVFs were demonstrated by carotid roadmaps, and a 2 tip 0.017 inch microcatheter (Headway; MicroVention Inc., Tustin, CA, USA or Echelon; Covidien, Minneapolis, MN, USA) and a 0.014

Table 1
Demographics and clinical outcomes of 20 patients with cavernous sinus dural arteriovenous fistulas (CSDAVFs), managed by trans-angiographic occlusive inferior petrous sinus (IPS) embolization.

Patient/sex/age (y), mean = 60 y	Clinical manifestations	Occlusive or patent IPS	Fistulae flow drainage	Procedural time (min), mean = 123 min	Angiographic outcome	Complication	Clinical follow-up (mo), mean = 18 mo
1/M/62	Chemosis, ophthalmalgia	Occlusive	SOV, SMCV	101	Cure	Nil	11
2/F/67	Chemosis, impairment of visual acuity	Occlusive	SOV, C-CS C-SOV	107	Cure	Nil	25
3/M/55	Chemosis, bruit, impairment of visual acuty	Patent	SOV, C-CS C-SOV	157	Cure	Nil	21
4/F/48	Chemosis, bruit	Occlusive	SOV, SMCV	103	Cure	Nil	18
5/M/51	Chemosis, proptosis	Patent	SOV	137	Cure	Nil	17
6/F/58	Chemosis, bruit, ophthalmalgia	Occlusive	SOV, C-CS, C-SOV	162	Cure	Transient CN3 palsy	8
7/F/52	Chemosis, impairment of visual acuity	Occlusive	SOV, SMCV	138	Cure	Nil	19
8/F/66	Chemosis, proptosis, ophthalmalgia	Occlusive	SOV, SMCV, SPS	98	Cure	Nil	14
9/F/64	Chemosis, proptosis, ophthalmalgia	Patent	SOV, C-CS, C-SOV	115	Cure	Nil	10
10/F/47	Chemosis, impairment of visual acuity	Patent	SOV, SPS	97	Cure	Nil	15
11/M/52	Chemosis, proptosis	Occlusive	SOV	153	Cure	Nil	24
12/F/72	Chemosis, proptosis, ophthalmalgia	Patent	SOV, SMCV	147	Cure	Transient CN3 palsy	24
13/F/59	Proptosis, impairment of visual acuity	Occlusive	C-CS,C-SOV	107	Cure	IPS perforation	17
14/M/54	Chemosis, diplopia	Occlusive	SOV	failure	Cured by transfacial vein	Nil	7
15/M/46	Chemosis, proptosis	Occlusive	SOV, SMCV	116	Cure	Nil	31
16/F/67	Chemosis, impairment visual acuity	Occlusive	SOV, SPS	123	Cure	Transient CN6 palsy	21
17/F/72	Chemosis, ophthalmalgia	Occlusive	SOV, SPS	failure	Refer to GKS	Nil	NA
18/F/78	Limb weakness, respiratory failure	Occlusive	Pontomedullary vein	failure	Cured by direct puncture	Nil	34
19/M/53	Hemiparesis, aphasia	Patent	SOV, SMCV	106	Cure	Nil	13
20/F/67	Chemosis	Patent	Cerebellar vein, SPS, SOV	failure	Refer to GKS	Nil	NA

C-CS = contralateral cavernous sinus; CN = cranial nerve; C-SOV = contralateral superior ophthalmic vein; GKS = Gamma Knife surgery; IPS = inferior petrous sinus; NA = not available; SMCV = superficial middle cerebral vein; SOV = superior ophthalmic vein; SPS = superior petrous sinus.

inch microguidewire (Traxcess; MicroVention Inc.) were prepared. We attempted to use these devices to select and advance to the IPS and fistula site. Once the microcatheter was navigated into the CS, gentle and slow injection of a small amount of contrast through the microcatheter was performed to identify its position and the flow of contrast media. If there was any risk of injury to, or perforation of the IPS/CS, hand injection angiography was performed via the microcatheter to delineate the angioarchitecture and hemodynamics of the CSDAVFs. In addition, the procedural time of successful embolization of CSDAVF was measured from the time recorded on the diagnostic angiogram, and that time noted on postembolization carotid angiograms.

Truly occlusive IPS was assumed when pre-embolization carotid angiograms showed partial opacification of the proximal IPS without a direct connection with the IJV (Fig. 1), or when the hand injection angiogram demonstrated irregular, stenotic/occlusive IPS. Patent IPS with compartment of the IPS-CS was assumed if there was smooth navigation of the catheter/guidewire into the IPS. However, if there was difficulty in passage of the catheter or guidewire system to the fistula site (Fig. 2), hand injection angiograms demonstrated normal opacification of the IPS without communication of the CSDAVF (Fig. 2). Once the microcatheter was in the ideal fistula position and was confirmed by hand injection angiography, transvenous coil occlusion of the fistulous zone was performed. Occlusion of the CSDAVFs was commenced by selecting the proper detachable coils (Microplex and Hydrocoil; MicroVention Inc.) that would be used to pack the CS, taking care not to create an occlusion of the outflow of fistula drains with redirection of the fistulous flow toward the pial veins. Control digital subtraction angiography (DSA) images were obtained intermittently to evaluate the hemodynamics of CSDAVFs. The endpoint of the endovascular procedure was failure to access the fistula site of the CS after more than a 120 minute attempt, or successful access to the fistula site with complete occlusion of the fistula flow by coiling, or slow flow of the fistula after coiling associated with recoil of the microcatheter back into the IPS.

A post embolization angiogram was carried out immediately after the completion of the procedure to check for occlusion of the fistula. Of these 20 CSDAVF patients, 18 had neuroimaging follow-up. Conventional DSA was obtained for 15 patients, while magnetic resonance angiography was used for eight patients to evaluate the embolized CSDAVFs (mean, 8 months). Eighteen patients were followed up clinically for an average of 18 months (range, 7−34 months).

3. Results

The clinical findings and treatment outcomes of 20 CSDAVF patients are summarized in Table 1. The clinical manifestations of these patients were chemosis ($n = 17$, 85%), bruit ($n = 3$, 15%), proptosis ($n = 7$, 35%), ophthalmalgia ($n = 6$, 30%), impairment of visual acuity ($n = 6$, 30%), hemorrhagic ($n = 1$, 5%) or nonhemorrhagic neurologic deficit ($n = 1$, 5%) or respiratory failure ($n = 1$, 5%). True occlusive IPS was found in 13 (65%) CSDAVF patients, while patent IPS with compartment of the IPS-CS was demonstrated in seven (35%) CSDAVF patients. Most fistula flow drained to the superior ophthalmic vein (SOV; $n = 18$, 90%). However, there was contralateral CS/SOV drainage in five (25%) CSDAVF patients, and superior petrous sinus drainage in five (25%) patients. While fistula reflux to pial veins occurred in nine (45%) patients, only two (10%) patients presented with aggressive neurologic behaviors (brain stem edema = 1, intracerebral hemorrhage = 1).

Successful navigation of the microcatheter into the fistula site of the CSDAVF was achieved in the case of 16 patients (80%), whereas the procedure failed for four patients after many attempts. Two of these patients had undergone Gamma Knife radiosurgery 5 years and 6 years earlier, prior to embolization with residual fistula; they were then referred back to Gamma Knife radiosurgery to ascertain the feasibility of additional radiosurgery. The other two patients underwent transfacial venous or direct puncture of the CS with successful occlusion of the fistula in the same session. For 16 CSDAVF patients with successful catheterization, the procedural time ranged from 97 minutes to 162 minutes (mean, 123 minutes). The mean procedural times in truly occlusive IPSs with compartment of the IPS-CS were 111 minutes and 129 minutes, respectively ($p < 0.90$).

Complete fistula closures were documented on immediate postembolization angiograms in 15 CSDAVFs (Figs. 1 and 2); one patient with residual fistula underwent transvenous Onyx (Covidien) embolization with total fistula occlusion. Three patients experienced temporary impairment of sixth ($n = 1$) and/or the third ($n = 2$) cranial nerve function due to the coil mass effect in the CS; this resolved completely within 8 months. One patient suffered perforation of the IPS by the catheter/guidewire with small leakage of contrast media to the subarachnoid space which led to a temporal headache. No other significant procedure-related neurological complication was observed in the 20 patients. For those 16 patients who underwent successful embolization, their cephalic-ocular symptoms and signs related to fistulas such as bruit, chemosis, proptosis, and cranial nerve palsy gradually resolved after endovascular treatment. No evidence of recurrent or residual CSDAVF was demonstrated in these 16 treated patients through neuroimaging follow-up.

4. Discussion

CSDAVFs usually occur in middle-aged women and are fed by multiple small dural branches of the carotid arteries. Because of their slow-flow shunts, some CSDAVFs have a tendency to undergo spontaneous thrombosis with clinical and morphologic cures. Regarding management of CSDAVFs, if patients present with mild clinical symptoms, with no angiographic risk of hemorrhagic or nonhemorrhagic neurologic deficits, conservative treatment or a less invasive procedure such as observation, manual compression of the carotid artery[7] or radiosurgery[8] can be applied. If patients have pial reflux and/or are at risk of clinical deterioration such as gradual loss

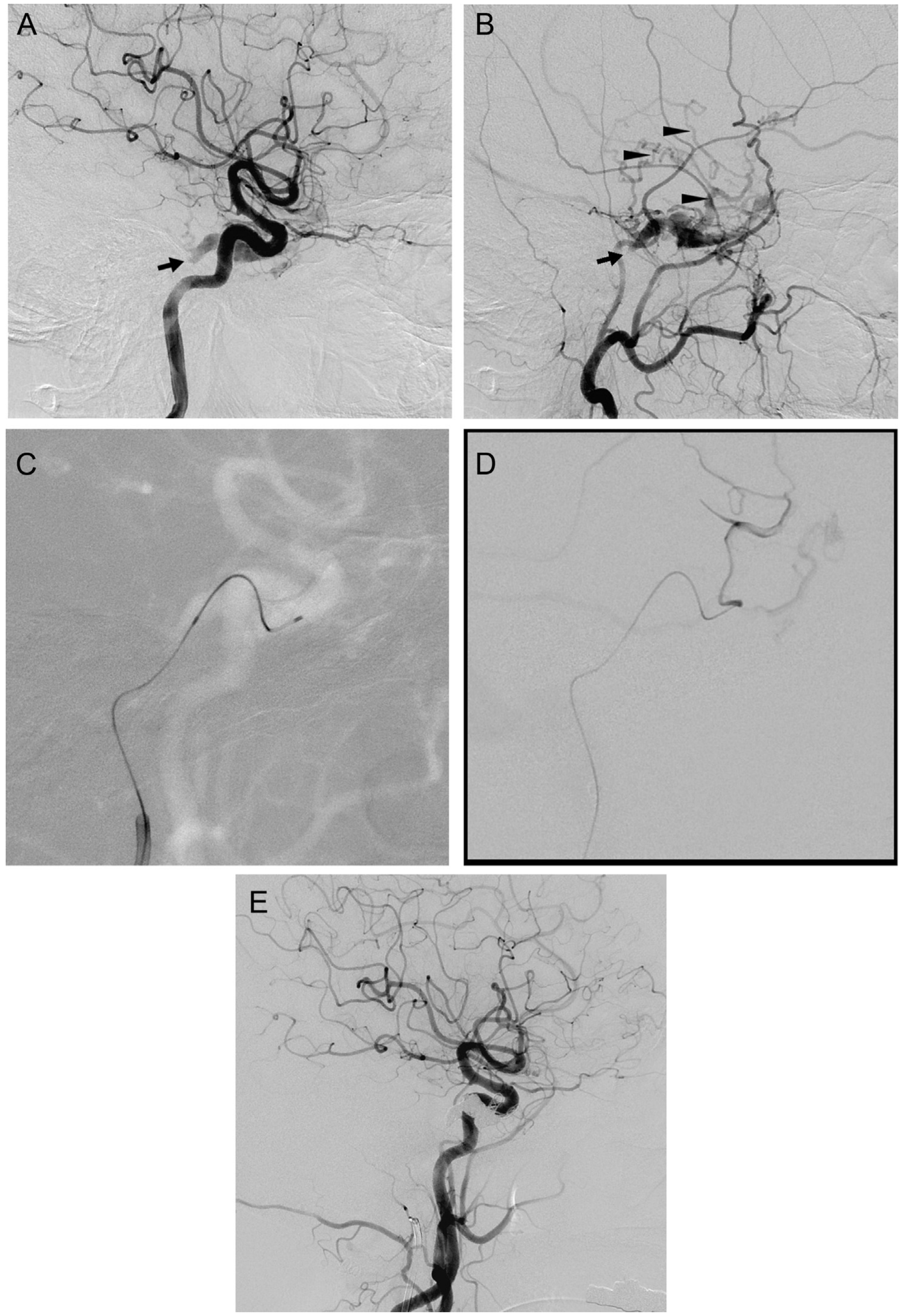

Fig. 1. A 66-year-old woman had right cavernous sinus dural arteriovenous fistula (CSDAVF) and presented with chemosis, proptosis, and ophthalmalgia. (A, B) Right lateral internal and external carotid angiograms revealed CSDAVFs with truly occlusive distal inferior petrous sinus (IPS; indicated by arrow) with pial reflux (indicated by arrowheads). (C, D) Transocclusive IPS embolization was performed with successful navigation of a microcatheter into the fistula site, as confirmed by hand injection angiograms. (E) A postembolization carotid angiogram demonstrated total occlusion of the fistula.

of visual acuity or cranial nerve palsy, embolization is required.[2,3,9,10] In our series, truly occlusive IPSs were demonstrated in 13 patients. However, insufficient fistula drains only occurred in two patients presenting with hemorrhagic ($n = 1$) or nonhemorrhagic stroke ($n = 1$). Other patients presented with ocular symptoms, largely because of the fistula flow diversion to other venous pathways such as contralateral CS, ophthalmic vein, and/or superior petrous sinus.

There are two endovascular treatment modalities to manage CSDAVFs: (1) transarterial embolization of arterial feeders and (2) transvenous CS embolization. Some studies have shown a good outcome with low complication rates for occluding CSDAVFs via a transarterial route by using liquid

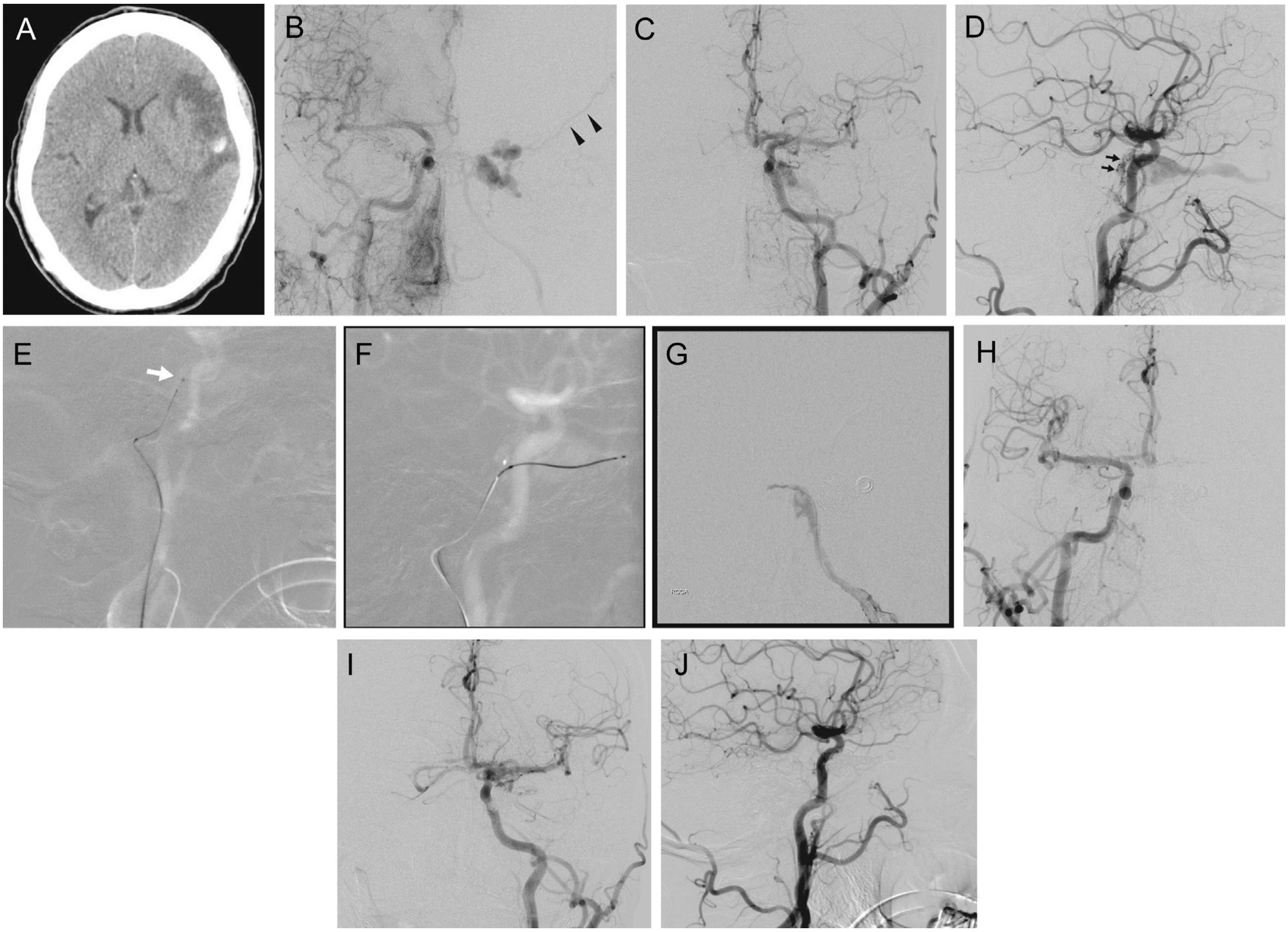

Fig. 2. (A) A 53-year-old man had left aggressive cavernous sinus dural arteriovenous fistula (CSDAVF) and presented with hemiparesis and dysphasia because of ischemic stroke with hemorrhagic transformation at the left fronto-temporal lobes. (B–D). Pre-embolization carotid angiograms showed CSDAVF fed by dural branches of bilateral carotid arteries (indicated by arrows), drained to the left ophthalmic vein and refluxed to the left superficial middle cerebral vein (indicated by arrowheads). (E–G). Transvenous inferior petrous sinus (IPS) embolization was attempted, navigation of the catheter/guidewire into the IPS was smooth, but further advancement of the catheter/guidewire was difficult because of compartment of the IPS-CS (indicated by white arrow). The catheter was eventually successfully navigated into the CSDAVF; recoil of the catheter into the IPS after coiling of the CSDAVF was found, and hand injection angiogram confirmed patent IPS with compartment of the IPS-CS. (H–J) Postembolization carotid angiograms demonstrated total fistula occlusion.

embolic agents;[11] however, this route may not always be feasible, because of multiple, small, and tortuous feeders of CSDAVFs. Furthermore, some risks may occur by inadvertent embolization of carotid territory with ischemic stroke via dangerous anastomosis of the external–internal carotid artery or embolization of feeders of cranial nerves. By contrast, transvenous coil embolization of the CSDAVF by occlusion of the affected CS is considered safe, with promising results.[4,6]

Choosing an appropriate transvenous route depends on the compartment of the CS involved in the fistula and its venous drainage. By far, the most common venous route is via the IPS by navigation of a guiding catheter to the IJV, then retrograde microcatheterization of the IPS up to the fistula site in the CS. This route is short, direct, and more easily accessed than other routes. This access is particularly useful in CSDAVFs with exclusive posterior drainage to patent IPS. However, this technique may not always be feasible in difficult fistula anatomies, particularly in patients with stenosis or occlusion of the IPS. Shiu et al[12] reported that the IPS could not be catheterized in 31% of cases due to its complex angioarchitecture. Previous studies also demonstrated that the IPS had numerous anastomoses with surrounding veins.[13,14] Mitsuhashi et al[14] reported that six types of venous drainage of the IPS depended on the level insertion of the IPS into the IJV and connection with surrounding veins. Therefore, a detailed knowledge of the anatomy of the IPS–IJV junction and pre-embolization work-up angioarchitecture analysis is essential to increase the success rate of catheterization and reduce the procedural time.

Angiographic nonopacification of the IPSs of CSDAVFs is due to a variety of factors and may relate to true occlusion, compartment of the IPS-CS, or agenesis. In cases of true occlusion of the IPS, diagnostic carotid angiograms usually demonstrated partial opacification of the proximal IPS because of the fistula flow; there being no direct connection of IPS-IJV. Hand injection angiograms via a microcatheter in the IPS showed irregular, stenotic/occlusive features of the IPS. If the IPS is patent with compartment of the IPS-CS, the fistula flow usually uses an alternate drainage pathway, such as the superior ophthalamic vein and/or the superficial middle cerebral vein. Pre-embolization carotid angiograms usually disclose the dense opacification of the CS because of fistula flow; the patent IPS can only be demonstrated in the hand injection IPS angiogram or on rare occasions, in the later normal venous phases of carotid angiograms.

Access to the CS through an angiographic nonopacified IPS was first described by Hallbach et al[15] in 1988. Subsequently, some small and sporadic series reported the success rate varied from 50% to 75%.[16,17] In our series, we had successful navigation of the microcatheter into the fistula site with the achievement of total fistula occlusion in 16 of 20 patients (80%). This result is slightly better than previously reported, thanks to more highly developed access devices, high-quality images, and experience in catheterization through the venous route. In this series, we failed to access the fistula via angiographic occlusive IPSs in four patients; two were truly occlusive IPSs, the other two patients had patent IPSs with compartment of the IPS-CS. The success of catheterization to the fistula site in angiographic occlusive IPS is theoretically related to the timing of thrombosis in the IPS/CS and/or fistula anatomy (e.g., length of true occlusion). Chronic occlusive IPS with solid thrombosis is a strong barrier for passage of the catheter/guidewire system to the fistula as evidenced by Patients 17 and 20, with 5- and 6-year histories of CSDAVFs, respectively. By contrast, soft thrombosis is easier and more feasible to pass than those with chronic occlusion. Length of occlusion is another factor associated with the success of navigation, where short segment occlusion such as that seen with Patient 5 (Fig. 1) is easily passable compared to those with longer segment occlusion.

In our experience, we found the major difficulty in navigation of microcatheter to the CS via angiographic occlusive IPS is to find the orifice of the IPS-IJV because of blind navigation of the microcatheter due to a lack of roadmap guiding. Therefore pre-embolization understanding of the various insertion locations of the IPS-IJV is crucial. In those CSDAVFs with patent IPS with compartment of the IPS-CS, the microcatheter could be easily navigated into the IPS, but the difficulty lay in passing the septum in IPS-CS. By contrast, navigation and advancement of the catheter/guidewire into IPS was difficult in cases of true occlusive IPS. Once the catheter/guidewire was successfully navigated into the CS, gentle manipulation and advancement of the catheter/guidewire up to the fistula site were attempted. This procedure usually takes time; therefore, patience with repeated advancement–withdrawal procedures of the catheter/guidewire system, to find the true lumen of the IPS-CS, is necessary. In this series, the procedural time for transvenous detachable embolization ranged from 97 minutes to 162 minutes (mean, 123 minutes). The procedural timing in truly occlusive IPS versus compartment of the IPS-CS was 111 minutes versus 129 minutes ($p < 0.90$). There was no statistical significance between the procedural times in these two different fistula anatomies. Our strategy of transvenous catheterization, if we failed to access to the fistula site after 120 minute attempts, was to give up this access route. Instead, alternative routes, such as transfacial veins or direct puncture of the CS/superior ophthalmic vein, were selected or the patient was referred to undergo Gamma Knife radiosurgery, depending on the angioarchitecture and the patient's clinical manifestations.

The approach to the CS via the nonopacified IPS is considered safe, even in cases where the IPS is not visualized and there is a lack of roadmap guiding. Benndorf et al[16] reported no complications in their series of 14 patients. The most serious complication of the transocclusive IPS embolization of CSDAVFs approach was injury or perforation of the IPS leading to catastrophic hemorrhage. This complication occurred mostly due to blind advancement of a sharp guidewire tip, stiffened by the catheter, and the narrow vascular structure which, aggravated by powerful contrast injection, led to enlargement of the perforation. To avoid this complication, careful and gentle manipulation of microcatheter/guidewire system is crucial. Lekkhong et al[17] utilized a 0.035 inch guidewire to access the IPS. They utilized this wire to create a track and a roadmap by pulling out the wire for subsequent microcatheterization, because the tip of a 0.035-inch guidewire is rounded and less traumatic, especially when it is constantly rotated. In our series, we preferred to select a 0.014/0.017 inch catheter/guidewire system, largely because the guidewire tip was softer due to recent developments in the technology. In addition, the diameter of the guidewire was smaller than those of 0.035 inch, thus inducing less traumatic hemorrhage once it perforates the IPS. On occasion, the increase of intrasinus pressure during hand injection angiogram may lead to catastrophic hemorrhage. Therefore, we didn't recommend performing hand injection angiograms before the catheter was successfully navigated into the fistula site with back flow of the blood from the microcatheter. In this series, we had one case with microcatheter perforation of the IPS leading to a small amount of contrast leakage into the subarachnoid space associated with temporary headache.

In conclusion, most CSDAVFs with angiographic occlusive IPSs presented with benign process. Angiographic occlusive IPS of CSDAVF may relate to truly occlusive IPS or patent IPS with compartment of the IPS-CS. There is no statistically significant difference in procedural times in these two different fistula anatomies.

Transvenous embolization via angiographic occlusive IPS is a feasible and effective method to manage CSDAVF with a high success rate and a low rate of periprocedural risk.

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