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Endovascular Management of Direct Carotid-Cavernous Fistula

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ABSTRACT

Background: Carotid-cavernous fistulas (CCF) are aberrant arteriovenous connection between the carotid artery system and the venous compartments of the cavernous sinus (CS). Endovascular techniques established themselves as the primary approach for treating direct CCFs, aiming principally to seal the fistula while maintaining the patency of the internal carotid artery (ICA).**Objec tive:** This study aimed to assess the safety and effectiveness of endovascular management in treating direct carotid-cavernous fistulas. **Patients and methods:** We prospectively collected data pertaining to 15 patients with direct type CCFs who underwent endovascular treatment using different techniques, including coiling, coiling and Onyx, detachable balloons, graft stenting and ICA sacrificing, at our institution department and other affiliated centers between June 2023 and January 2025 (10 males and 5 females with a mean age of 38.30 ± 11.88 years. The type of fistula, route of embolization, additional use of coils, technical success, inadvertent events, procedural complications, recurrence rate and clinical follow-up were recorded.

Results: 14 patient (93.3%) presented with unilateral ecchymosis and proptosis while 1 (6.7.0%) patients presented with bilateral ecchymosis and proptosis. Regarding the approach used for embolization, 3 (20.0%) patients underwent trans-venous embolization (TVE), of which 1 underwent embolization through superior ophthalmic vein (6.3%), 1 (6.3%) patient underwent TVE through inferior petrosal sinus, and 1 (6.3.0%) patient underwent TVE through facial vein, 12 (80.0%) patients underwent trans-arterial embolization. Coils were used in 12 (80%) patients. Angiographic total occlusion was reported in all of patients in the present study with no incidence of recanalization.

Conclusion: Endovascular approach in treating CCFs was safe and effective method in treatment of direct type CCF, whereas despite its efficacy and benefits, it is not without side effects. Therefore good selection of patients is needed and some technical tips and tricks should be respected.

Keywords: Carotid-cavernous fistulas, Cavernous sinus, Internal carotid artery.

INTRODUCTION

CCFs represent abnormal arterio-venous communications within the CS. Direct CCFs result from a tear in the intra-cavernous segment of the ICA. They are classically characterized by high flow, commonly present with ocular-orbital venous congestion and audible eye bruit [1, 2]. Trauma, including basilar skull fractures, projectile or slash injuries, or iatrogenic causes, accounts for 70% to 75% of all CCFs. These injuries typically occur in young males and often involve high-flow, direct fistulas [3, 4]. On the other hand, spontaneous CCFs make up 30% of cases and arise from conditions such as aneurysm rupture or genetic predispositions like Ehlers-Danlos syndrome or dysplasia of the fibromuscle. They cause type D indirect fistulas with poor flow and are more common in elderly women. On the other hand, spontaneous fistula often has many artery dural feeders and several micro-fistulas inside the CS wall while traumatic fistulas have principally one or less commonly more than one communication between sinus and ICA [5, 6].

Typically affecting young males due to closed head injuries associated with basilar skull fractures, traumatic CCFs can arise from direct tearing of the carotid artery by bone fractures or shear forces during trauma. **Helmke *et al.*** [7] offered an alternate explanation wherein abrupt intraluminal pressure rise in the ICA and contemporaneous distal artery compression might lead to arterial wall rupture and CCF development, even without obvious skull fractures in some patients [7].

Most traumatic CCFs are direct, with high-flow connection between the cavernous carotid artery and the sinus. However, indirect CCFs have also been reported post-trauma. Projectile or slash injuries can cause cavernous carotid artery lacerations, further contributing to traumatic CCFs. Rare instances of iatrogenic CCFs have been documented during procedures like craniotomy, carotid endarterectomy, and endovascular interventions [8, 9].

Bilateral traumatic CCFs are observed in 1%-2% of cases. In contrast, spontaneous CCFs, constituting about 30% of cases, typically affect older female patients. They are frequently linked to burst cavernous ICA aneurysms or hereditary disorders such as fibromuscular dysplasia, Ehlers-Danlos syndrome, and pseudoxanthoma elasticum. Individuals without these diseases, microscopic venous thrombosis or elevated venous sinus pressure due to factors such as hypertension, atherosclerosis, pregnancy and minor trauma, or vascular diseases like diabetes and collagen vascular disorders can predispose to spontaneous CCF formation [10, 11, 12].

In patients without cavernous aneurysms or predisposing syndromes, microscopic venous thrombosis or increased venous sinus pressure are theorized to contribute to CCF development. These conditions may cause tiny breaks in dural vessels leading to the CS. Contributing variables include arterial hypertension, atherosclerotic vascular disease, pregnancy, mild trauma, straining, diabetic vascular

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disease, and collagen vascular diseases [13]. This work aimed to assess the safety and effectiveness of endovascular management in treating direct CCFs.

PATIENTS AND METHODS

*** Data collection and analysis:** We prospectively collected data pertaining to 15 patients with direct type CCFs who underwent endovascular treatment using different techniques including coiling, coiling and Onyx, detachable balloons, graft stenting and ICA sacrificing, at our institution department and other affiliated centers between June 2023 and January 2025 (10 males and 5 females, age ranged from 18 to 62 years with average of 38.3 ± 11.88). The type of fistula, route of embolization, additional use of coils, technical success, inadvertent events, procedural complications, the recurrence rate and clinical follow-up were documented.

*** Clinical assessment:**

Full ophthalmological assessment was done before intervention including anterior segment examination to assess ciliary congestion, refraction, intraocular pressure, extra-ocular motility and fundus examination. Using a ruler, the degree of proptosis and dystopia was determined. The visual acuity was measured using the logarithm of minimum angle resolution best-corrected visual acuity (log MAR BCVA). Follow up ophthalmological assessment was repeated after 3 months and 6 months.

***Angiographic features:**

Every patient had complete cerebral vascular angiography (including the bilateral ICA, the external carotid artery, and the vertebral artery) to determine the precise location of the fistula, feeding arteries, draining veins, compensatory blood supply, and other vascular abnormalities.

Endovascular procedure: All endovascular operations were conducted while the patient was under general anesthesia.

A. Trans-venous embolization

1. IPS trans-femoral approach: We gained percutaneous femoral venous access with a 6f sheath and contralateral femoral arterial access with a 6Fr sheath. A 5Fr diagnostic catheter was inserted into the ipsilateral cervical CCA. A 5Fr Bern catheter or a 6F guide catheter was guided through the venous system to the IPS or, less typically, the origin of the facial vein, followed by the insertion of an Echelon 10 (ev3 Neurovascular, Irvine, CA) micro-catheter into the cavernous sinus using a roadmap. Angiography was done using the micro-catheter to confirm catheter placement into the cavernous sinus and further define cavernous sinus drainage. The dead space within the micro-catheter was gradually filled with DMSO, followed by coil deployment and Onyx injection and detachable balloon implementation or covered stent using a subtracted roadmap.

2. IPS recanalization: In case of non-filling of the IPS, recanalization was needed to be able to reach the cavernous sinus. Advancement of 5Fr Bern catheter was done reaching the expected site of the IPS at its junction with the sigmoid sinus/IJV. A 0.035 Terumo wire was used to recanalize the IPS. Once the IPS was recanalized, retrieval of the wire was done achieving negative road map to delineate its track. Advancement of an Echlon micro-catheter over 0.014 micro-wire passing through the recanalized IPS reaching the CS followed by coil deployment and Onyx injection using a subtracted roadmap. For cases where we deployed covered stents, we used guider 8 F catheters, advanced into proximal cervical segment of ICA. In some cases we used two microcatheters, Echlon and SL10 through 8 Fr guider catheter or Chaperon guider catheter for deployment of coils and injecting Onyx.

B. Trans-arterial embolization

Direct type fistula:

A 6Fr sheath was used to provide percutaneous femoral artery access. Heparinization was employed to keep the anticoagulant status (70-80 IU/kg loading dosage followed by 20 IU/kg/hr maintenance dose). A 6 Fr guide catheter was inserted into the ICA. High frame fluoroscopy (6–10 frames/sec) was used for angiography through the micro-catheter in order to better define the fistula and identify potentially hazardous anastomoses. DMSO was gradually added to the dead area inside the micro-catheter, and then Onyx was embolized using a subtracted roadmap.

In coil instances, detachable coils were inserted into the CS at the major site of the fistula and surrounding drainage venous exits for partial embolization and as a framework for later Onyx embolization. Therefore, packing the CS with coils was not essential. Three or four coils might be inserted before Onyx infusion began.

Before Onyx embolization, angiography from the guiding catheter in the ICA was performed to confirm good occlusion of the arterial tear by the hyperglide balloon to avoid retrograde onyx leakage within the ICA. Therefore we used long 30 mm hyperglide balloons to secure the whole cavernous segment of the ICA. Injection from the micro-catheter was also performed to confirm good localization of the tip of the micro-catheter.

Deflation of the balloon is performed every 5 minutes to perfuse the brain and control angiogram was performed. The procedure is finished when the control angiogram showed total occlusion of the fistula. Graft stent was deployed in some cases after loading the patient with double antiplatelet for 5 days prior to procedure.

Ethical approval: Sohag Faculty of Medicine's Ethics Committee accepted this work. After receiving all of the information, each participant signed a permission. The Helsinki Declaration was followed throughout the course of the investigation.

Statistical analysis

For the purpose of coding, processing, and analysis, SPSS version 24.0 for Windows® was utilized. The qualitative data were shown as relative percentages and frequencies. Mean ± SD was used to convey quantitative data.

RESULTS

*** Demographic data of study population:**

In this study, 6 of patients with CCF who underwent embolization of CC with the ethylene vinyl alcohol copolymer, Onyx were included plus coiling, 4 had coiling only, 2 cases used detachable balloon and coils and three cases had their ICA sacrificed.

Their mean age was 38.30±11.88 years ranging between 18 and 62 years. 10 (66.0%) patients were males and 5 (33.0%) patients were females. 5 cases through trans-venous route and 10 cases through trans-arterial route.

Table (1): Demographic data of study population

Age	Mean ± SD	38.30 ± 11.88 (18-62)
Gender	Male Female	10 5

*** Descriptive data of study population:**

14 patient (93.3%) patients presented with unilateral ecchymosis and proptosis while 1 (6.7.0%) patients presented with bilateral ecchymosis and proptosis.

Regarding the approach used for embolization, 3 (20.0%) patients underwent trans-venous embolization (TVE), of which 1 underwent embolization through superior ophthalmic vein (6.3%), 1 (6.3%) patients underwent TVE through inferior petrosal sinus, and 1 (6.3.0%) patient underwent TVE through facial vein. 12 (80.0%) patients underwent trans-arterial embolization. Coils were used in 12 (80%) patients (Table 2).

Table (2): Descriptive data of study population.

		Number of cases (Total 15)
Clinical presentation	Unilateral ecchymosis and proptosis	14
	Bilateral ecchymosis and proptosis	1
Route	Coils and Onyx	6 (40%)
	Coil only	4 (27%)
	Detachable balloon and coils	2 (13.3 %)
	ICA occlusion by coils	3 (20%)

***Outcome of endovascular approach:** Angiographic total occlusion was reported in all patients of the present study with no incidence of recanalization (Table 3).

Table (3): Outcome of endovascular approach among population

		Count (%)
Total occlusion of fistula in one session	Yes	15 (100%)
Recanalization	No	15 (100%)

*** Complications and mortality among study population:**

Regarding inadvertent events in this study, onyx leak beyond the balloon during TAE of a direct type CCF was reported in 1 (6.6%) patient.

This leak of Onyx was because we used tow protective balloons rather than single long balloon to protect agonist Onyx leak. We successfully aspirated this leaked Onyx with aspiration catheter with no detected arterial occlusion or residual neurological deficit (Table 4).

Table (4): Complications and mortality among population

		Count (15)
Inadvertant event	Onyx leak	1 (7%)

CASES

CASE (1)
Clinical presentation: A 53 years old male patient, presented with headache, right sided ecchymosis and proptosis. The patient had history of head trauma 3 months before.

Radiological findings: * Diagnostic angiography revealed a direct type right sided CCF.

Technical details:
* We planned to treat the patient through trans-arterial route.
* Passing Echlon 10 micro-catheter through fistulous opining.
* Deployment of Coils followed by injecting a cast of Onyx.
* The main goal of treatment was to totally occlusion of the fistula
* Control angiogram showed complete occlusion of fistula with absence of venous filling.

RESULT
* The final control angiogram showed total occlusion of the fistula.
* The procedure was ended without any complications.
* The patient displayed complete reversal of symptoms at the three and six months.

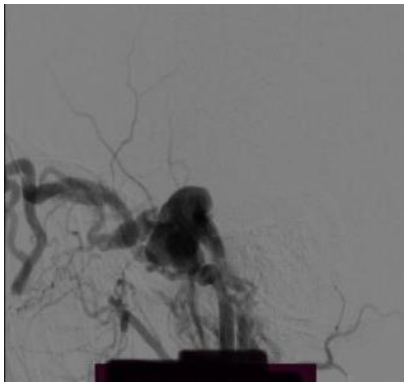

Fig. (1): Abnomal filling of cavernous segmnet during arterial angiogram

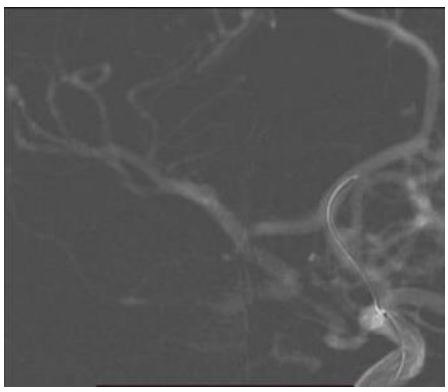

Fig. (2): Passage of micro-wire and microcatheter.

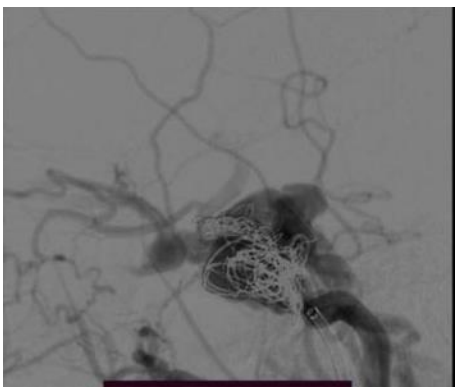

Fig. (3): Deployment of coils via microcatheter

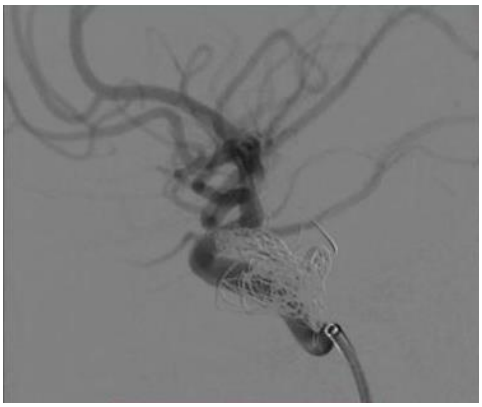

Fig. (4): Control angiogram after deployment of coils.

CASE (2)

Clinical presentation: A 16 years old male patient, presented with headache, right sided ecchymosis and proptosis. The patient had history of head trauma 3 months before.

Radiological findings: * Diagnostic angiography revealed a direct type right sided CCF.

Technical details:
* We planned to treat the patient through trans-arterial route.
* Passing Echlon and SL 10 micro-catheter through fistulous opining.
* Deployment of Coils followed by injecting a cast of Onyx.
* Follow up after 3 months revealed still filling of fistula.
* Second session through trans-venous approach was done by extra-coils and Onyx injection.
* The main goal of treatment was to totally occlude the fistula
* Control angiogram showed complete occlusion of fistula with absence of venous filling.

RESULT
* The final control angiogram showed total occlusion of the fistula.
* The procedure was ended without any complications.
* The patient displayed complete reversal of symptoms at the three and six months.

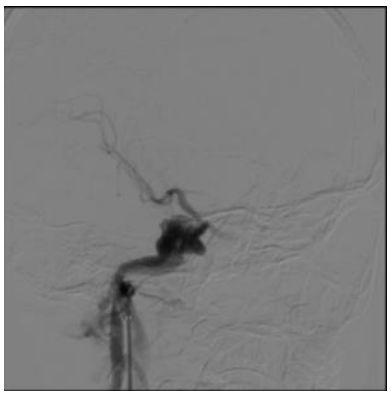

Fig. (5): Abnormal right cavernous sinus filling during arterial angiogram.

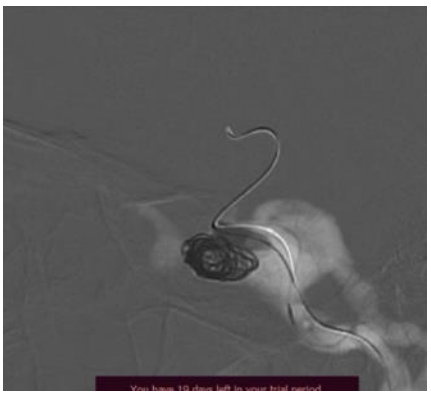

Fig. (6): Deployment of coils with inflation of protection balloon in right ICA (Balloon assisted).

Fig. (7): Arterial angiogram shows early venous filling of inferior petrosal sinus.

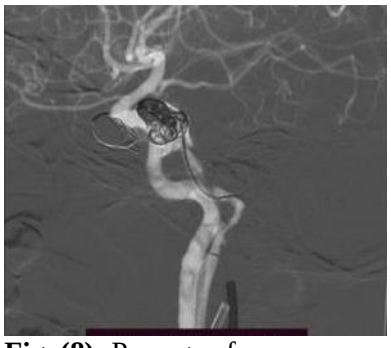

Fig. (8): Passage of microcatheter through inferior petrosal sinus.

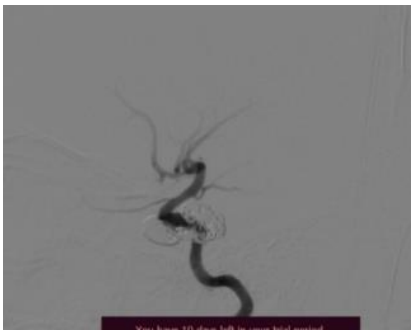

Fig. (9): Control angiogram showed total occlusion of fistula.

DISCUSSION

CCFs are aberrant arterial connections formed by the internal, external, or both carotid arteries and the cavernous sinus. This shunting of blood can cause ocular venous hypertension and orbital congestive symptoms. Several therapies have been tried throughout the years, with inconsistent effectiveness. The endovascular technique to CC therapy has shown both safety and long-term success [(14)].

Direct CCFs are difficult to treat. Endovascular techniques are now the recommended course of therapy due to developments in micro-catheters and other embolic materials. CCFs can be managed endovascularly using a variety of methods. The aim of therapy was to keep the artery open while blocking the cavernous sinus's and artery's connection. Transvenous embolization, covered stents, detachable balloons, embolization materials, and ICA sacrifice were among the available therapy methods. The kind, size, and operator preference of the artery defect, as well as the architecture of the fistula, all influence the treatment decision [(15)].

Direct fistulas are treated using detachable balloons that are transported via the airway. Another approach for causing cavernous sinus obliteration is the use of coils and embolic materials, which are administered via the venous or arterial route. Another excellent choice for direct CCF is covered stents. The primary technical challenge is the covered stents' rigidity, which might make it impossible to navigate the carotid siphon, particularly in arteries with twists. The basilar plexus, pterygoid plexus, facial vein, and superior ophthalmic vein are further endovenous options, however the IPS is the simplest and fastest venous route to the cavernous sinus [(15)].

Onyx-induced cavernous sinus obliteration offers several benefits over coils or n-Butyl cyanoacrylate (NBCA). In contrast to coils, which have the potential to compartmentalize the cavernous sinus and cause partial obliteration, onyx penetrates the sinus gradually. Onyx may be injected more slowly and accurately while requiring fewer catheterizations than NBCA because it progressively precipitates in a radial pattern from the outside inside, generating a cast, as opposed to NBCA, which polymerizes fast [(15)].

In this study, 6 of patients with CCF who underwent embolization of CC with the ethylene vinyl alcohol copolymer, onyx were included plus coiling, 4 had coiling only, 2 cases had detachable balloon and coils and three cases had their ICA sacrificed. 14 patient (93.3%) presented with unilateral ecchymosis and proptosis while 1 (6.7.0%) patient presented with bilateral ecchymosis and proptosis.

Coils, on the other hand, were not the most effective embolic materials for large fistulas and dilated CS. A dense packing of the CS was necessary to completely occlude the fistula, which may result in cranial nerve palsy due to coil mass effect as reported by **Kashiwazaki *et al.*** [(16)]. They reported that four (5.5%) out of seventy three patients developed abducent nerve palsy between three and sixty-five months following TVE. For eight to eighty months, all four of the patients with delayed abducent nerve palsy were monitored. Nonetheless, all 4 patients continued to have delayed abducent nerve palsy. In certain situations, using onyx exclusively is a practical and cost-effective solution. A protective hyperglide balloon that is not removable is utilized in direct CCF to stop Onyx from seeping into the artery circulation. Onyx use, however, would not be appropriate if the fistulous ostium is sufficiently big to prevent retrograde leaking within the ICA even with balloon protection [(17)].

Going back to our whole study in CCF treatment, we found that in some cases of direct CF we decided to avoid onyx injection as the fistula was too large. Therefore, we decided to use coils only in those cases. Long-term balloon obstruction within the ICA during onyx injection may cause cerebral hypoperfusion and ischemic insult. Hence intermittent balloon deflation was needed to re-perfuse brain every few minutes and to avoid blood stagnation proximal to the inflated intra-arterial balloon with consequent clot formation that may embolize distally after balloon deflation. Moreover, good heparinization of the patient and rapid continuous saline flow through the guiding catheter proximal to the inflated balloon is also needed to avoid such complication. Furthermore, even though the protective balloon is highly conformable, it may not always be able to completely occlude the fistula due to compensatory dilatation of the ICA and the extremely tortuous cavernous segment. This could result in an unintentional onyx leak through the fistulous opening. In some cases, multiple tears of the intra-cavernous segment of the ICA may be present even if not clearly identified in the angiogram. In such case if we have inflated the balloon against one tear, onyx may leak from the other unsecured tear. Therefore, we have to secure the whole intra-cavernous segment of the ICA by a long balloon example 4x30 mm balloon that we used in our series. That was shown in our study in **case (2)** in our illustrative cases. In one of our cases, we didn't have a long balloon available, so we had to use 2 balloons to secure he whole intra-cavernous segment of the ICA. In this case, onyx was able to leak in-between the two balloons and we were able to retrieve the leaked onyx from the ICA by aspiration technique at the end of the procedure. However, this inadvertent side effect indicated usage of one long balloon as we mentioned.

Pre-coiling before onyx injection was an alternative option that we used in 6 patients in our study. This approach has been employed for endovascular treatment of direct CCFs since **Baccin *et al.*** [(17)] reported the first embolization utilizing onyx and coils for direct CCFs. When the dimethyl sulphoxide (DMSO) solvent diffuses out of the blood, onyx solidifies and casts in the coil mass enough. This special characteristic allows the coils and hardened onyx to create a "Strong concrete" structure, which stops coil migration when the

protecting balloon in ICA is deflated. We can thus conclude that the use of onyx reduces the time and expense of the process by eliminating the need for tight packing of the CS and replacing coils as the framework.

Unlike previous techniques, a thin membrane is usually present on the internal, adluminal, or both sides of covered stents. They have uses in the therapy of peripheral vascular diseases and coronary heart disease, and were first created to repair burst or perforated vessels [(18)]. Covered stents provide a number of benefits, even if the occlusion rates of direct carotid cavernous fistulas (dCCFs) appear to be similar among conventional endovascular procedures. The installation of covered stents is a relatively short operation, which is important for patients with multisystem injuries, and they have no mass effect on the cranial nerves in the cavernous sinus or danger of coil herniation into the ICA lumen [(19)].

Our study, regarding the approach used for embolization, 3 (20.0%) patients underwent trans-venous embolization (TVE), of which 1 underwent embolization through superior ophthalmic vein (6.3%), 1 (6.3%) patients underwent TVE through inferior petrosal sinus, and 1 (6.3.0%) patient underwent TVE through facial vein. 12 (80.0%) patients underwent trans-arterial embolization. Coils were used in 12 (80%) patients.

6 cases of direct CCFs treated with stent-assisted coil embolization were described by **Morón *et al.*** [(20)]. Transvenous treatment was used in three patients, whereas transarterial treatment was used in the other three. In each of the six cases, direct CCFs were fully blocked without any complications. Dual antiplatelet medications must be used before to treatment in order to prevent acute stent thrombosis. Nevertheless, antiplatelet therapy may lessen the coil mass's occlusive effects on direct CCFs.

In our study, angiographic total occlusion was reported in all of patients with no incidence of recanalization. Regarding inadvertent events in this study, onyx leak beyond the balloon during TAE of a direct type CCF was reported in 1 (6.6%) patient.

52 of the 126 cases of direct CCFs described by **Dai *et al.*** [(21)] were treated with PAO. Three of these patients developed Horner's syndrome. Neither the PAO group nor the ICA preserved group experienced an ischemic stroke. Nine patients (12.2%) in the ICA preserved group experienced a recurrence of CCFs during follow-up, but none in the PAO group did. **Dai *et al.*** [(21)] reported positive treatment outcomes, but the PAO operation has a risk of cerebral infarction because of hypoperfusion and stagnated blood embolism at the stump distal to the occlusion site. Neurological impairments following PAO occur in 3% to 7% of patients, including those who are tolerant of balloon test occlusion.

CONCLUSION

We found out that endovascular approaches are effective in the treatment of CCFs but not without hazards. We were able to achieve excellent clinical and angiographic outcomes with a low rate of complications for direct CCFs. There is no absolute theoretical contraindication to use onyx for treating CCFs, whereas despite efficacy and benefits of endovascular treatment of CCFs, it is not without side effects. Therefore good selection of patients is needed and some technical tips and tricks should be respected.

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