Endovascular Occlusion of Dural Cavernous Fistulas through a Superior Ophthalmic Vein Approach

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SUMMARY – *Dural cavernous fistulas are low-flow vascular malformations with usually benign clinical course and a high rate of spontaneous resolution. Cases with symptom progression must be treated with an endovascular approach by arterial or venous route. We report 30 patients with dural cavernous fistulas treated by coil embolization using surgical exposure and retrograde catheterization of the superior ophthalmic vein (SOV). The procedure resulted in closure of the fistula without other endovascular treatments in all 30 patients and clinical remission or improvement in 20 and eight patients, respectively. Embolization via a SOV approach is a safe and easy endovascular procedure, particularly indicated for dural cavernous fistulas with exclusive or prevalent internal carotid artery feeders and anterior venous drainage.*

Introduction

Dural fistulas are arteriovenous malformations draining in a dural venous sinus accounting for 10-15% of all intracranial vascular malformations¹. They are classified according to the intracranial localization and to the venous drainage type¹⁻³. The classification proposed by Borden et al. separates benign lesions, draining into a dural venous sinus or meningeal vein only (grade I), from aggressive lesions with retrograde leptomeningeal venous drainage additionally (grade II) or alone (grade III)⁴.

Dural carotid-cavernous fistulas (DCFs) are caused by abnormal communications between the meningeal branches of the internal (ICA) or external carotid artery (ECA) and the cavernous sinus, and are usually characterized by low flow and a high rate of spontaneous resolution. The venous drainage of DCFs may be posterior (through the inferior petrosal sinus) or more often anterior (through the ophthalmic

veins) when the cavernous sinus is partially thrombosed. Symptoms of ocular involvement occur when venous drainage is diverted to the ophthalmic veins. Endovascular treatment is indicated in cases of symptom progression. However, the best route for endovascular occlusion [arterial, anterior venous (SOV), posterior venous (inferior petrosal sinus), or through the facial vein] is still debated. This paper reports 30 patients with DCFs treated by endovascular cavernous sinus occlusion with coils using a SOV approach. The indication and advantages of arterial and venous approaches and the results of the endovascular treatment of these dural fistulas are discussed.

Materials and Methods

Thirty patients with DCFs who underwent endovascular occlusion through a SOV approach were reviewed. Besides these cases, eight pa-

A

B

C

Figure 1 Surgical exposure of the superior ophthalmic vein (SOV). A small curvilinear incision was made (A) at level of the shown eyebrow to expose the SOV (B) and an angiocath was inserted into the vein for embolization procedure (C).

tients who experienced clinical and angiographic remission as a result of the noninvasive procedures, such as manual carotid compression and subcutaneous heparin injection, were excluded.

Clinical examination was performed separately by a neurologist and an ophthalmologist. All patients were explored by computed tomography (CT), 15 by magnetic resonance (MRI) and six by orbital echography; all underwent selective digital angiography (DSA) by transfemoral catheterism.

Previous therapeutic procedures included unsuccessful manual compression or heparin therapy in all cases, endovascular treatment via the inferior petrous sinus in four patients (including two with occlusion of the ECA branches and increased ICA flow, and another with sphenoparietal sinus enlargement and flow reversal), and transfemoral embolization of the internal maxillary artery in six. Control DSA was performed one week and six months after the endovascular procedure. The current clinical follow-up ranges from five months to 12.5 years.

Clinico-diagnostic findings

Patients include 22 females and eight males, ranging between 13 and 68 years (average 51 years). Clinical history before the procedure ranged from 20 days to 12 months (average five months) in 29 patients; only one patient had a two-year history.

Ophthalmic signs and symptoms included unilateral exophthalmos in all cases, diplopia in 14 (46.5%), ptosis in 16 (53.3%), congiuntival chemosis in 16 (53.3%). Visual acuity in the involved eye was 20/20 in 14 cases and below 20/25 in 16. The intraocular pressure was normal in 22 (73.3%) patients, abnormal in eight cases: between 21 and 30 mmHg in six and more than 30 in two. Ocular fundus examination was normal in 16 patients (53.3%), disclosed venous ectasia in ten (33.3%) and edema with blurred margins in four (13.3%). There were no other clinical signs. DSA showed that DCF was fed by ICA meningeal branches in 26 cases and by both the internal maxillary artery and meningo-hypophyseal trunk of the ICA in four. The preferential venous drainage was anteriorly directed to the ipsilateral SOV.

Endovascular technique

Surgical exposure of the SOV was performed under loco-regional anaesthesia by an expert ophthalmologist surgeon in the angiography

Figure 2 Left common carotid artery angiogram in anterior-posterior view (A) and lateral view (B). Dural fistula of the cavernous sinus draining anteriorly into the ectatic SOV.

Figure 3 Operative DSA (A) shows dural fistula of the anterior segment of the cavernous sinus. Microcatheter is placed in the SOV with distal tip in the cavernous sinus. Control DSA (B-C) after endovascular therapy with mechanical detachable coils showing total occlusion of the fistula.

suite. A small curvilinear incision was performed over the shorn eyebrow for aesthetic reasons. Subcutaneous tissues were carefully dissected to expose the vein, then a haemostat was placed underneath the vein, which was tied on the distal end. Finally, an angiocath was inserted into the vein for the embolization procedure (Figure 1A-C). A 5F catheter had been previously placed in the common carotid artery to obtain control angiograms.

The embolization procedure was performed in different ways and with different embolic materials. In five cases a 3F teflon catheter (T3.0 Cook) on a 0.18 inc. wire was introduced into the SOV and navigated to the cavernous sinus. Four to six curved minicoils (3 mm×10 mm, Hilal minicoil Cook) were placed through the catheter into the cavernous sinus. In six cases a microcatheter (18 or 10) was introduced coaxially through a 18G2 cannula in the fis-

A

B

C

Figure 4 Patient's clinical appearance before (A), early after the procedure (B) and during the follow-up (C).

tula, and two platinum helical microcoils (4×40 mm) were placed. In 19 cases, detachable coils (GDC) were placed through a microcatheter.

Serial control angiograms were performed through the catheter inserted into the common carotid artery, in order to assess the result of

treatment (Figure 2A,B). When the occlusion was considered satisfactory (no fistulous flow on the angiogram), the venous catheter and sheath were removed, the vein was ligated and the eyebrow incision was closed (Figure 3A-C).

Results

Embolization through a SOV approach determined the immediate closure of the fistula in 29 patients. DSA (at one week and six months) disclosed residual filling in one patient with cortical venous drainage and involvement of the antero-inferior and postero-superior cavernous sinus compartments; in this case complete occlusion of the fistula was observed one year after the procedure.

Clinical follow-up showed complete remission of all ocular symptoms and signs in 21 patients (70.%) (Figure 4) and persistence of slight ptosis in seven (23.3%). One patient had unchanged diplopia which required surgical correction. A poor clinical outcome with persistence of ptosis, visual impairment and corneal damage was observed only in one case (3.3%). This patient had concomitant erosion of the sphenoid bone due to a multiple myeloma.

The procedure-related complications included glaucoma in one case and thrombophlebitis in another, probably due to lack of heparin therapy after the procedure. Thus three-day heparin therapy after the procedure is indicated in these patients.

Discussion

Dural carotid-cavernous fistulas (DCFs) are stable or slowly evolutive lesions, usually associated with benign clinical manifestations. Proptosis is slight and non-pulsatile in most cases. Patients more often require medical observation because of the decrease of visual acuity. A red eye with arterialized episcleral vessels may be the unique clinical sign in some cases^{5,6}. Therefore diagnosis is often difficult and may be delayed for months. Clinical presentation of a DCF can be closely related to the venous drainage pattern: drainage via the SOV is associated with orbital and neuro-ophthalmological symptoms, whereas leptomeningeal drainage correlates with neurological symptoms or intracranial haemorrhage². The finding of enlarged draining veins on contrast-enhanced CT, MRI and MR angiography (a) supports the clinical suspicion. Hyperintensity of the SOV (instead of the flow void) on MRI and flow reversal in the enlarged vein on MRA are the main findings suggesting a DCF.

DCFs may have a benign natural history, with a high rate of spontaneous closure (from 17% up to 50%)⁷. Regression may also occur

after manual carotid compression⁸, during diagnostic angiography^{9,10}, or secondary to barometric changes during airplane flights; thus, even a slight change in the haemodynamics of the fistula may sometimes allow its closure. This explains why embolization of only ECA branches may result in complete occlusion.

DCFs with mild stable symptoms do not require angiography or embolization and must be treated conservatively^{5,11}. DSA is reserved for cases with symptom progression to endovascular occlusion. Bilateral ICA and ECA injections are advisable, because of the frequent contribution of contralateral dural vessels^{13,14}.

Several noninvasive treatments can allow closure of the dural fistula. Manual carotid compression results in a 30% rate of definitive cure⁸. Low dose heparin systemic infusion for at least two months¹⁵ may result in resolution of clinical symptoms (in three patients excluded from this study), thus suggesting a venous thrombotic disease as the cause of cavernous sinus occlusion.

An endovascular treatment is indicated in patients with symptom progression, particularly visual loss, glaucoma and persistent ophthalmoplegia^{12,16-17}. The endovascular occlusion of DCFs may be achieved by arterial or venous approach, according to the vascular anatomy of dural malformation.

The arterial route may be considered the first endovascular treatment for DCFs with ECA feeders and has a high success rate^{14,1}. Transarterial embolization of DCFs generally is cumbersome because of the small size, tortuous anatomy, and multiplicity of arterial feeders. Especially in cases supplied predominantly by ECA meningeal branches, the microcatheter must be placed as close as possible to the fistulous site for the injection of proper embolic agents under fluoroscopic control with the goal of occluding the fistulous connection and penetrating the cavernous sinus. The risk of transarterial embolization lies in the anastomotic communication between dural arteries supplying the fistula and meningeal and pial vessels supplying cranial nerves and brain tissue, increasing the risk of cranial nerve palsy and stroke, respectively⁴⁵.

The venous route is necessary when there is a predominant ICA supply or when ECA embolization is ineffective. It has become the treatment modality of choice for symptomatic DCFs due to its better results compared with other therapeutic modalities. Transfemoral venous embolization is feasible when the drainage is directed to the inferior petrosal sinus

^{16,18} or through the facial vein ¹⁹. However this procedure is more difficult because of the long catheterization route, and requires more catheter manipulations, resulting in a greater risk of rupture of arterialized veins. Moreover, catheterization of the inferior petrosal sinus may be difficult and unsuccessful, even if it is angiographically demonstrable ¹².

The SOV route was described more than 30 years ago for electrically induced thrombosis of the cavernous sinus ¹⁸. It was initially used for embolization of carotid-cavernous fistulas with different techniques ^{5,20-24} and later also for DCF

^{12,15,18, 23-29}

The SOV approach for DCF is indicated in cases with exclusive or prevalent anterior venous drainage and with decreased visual acuity and increased pressure in the orbital venous system. Phlebography through the SOV is very useful to define the precise location of the fistula before its occlusion. We prefer the surgical exposure of the SOV rather than its direct puncture. In fact, a small aesthetic incision over the eyebrow allows the direct visibility of the SOV, which can be cannulated even if not enlarged. The surgical exposure in local anesthesia requires an acceptable extratime (less than one hour in all our cases) with no complications.

Klisch et al ⁴⁶ reported 17 AVFs of the CS treated by transvenous approach. Eleven patients with AVFs of the CS (63%) were cured with respect to clinical symptoms, and six patients experienced improvement (37%). With the approach via the facial vein, there was a 50% success rate. The superior ophthalmic vein approach was associated with a high rate of technical success (100%), with a rate of complete fistula occlusion of 80%.

The morbidity reported in the Klisch's series was 23.5% of the cases; in our series it was only 6.6%.

Jiang et al ⁴⁷ reported nine patients embolized using direct surgical exposure and cannulation of the SOV, when the cavernous sinus dural fistulas (CSDF) could not be treated via the transarterial or transfemoral venous route. All nine patients were successfully treated by introduction of Onyx (Covidien ev3 Neurovascular) in conjunction with detachable coils through the catheterized SOV to the affected cavernous sinus. Symptoms and signs resolved completely in all patients (100%) after successful occlusion of the CSDF.

This two reports confirms the safety and the effectiveness of the surgical exposure and cannulation of the SOV approach used in our serie.

Several embolic agents can be used in order to obtain cavernous sinus thrombosis: detachable balloons, fibrin glue, cyanoacrylate glue, sclerosing and minicoils ³⁰.

The advantage of using coils lies in its radiopacity, easy use, controlled deployment, and possibility to be removed if the initial placement is not optimal ³¹. Also, coils adopt the shape of the fistulous compartment and rarely migrate or experience deformation ³¹.

Different types of coils were used in our patients. This kind of material can be deposited through small size catheter without exerting traction as in detachable balloons. The risks related to the minicoils are due to their low handling, because their position is difficult to be modified when delivered; an incorrect release or migration may occlude an efferent vessel with secondary symptom worsening. An accurate choice of the coil size and configuration can reduce this risk; the use of replaceable and detachable coils ^{18,32-34,40-44} allows to control their deposition and to compact them in the correct site.

The largest reported series using the transvenous approach for DCFs comes from Kirsch et al. ³⁵, with 141 patients who underwent 161 treatment sessions achieving complete obliteration of the fistula in 81% of patients. Meyers et al. ³⁶ reported the largest series of indirect CCF treated by endovascular approach with 133 patients and a mean follow-up of 56 months; they reported a cure rate of 90%, with good clinical outcomes in 97% of the patients and a procedure-related morbidity of 2.3%.

Although the potential surgical complications of the SOV approach are hemorrhage, damage to the trochlea or other orbital structures, and infections, this approach is a safe, direct, and efficient way to access and occlude the cavernous sinus ³⁷. Despite the risk of the approach itself, the main complication associated with transvenous embolization is over-packing of the cavernous sinus resulting in nerve palsies, dural dissections, or penetrations ³⁷⁻³⁹.

The results of embolization of DCF via SOV approach are very good in our series, with immediate occlusion in 29 among 30 cases [96%]. This is likely due to the direct occlusion of the fistulous communication at the cavernous sinus. Remission of all ocular symptoms occurred in 2/3 of our patients. This approach could be done when normal route (arterial or venous) fails.

The use of Onyx (Covidien ev3 Neurovascular), a liquid embolic agent that can be used alone or in combination with coils and stents,

is not exempt from complications such as transient compressive neuropathies or cranial nerve ischemia/infarction caused by post-embolization cavernous sinus thrombosis and penetration within arterial collaterals, respectively³¹. There is a need for larger series and follow-up data to determine if Onyx can be considered a definitive treatment for this type of lesion³¹.

Conclusion

For many years, DCFs have been almost exclusively treated by endovascular embolization. The endovascular technique has dramatically

changed over the past 20 years since the development of the transvenous approach in association with controllable detachable coils³⁹.

Embolization of DCFs via the SOV may be considered a safe and rather easy endovascular procedure. Retrograde catheterization of the SOV allows to directly reach the cavernous sinus and occlude the fistula with good angiographic and clinical results.

This approach have to be considered the first choice in DCFs with exclusive or prevalent ICA feeders and a possible route also in cases where arterial embolization of ECA feeders fails and transfemoral venous approach via the inferior petrosal sinus is difficult.

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