NEUROLOGY

Cite as: Archiv EuroMedica. 2024. 14; 3. DOI [10.35630/2024/14/3.334](10.35630/2024/14/3.334)

Received 11 April 2024; Accepted 30 May 2024; Published 17 June 2024

CAROTID - CAVERNOUS FISTULA - CCF

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ABSTRACT

Carotid-cavernous fistulas are a rare vascular disorder resulting from an abnormal connection between the cavernous sinus and the carotid arteries. Direct carotid-cavernous fistulas require endovascular treatment. Indirect fistulas may resolve spontaneously or with non-invasive treatment, but worsening symptoms may also require endovascular treatment. Endovascular treatment is performed using detachable balloons, detachable coils, stents, and embolization materials such as n-BAC or Onyx. The symptoms occur as a result of increased pressure within the venous drainage vessels. The most common clinical manifestation are symptoms within the eyeball. Due to their rare occurrence and often non-uniform clinical symptoms, carotid-cavernous fistulas may pose diagnostic difficulties.

The Aim of this work: Carotid-cavernous fistula is a disorder that may result in complete loss of vision. Appropriate diagnostics and the involvement of an interdisciplinary team of specialists are important. Such a team should consist of an ophthalmologist, a radiologist and a neurosurgeon. The fistula requires differentiation from other more common diseases with similar symptoms, hence the knowledge of the etiology, diagnosis and treatment of the fistula is crucial.

Methods: Selected articles from Pubmed and specialist literature were analyzed in detail. We focused on selected issues related to carotid-cavernous fistulas.

Conclusion: When the clinical symptoms are vague, the diagnosis may be incorrect or established with a long delay. Early correct diagnosis can effectively prevent irreversible vision impairment.

Keywords: Carotid-cavernous fistula, proptosis, embolization, endovascular treatment

INTRODUCTION

Carotid cavernous fistula (CCF) is a vascular disorder whose essence is the passage of arterial blood from the internal and/or external carotid artery into the lumen of the cavernous sinus, leading to hemodynamic changes in the intracranial venous system. The cavernous sinus, due to its close proximity to the orbit, its location in the middle cranial fossa and its adhesion to important anatomical structures such as the sphenoid sinus or pituitary gland, is a region whose pathologies are of interest to ophthalmologists, neurosurgeons and interventional radiologists.

The classification of carotid-cavernous fistulas can be based on:

a. direct or indirect angiographic examination,
b. according to hemodynamic features for low-flow or high-flow fistulas:
    - the low-flow variety may occur in pregnant women, the elderly, during childbirth, and in postmenopausal women. Risk factors include: hypertension, diabetes, atherosclerosis, exercise, cavernous sinus thrombosis, sinusitis, vascular malformation,
    - the high-flow variant is most often a direct result of injury to the internal carotid artery,
c. due to etiology, post-traumatic and spontaneous. [1] Injuries occur due to iatrogenic causes or after accidents. The cavernous sinus lies in the line of skull base fractures, and for this reason, damage to the internal carotid artery and arterial blood outflow directly into the venous blood of the cavernous sinus often occur. [2]
    - spontaneous carotid-cavernous fistulas may occur due to a ruptured aneurysm of the cavernous section of the internal carotid artery or in patients with connective tissue diseases, e.g. Ehlers-Danlos syndrome, fibromuscular dysplasia as a result of rupture of a weakened arterial wall. [1]

According to the anatomical and angiographic classification proposed by Barrow et al., carotid-cavernous fistulas are divided into four types:

I. type A → direct connection between the internal carotid artery and the cavernous sinus. Most often of a high-flow nature. Intermediate fistulas (B-D) are low-flow dural arteriovenous fistulas,
II. type B → fistulas between the meningeal branches of the internal carotid artery and the cavernous sinus,
III. type C → fistulas between the meningeal branches of the external carotid artery and the cavernous sinus,
IV. type D → fistulas between the meningeal branches of both internal and external carotid arteries and the cavernous sinus. [3] Type D is the most common of the indirect carotid-cavernous fistulas. [4]

METHODS

PubMed platforms and specialized literature were searched using keywords. Articles that met the selection criteria were identified and analyzed thoroughly. Additionally, bibliographies of accepted works were searched to expand the publication base.

RESULTS AND DISCUSSION

To better understand the etiopathogenesis of carotid-cavernous fistula, it is necessary to know the anatomy of the cavernous sinus region.

The cavernous sinus belongs to the cerebral venous sinus system. It occurs in pairs on both sides of the shaft of the sphenoid bone. It is a cephalad extension of the epidural Batson's venous plexuses covering the dural sac. In frontal section, it resembles a triangle, the sides of which are formed by the upper, medial and lateral walls (Table 1).

Table 1. Cavernous sinus - limitations

Paries		
UPPER	MEDIAL	SIDE
it is formed by the dural lamina limiting the sella turcica from above (the so-called sella turcica diaphragm)	in its upper part it borders the pituitary gland, and its lower part adjoins the shaft of the sphenoid bone	it is covered with the dura mater separating the sinus from the laterally located temporal lobe

Carotid-cavernous fistulas are rare. Direct carotid-cavernous fistulas occur in 57% of cases as a result of trauma, most often in young men. Approximately 20% of cases are caused by spontaneous rupture of an aneurysm in the cavernous section of the carotid artery internal and occurs more often in women. In 10% of patients, the fistula may clot and become life-threatening. [5]

PATHOGENESIS

Damage to the internal carotid artery leads to a rapid inflow of blood into the cavernous sinus, which contributes to an increase in pressure in the sinus. The increase in pressure in the cavernous sinus causes blood to flow back into the orbital veins, resulting in venous hypertension and venous stasis in the orbit. [5] In a direct fistula, retrograde blood flow from the cavernous sinus to the superior ophthalmic vein occurs in 89%, and in an indirect fistula in 62%. [6]

CLINICAL SYMPTOMS

Clinical symptoms depend on many factors, including the size and location of the carotid-cavernous fistula, the speed of blood flow within them and the venous drainage routes. Symptoms result from excess pressure in the cavernous sinus and draining veins, as well as from the reverse direction of blood flow. [7] Most often, the direction of venous drainage is multidirectional. [8] The characteristic triad of symptoms of a direct high-flow carotid-cavernous fistula is:

a. proptosis of the eyeball,
b. noises heard by the patient,
c. conjunctival congestion.

The entire triad of symptoms occurs only in some patients. Other symptoms include: conjunctival edema, double vision, orbital pain, increased intraocular pressure, eye motility disorder, ophthalmoplegia, ptosis, trigeminal nerve disorders, and loss of vision. [9]

The increase in intraocular pressure is mainly caused by an increase in pressure in the episcleral veins, which causes impaired retinal perfusion, which contributes to decreased visual acuity. [10] Intracranial hemorrhage occurs in 5% of patients due to modified venous drainage into the sphenoparietal sinus with occlusion of other drainage routes. Ear bleeding and nosebleeds may occur in 3% of patients, while life-threatening massive nosebleeds occur in 1-2% of patients. [11, 12] Internal carotid artery blood steal syndrome may cause symptoms of cerebral ischemia. [5] Indirect carotid-cavernous fistulas most often do not present the classic triad of symptoms. Symptoms develop slowly and are usually milder. The most common symptoms include bloodshot eyes, ptosis, and proptosis that is mild or absent. [12,13] The main danger of untreated carotid-cavernous fistulas is permanent loss of vision.

DIAGNOSTICS

To visualize carotid-cavernous fistulas, computed tomography, Angio-CT, magnetic resonance imaging, Angio-MR, Doppler ultrasound, and digital subtraction angiography are used. CT and MRI examinations can show enlargement and irregular course of the superior ophthalmic vein, thickened extraocular muscles, enlargement of the cavernous sinus with a protrusion of the side wall, and proptosis of the eyeball on the side of the lesion. [14] Computed tomography also allows for the assessment of the presence of intracranial hematomas and possible injuries, while MRI also allows for the assessment of swelling within the orbit. [12]

In Doppler ultrasound, we can observe flow reversal in the ophthalmic veins and arterial blood flow in the dilated superior ophthalmic vein. [14] The above tests play an important role in making diagnostic decisions before angiography.

Digital subtraction angiography remains the diagnostic gold standard. DSA allows for imaging the size and location of the fistula, determining the type of fistula, and detecting an aneurysm of the cavernous segment of the internal carotid artery. It also enables the assessment of venous drainage from the fistula, the efficiency of cerebral circulation and the assessment of damage to other vessels. [8] Digital subtraction angiography is necessary to confirm the diagnosis. It allows the patient to be qualified for endovascular treatment. [12]

CONTENT OF THE REVIEW

Treatment of carotid-cavernous fistulas depends on the severity of symptoms, angiographic features and assessment of the risk of neurological disorders and intracranial hemorrhage. Direct, high-flow carotid-cavernous fistulas always require endovascular treatment. [7]

The treatment of choice is intravascular embolization using balloons, stents, detachable coils, and embolization materials. If embolization proves ineffective, neurosurgical surgery involving ligation of the internal carotid artery should be considered. [16] Indirect carotid-cavernous fistulas do not require endovascular treatment; symptomatic treatment should be used, but in case of severe symptoms and deterioration of the patient's health, endovascular treatment should also be considered. The planned treatment for low-flow carotid-cavernous fistulas is stereotactic radiosurgery. This method cannot be used to treat high-flow fistulas. [16]

INDIRECT CAROTID-CAVERNOUS FISTULAS

Treatment of indirect carotid-cavernous fistulas with mild symptoms includes observation, symptomatic treatment, and compression therapy. The severity of symptoms requires endovascular treatment via arterial or venous route. Neurosurgery and stereotactic radiosurgery may be considered in the management. Small indirect fistulas may spontaneously close due to the formation of a blood clot at the site of vessel damage. [6]

INTERNAL CAROTID ARTERY COMPRESSION

A non-invasive treatment method that can lead to the closure of the fistula. The patient clamps the internal jugular artery and vein with the contralateral hand for 10 seconds 4-6 times per hour. [12] This method is effective in patients with low intraocular pressure and short duration of symptoms. Therapy is contraindicated in patients who cannot tolerate transient occlusion of the internal carotid artery or when vision deteriorates or periocular pain occurs. [17] A study conducted by Higashida et al. proved the effectiveness of this method in 30% of patients. Closure of the fistula occurred at various times, from a few minutes to 6 months without recurrence of symptoms. [18]

TRANSARTERIAL EMBOLIZATION

It is a complicated procedure to perform due to its small size, complex anatomy and the large number of dural branches of the carotid artery. Access to the vessels is often difficult, requiring multiple approaches, or impossible. The procedure involves inserting a microcatheter directly into the identified dural branch of the carotid artery under the control of X-ray fluoroscopy, then embolization material is introduced to close the fistula. The embolization agents used are n-BCA and Onyx. [12] When using n-BCA, polymerization occurs as a result of contact with negative charges on the surface of blood vessels and morphotic elements. The addition of Lipiodol, an iodinated contrast agent, allows for modification of the physicochemical properties of n-BCA. The advantage of n-BAC is easy introduction through the catheter, good penetration and permanent closure of the vessel after polymerization. The disadvantage is the quick polymerization time, which causes tissues and catheters to stick together. Onyx is a classic polymer, a mixture of polyvinyl alcohol copolymer, DMSO (solvent) and micronized tantalum (tracer). The advantage of Onyx is excellent penetration and the fact that, unlike n-BAC, it is a non-adhesive agent. The administration time is long, but the lack of adhesion to the walls of vessels and catheters allows the injection time to be extended. [12,20] The study by Rabinov et al. comparing the effectiveness of n-BCA with Onyx proved the greater effectiveness of Onyx. [21] Technical difficulties and potential complications limit the choice of transarterial embolization to the primary treatment of indirect carotid-cavernous fistulas.

TRANSVENOUS EMBOLIZATION

Transvenous embolization is the preferred method of treating indirect carotid-cavernous fistulas. The possibility of using different access routes to the cavernous sinus makes this method easier to perform compared to transarterial embolization. The fistula is often closed during the first procedure, providing a beneficial and long-term therapeutic effect. [12]

The most frequently used vascular access is the inferior petrosal sinus because it is the simplest and shortest route to the cavernous sinus. If this access is limited, the superior ophthalmic vein, pterygoid venous plexus, superior petrosal sinus, facial vein, and inferior ophthalmic vein can be used. [12,20]

Transvenous embolization can be performed using detachable coils, Onyx, acrylic glue, and stents. Individually or in various combinations. [21] Using the most common venous access through the inferior petrosal sinus, the cannulas are inserted from behind through the internal jugular vein, then the catheter is passed through the inferior petrosal sinus to the carotid-cavernous fistula. This route allows catheterization to be performed in over 90% of cases. [22]

The advantage of detachable spirals is that they can be removed or repositioned in the event of incorrect placement. The disadvantage is that it is difficult to completely close the vessel, but the use of Onyx or n-BCA allows full embolization during the first approach to the procedure. [12,23] An alternative access to the cavernous sinus in case of failure of catheterization through the inferior petrosal sinus is the superior ophthalmic vein. A retrospective study by Simon CH Yu et al. included 98 patients. The overall success rate of surgical embolization was 86.5%. [24] In very severe cases of obstruction, stenosis, and tortuous course of venous vessels, access to the cavernous sinus can be obtained by combining surgical and endovascular methods. [22]

Quiñones et al. presented the results of patient treatment by surgical exposure of the superior ophthalmic vein and retrograde venous catheterization in patients with symptoms of reduced visual acuity and secondary glaucoma. Catheterization and embolization resulted in a beneficial effect in 92% of patients. [25] JB White et al. conducted a study showing safe and effective embolization without the need for surgery. They proposed direct transorbital puncture of the cavernous sinus or indirect puncture through the inferior ophthalmic vein. All patients underwent successful endovascular treatment. [26] Potential complications of the above methods include hemorrhage within the eyeball, nerve damage, infections, and damage to the internal carotid artery, which may result in the development of a direct carotid-cavernous fistula. [25,26] Direct percutaneous access to the facial vein can be obtained under ultrasound guidance. The method should be considered when standard intra-arterial and endovenous procedures have failed. Facial vein puncture allows access to the superior ophthalmic vein and effective embolization using platinum electro-detachable coils and n-BCA. Percutaneous access to the facial vein is easily achieved, safe and effective if other vascular accesses are unavailable. [27]

Matsumoto et al., in their analysis of previous reports on access to the facial vein through the femoral vein, confirmed the effectiveness of this method in 50-100%. If femoral access is unavailable, the facial vein should be punctured directly. [28] There are scientific reports describing approaches to the cavernous sinus through the foramen ovale and catheterization of emissary veins. This method is considered in cases of spontaneous and isolated indirect carotid-cavernous fistula when common methods are unavailable. [29]

STEREOTACTIC RADIOSURGERY

Stereotactic radiosurgery using a gamma-knife is an alternative method of treating indirect carotid-cavernous fistulas when endovascular treatment is ineffective. The aim of this procedure is to destroy the vessel that caused the fistula using a therapeutic dose of radiation of 20-50 Gy. [30] A study conducted by Seong-Hyun et al. aimed at assessing the effectiveness of stereotactic radiosurgery demonstrated complete disappearance of the indirect carotid-cavernous fistula in 83% of patients. The risk of complications related to radiation was low, the improvement of neurological function after 6 months was 94%, therefore, this method is an effective and safe treatment in patients with mild symptoms and no improvement after embolization. [31]

DIRECT CAROTID-CAVERNOUS FISTULAS

They constitute an abnormal connection between the internal carotid artery and the cavernous sinus. In 75% - 80% of cases, direct carotid-cavernous fistulas are post-traumatic. They always require endovascular treatment, and in extreme cases, neurosurgical treatment, because untreated direct carotid-cavernous fistulas can cause 80-90% of permanent vision loss. [6] There are many different endovascular treatment methods. The choice of the appropriate method depends on the anatomy and size of the fistula and the operator's preferences. The aim of treatment is to close the fistula while maintaining the patency of the internal carotid artery. [22]

DETACHABLE BALLOONS

The method of closing the carotid-cavernous fistula with a detachable balloon involves inserting a catheter with a silicone balloon into the artery lumen. The catheter is inserted through the femoral or common carotid artery. The uninflated balloon is advanced to the end of the catheter guided by X-ray guidance. The balloon should be inflated to a volume larger than the fistula opening and detached from the catheter. After appropriate positioning of the balloon, follow-up angiography is performed to confirm the patency of the internal carotid artery and closure of the fistula, then the catheter is withdrawn. [6,22] The size of the fistula should not be too large because the inserted balloon may backflow into the internal carotid artery. For this reason, Teng et al developed the double balloon technique. [32] Possible complications include rupture of the balloon inside the vessel, displacement of the balloon into the cavernous sinus, mass effect, i.e. the pressure exerted by the balloon wall on the surrounding nerves, and double vision. [6, 33]

DETACHABLE SPIRALS

Currently, detachable platinum coils are the basic method of treating direct carotid-cavernous fistulas. In many countries, they replace balloons that had technical problems related to their mechanism of operation. The advantage of detachable spirals is the ease of use and the ability to adjust their position in the fistula. [12,9] Embolization with detachable coils is performed as in the case of indirect carotid-cavernous fistulas, using transarterial or transvenous access. In transarterial embolization, the catheter is placed in the internal carotid artery, then the microcatheter is inserted into the cavernous section of the internal carotid artery. Using a microcatheter, a detachable coil and n-BAC or Onyx embolization material are introduced into the fistula. [12] In transvenous embolization, the cavernous sinus is most often catheterized through the inferior petrosal sinus, but access through the facial vein, orbital veins, the opposite pterygoid plexus, and the superior petrosal sinus is also possible. [20, 34]

STENTS

Stents are an alternative method in the treatment of direct carotid-cavernous fistulas when detachable balloons or coils have proven ineffective. They are used in cases of severe damage to the internal carotid artery, allowing the artery to remain patency without the need to ligate it. [9] Self-expanding or polyfluorotetraethylene (PTFE)-coated stents are used in endovascular treatment. [12,35] The results presented by Gomez et al. show the effectiveness of this method. In all patients, after using PTFE-covered stents, the fistula was closed and the patency of the internal carotid artery was preserved. [35] The study by Ducruet et al. included 100 patients. 42 patients with direct carotid-cavernous fistula and 58 with indirect carotid-cavernous fistula. In 40 (95%) patients with direct fistula, endovascular treatment was successful. In this group, only 8% complications and 2% mortality were recorded. A group of these patients was treated with detachable balloons and then detachable coils. In 58 patients with indirect carotid-cavernous fistula, successful endovascular access was achieved in 48 (83%) patients. Complications were 8% and no deaths were reported. Transvenous access in these patients was performed through the femoral vein or directly through the ophthalmic veins. Immediate closure of the fistula was noted in 37 (77%) patients. Thrombosis was observed in 1 of 11 patients with a residual fistula. [36]

CONCLUSIONS

Carotid-cavernous fistulas are rare and may cause diagnostic difficulties in the case of non-specific, mild clinical symptoms. In post-traumatic direct fistulas, symptoms may be masked by other post-traumatic changes. Recent advances in endovascular technology have enabled a variety of different fistula treatment options. As a result of these advances, the endovascular approach has evolved as the primary treatment option in clinical emergencies and after failure of noninvasive treatments. The treatment method of choice in direct fistulas is transarterial embolization, and in indirect fistulas, transvenous embolization. The prognosis in untreated direct carotid-cavernous fistulas is unfavorable, leading to permanent loss of vision, so early diagnosis helps avoid complications and provides a chance for complete recovery.

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