# Endovascular Treatment of Carotid-Cavernous Fistulas

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**KEYWORDS**

• Cavernous sinus • Carotid-cavernous fistulas • Endovascular treatment • Direct • Indirect

**KEY POINTS**

- The diagnosis of carotid-cavernous fistulas (CCFs) requires a high index of suspicion; a delay in treatment may lead to irreversible damage.
- Angiography remains the gold standard for diagnosing CCFs.
- The endovascular approach is the first-line treatment given the low complication rate and the favorable long-term outcome.
- The agents used for the endovascular management are balloons, coils, liquid embolic substances, and stents.
- Certain fistulas may require multiple agents or multiple sessions for complete closure.

## INTRODUCTION

CCFs are arteriovenous malformations that result in shunting of the blood from the carotid artery to the cavernous sinus (CS). The pressure inside the CS increases, the draining vessels engorge, and the flow may get reversed leading to a myriad of clinical manifestation and mimicking many head and neck diseases. The management for most CCFs has shifted from open surgery to endovascular treatment. This novel therapy is still evolving in its approach, technique, and agents. The agents vary from balloons, to coils, to different liquid embolic substances, and recently, stents. The decision on the treatment modality is tailored to suit each patient depending on the risk factors and the characteristics of the fistula. This article reviews many aspects of the CCF while focusing on the endovascular management, which is the preferred treatment modality.

## RELEVANT ANATOMY

The CS is located lateral to the sella turcica, expanding from the superior orbital fissure to the apex of the petrous bone. The CS is neither a sinus nor cavernous per se, rather it is a reticulated structure, formed by an assembly of multiple

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thin-walled veins, as demonstrated by Parkinson and later by Hashimoto and colleagues.[1,2] Therefore, the name lateral sellar compartment was proposed to be more accurate and to avoid any misinterpretation.[2,3] The importance that this distinction brought has modified the CCF surgery (clipping a fistulous point) and more notably, the choice of embolic agent used to avoid compartmentalization, as discussed below (see Endovascular Treatment). The CS encloses important neurovascular structures responsible for the compliance of patients with fistula. The CS is divided into 4 compartments by the internal carotid artery (ICA), namely, medial, lateral, anteroinferior, and posterosuperior, in relation to the intracavernous portion of the ICA.[4] The CS receives:

- Anteriorly: the superior and inferior ophthalmic veins
- Laterally: the superficial middle (sylvian) cerebral vein, the deep middle cerebral vein, and the sphenoparietal sinus
- Posteriorly: the superior and inferior petrosal veins drain the CS
- The basilary plexus, which is posterior in location, and the intercavernous sinus are examples of venous anastomoses that join the 2 CS.

The connection between the multiple pathways represents alternative routes for drainage when the CS becomes obstructed and also serves as multiple ports of entry to the CS when endovascular treatment is being performed.

## FISTULA CLASSIFICATION AND CHARACTERISTICS

CCF is sorted according to its cause, hemodynamic behavior, and angioarchitecture. Barrow and colleagues[5] classified the CCFs in to 4 distinct types (A, B, C, and D) depending on the arterial supply. This classification is preferred because it encompasses indirectly the cause and the hemodynamic features; it also has a therapeutic implication.

### *Direct CCF*

Type A or direct CCF is the most common type accounting for up to 80% of all CCFs.[6] This type is a direct connection between the cavernous ICA and the CCF, mostly because of a tear in the carotid wall after trauma.[6] Rupture could be due to the collision of the vessel against a bony fracture, shearing forces that act on the vessel wall, or increased intraluminal pressure after the distal compression of the vessel.[7] Traumatic CCF can be bilateral in 2% of cases.[6] If so, it is usually more deadly and more severe at presentation.[6] The carotid disruption can result from blunt as well as penetrating head trauma, which explains the higher prevalence in young males. Direct CCF can be iatrogenic, following transsphenoidal surgery,[8] endovascular procedures, and percutaneous trigeminal rhizotomy.[6] This type of CCF can also be spontaneous in 20% cases,[9] which happens when an ICA aneurysm spontaneously ruptures in the CS or when the patient has any disease that weakens the carotid wall predisposing it to rupture.[9] It is important to be prudent when such diseases are present because of the increased risk of angiographic complications. Most Type A CCFs are high-flow lesions with minimal chance of spontaneous resolution.[6,7]

### *Indirect CCF*

Type B, C, and D CCFs are indirect fistulas that arise from meningeal branches of the ICA or the external carotid artery (ECA). Type B is the least frequent; it arises from the meningeal branches of the ICA. Type C arises from the meningeal branches of the ECA, and Type D arises from meningeal branches of both the ICA and the ECA; it is the most frequent indirect type of CCF.[6] The indirect fistulas, also named dural fistulas, most commonly arise spontaneously but can occur after trauma. These fistulas are frequently nourished by the internal maxillary artery, the middle meningeal artery, the meningohypophyseal trunks, and the capsular arteries.[10] The underlying mechanism that leads to the formation of these fistulas remains unknown. It has been postulated that thrombosis of the microscopic venous vessels or partial thrombosis of the sinus leads to high pressure and rupture of the thin-walled dural vessel that traverses the sinus.[5,7,11] Reported predisposing factors are pregnancy, diabetes mellitus, collagen vascular disease, arterial hypertension, and phlebitis.[12–15] As with spontaneous direct CCF, arterial wall defect may also lead to spontaneous indirect CCF formation after minor strains.[7] Indirect fistulas occur in postmenopausal women most frequently, but can occur at any age including infancy.[9,11,16] Some reported indirect CCFs were considered to be congenital.[6,17] A subset type of indirect CCF is the posttraumatic CCF, and it differs from the spontaneous ones by having a single vessel for blood supply.[18] Unlike direct fistulas, indirect fistulas can have contralateral feeders and require bilateral angiography of the ICA and ECA.[19,20] Dural fistulas are low-flow lesions, have gradual onset, and may resolve spontaneously or by manual carotid compression