1042–3680/94 $0.00 + .20

ENDOVASCULAR THERAPY OF CAROTID CAVERNOUS FISTULAS

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Carotid cavernous fistulas are classified into two major categories: direct and indirect.[2] The direct, or type A, fistula is generally, though not necessarily, posttraumatic in nature and involves a direct connection between the internal carotid artery and cavernous sinus veins (Fig. 1). The indirect type is an arteriovenous fistula located within the dura surrounding the cavernous sinus (Fig. 2). This type of fistula is supplied by small arteries within the dura. The indirect, or dural, carotid cavernous fistula is further classified into three types according to the arterial supply. Type B carotid cavernous fistulas are supplied entirely by small branches from the cavernous segment of the internal carotid artery. This type of fistula is considered exceedingly rare.[8] Type C carotid cavernous fistulas are supplied by the dural branches of the external carotid artery. Type D carotid cavernous fistulas are supplied by branches from both the internal and external carotid arteries.

Direct carotid cavernous fistulas usually result from trauma that cause fractures of the sphenoid bone, or occasionally from direct surgical trauma, such as sphenoid sinus biopsy, retrogasserian rhizotomy, or use of Fogarty catheters during carotid endarterectomy.[16, 36, 42, 58] This type of fistula may also result from a tear in the wall of a congenitally weak cavernous carotid artery. This is seen with collagen vascular diseases such as the Ehler-Danlos syndrome or fibromuscular dysplasia.[5, 11, 16, 18, 34, 52] Rupture of cavernous internal carotid artery aneurysms will also produce a direct carotid cavernous fistula.[8, 16] By virtue of occupations and lifestyles associated with head trauma, direct carotid cavernous fistulas are much more common in males than females. In all of these cases, there is a hole in the cavernous segment of the internal carotid artery.

Indirect carotid cavernous fistulas are most commonly spontaneous in onset. There is a marked female prevalance in this type of carotid cavernous fistula. An association with pregnancy has been suggested by Walker and Allegre, although the overwhelming majority of cases occur in postmenopausal women in their 50s and 60s.[2, 19, 22, 55, 57] Trauma may occasionally result in the indirect type of carotid cavernous fistula. This occurs when there is injury to the intracavernous branches of the internal carotid artery.[47]

CLINICAL MANIFESTATIONS

The clinical manifestations of carotid cavernous fistulas are similar in nature to both

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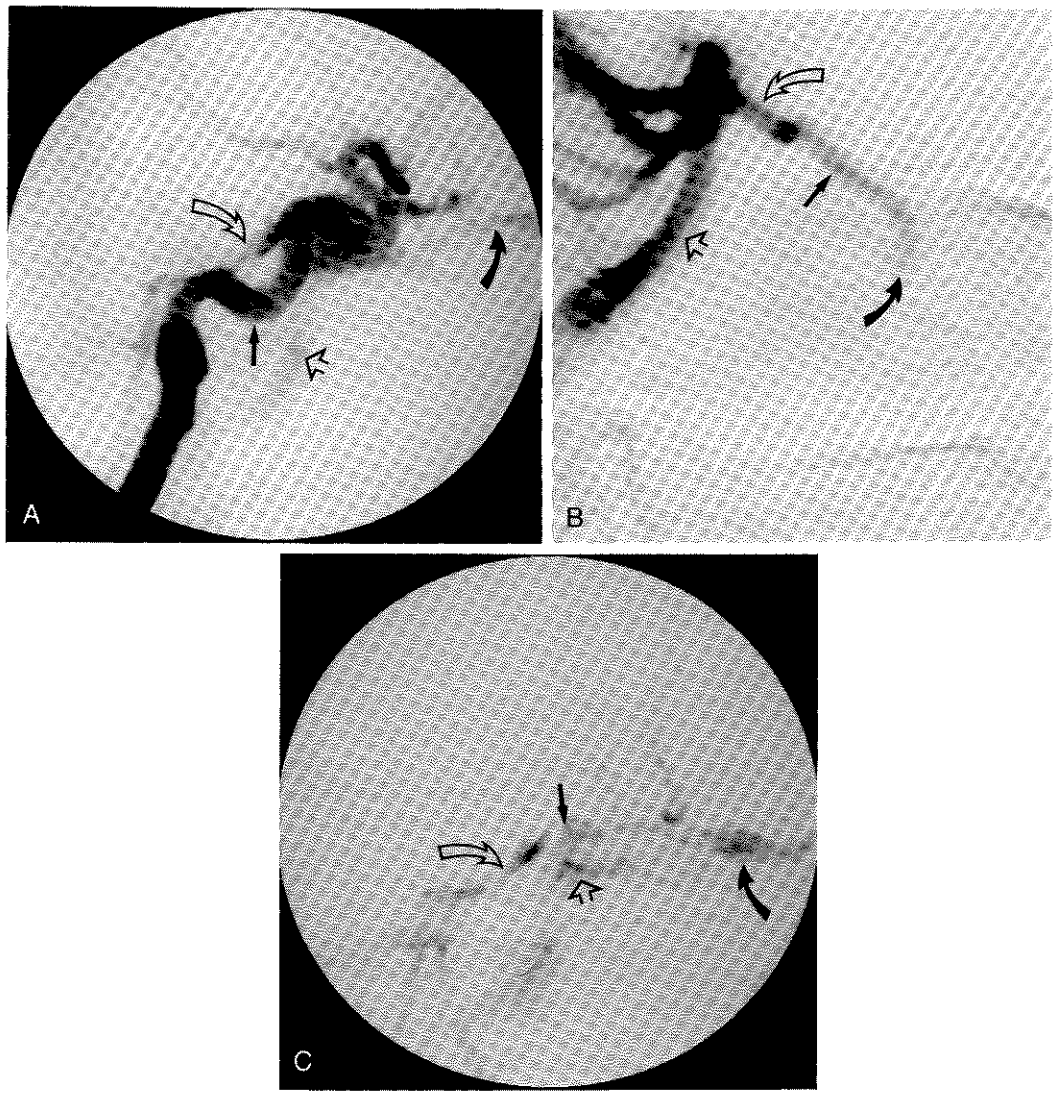

Figure 1. A 42-year-old man with Ehler-Danlos syndrome with spontaneous onset of a left-sided direct carotid cavernous fistula. *A,* Left internal carotid artery injection, lateral projection, shows that the internal carotid artery (*straight arrow*) fills the veins of the cavernous sinus. From the cavernous sinus, venous drainage goes to the superior ophthalmic vein (*curved arrow*), the pterygoid plexus (*open straight arrow*), and the inferior petrosal sinus (*open curved arrow*). It is difficult to demonstrate the exact site of the hole in the internal carotid artery. *B,* Vertebral artery injection, lateral projection, shows filling from the basilar artery (*open straight arrow*) to the posterior communicating artery (*open curved arrow*) and then to the internal carotid artery (*straight arrow*). Flow is retrograde in the internal carotid artery to the site of the fistula (*solid curved arrow*). This maneuver is useful in demonstrating that the hole in the internal carotid artery is at the genu of the cavernous carotid artery. This fistula was treated by advancing a Tracker into the internal carotid artery and through the hole in the artery, out into the cavernous sinus. *C,* Cavernous sinus injection, lateral projection, shows that the tip (*straight arrow*) of the Tracker catheter is outside of the artery and in the cavernous sinus (*open straight arrow*). This injection allows one to know that the tip of the catheter is outside of the artery and that it would be safe to place embolic agents in the cavernous sinus without occluding the internal carotid artery. Note the inferior petrosal sinus (*open curved arrow*) and superior ophthalmic vein (*solid curved arrow*).

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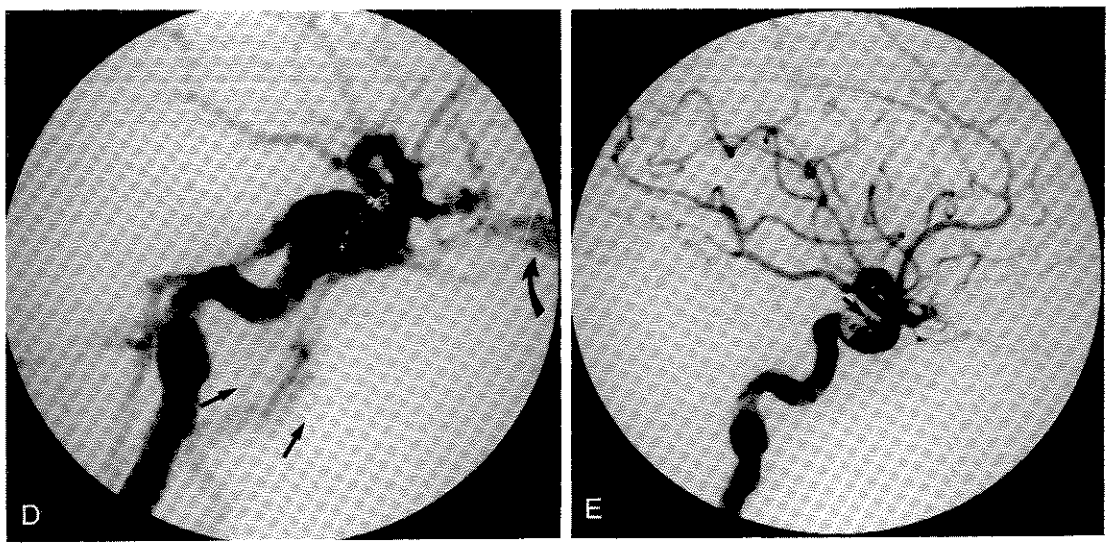

Figure 1 (*Continued*). *D*, Left internal carotid artery injection, lateral projection, with calibrated measurement devices (*straight arrows*) on the patient's skull which allow for measurement of the size of the draining vein in the cavernous sinus. These measurements (*white dotted lines*) permit one to choose an embolic agent, either platinum coils or a balloon, of sufficient size to occlude the cavernous sinus fistula without risk of going into the superior ophthalmic vein (*solid curved arrow*). *E*, Left internal carotid artery injection, lateral projection, after the fistula was embolized with detachable platinum coils. The fistula is closed completely. There is a small remaining pseudoaneurysm (*straight arrow*). On other projections (not shown), the coils can be shown to be outside of the internal carotid artery and within the cavernous sinus.

direct and indirect fistulas. The indirect fistulas, however, may often be less severe because of the lower flow associated with this type. As with virtually all dural arteriovenous fistulas, the clinical syndrome relates to the pattern of venous drainage.[1, 35, 38, 49, 56] Clinical signs include exophthalmos, bruit, headache, chemosis, oculomotor palsies, and loss of vision. The exophthalmos results from venous congestion of the orbit. A bruit is present in the vast majority of all direct carotid cavernous fistulas and about one half of the indirect types.[30] Headache is very common and may be related to distention of the dura or compression of the trigeminal nerve. The arterialization and dilation of veins in the conjunctiva and sclera result in chemosis. The oculomotor palsies usually result from dysfunction of the abducens nerve which is free in the cavernous sinus, although the oculomotor and trochlear nerves may also be affected. The greatest risk to vision is related to ischemia and may be irreversible if untreated.[51] Low-mean ophthalmic arterial pressures coupled with elevated venous pressures equate to a relative hypoperfusion and hypoxia of the eye. Cases of brain-stem edema related to posttraumatic, direct carotid cavernous fistulas have been described.[54] As expected, this problem results from abnormal venous drainage from the carotid cavernous fistulas to veins in the posterior fossa. Successful treatment of the fistula results in resolution of these problems.

ANGIOGRAPHIC IMAGING

The angiographic evaluation of carotid cavernous fistulas is complex and requires more than simply imaging the involved vessel.[9, 44] For direct carotid cavernous fistulas, evaluation of the location of the hole in the internal carotid artery may be difficult because of high flow into the fistula. Flow through the fistula may be so high that all of the contrast injected goes into the cavernous sinus and does not opacify the internal carotid artery distal to the hole. This problem is especially common if there is stealing of blood from the intracranial internal carotid artery back down into the fistula. Rapid filling of veins in the cavernous sinus may also obscure visualization of the internal carotid artery. Some of these problems can be overcome by rapid image acquisition, up to 30 images per second, in which flow out of the internal carotid artery into the