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Treatment of Traumatic Carotid-Cavernous Fistula Using Detachable Balloon Catheters

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The goal of therapy in patients with traumatic carotid-cavernous fistulas is to occlude the fistula, preferably while maintaining the carotid blood flow. Surgical techniques that treat the fistula remote from the cavernous sinus often cannot maintain carotid patency. Various interventional techniques using detachable balloons have been developed. The most common technique uses the endarterial route, introducing the balloon catheter in the neck or the groin. If the balloon is detached in the cavernous sinus, the carotid blood flow will be preserved. A second approach uses the venous retrograde route through the jugular vein, inferior petrosal sinus, and cavernous sinus. Elegant and safe, this method is appropriate when the fistula drains posteriorly. A third approach involves surgical exposure of the cavernous sinus and direct introduction of the balloon. This is sometimes the only recourse when the fistula has been previously treated with internal carotid ligation.

Traumatic carotid-cavernous fistulas are caused by injury to the cavernous portion of the internal carotid artery. Generally there is only one hole in the carotid artery and the external carotid branches are normal. Traumatic fistulas must be distinguished from spontaneous carotid-cavernous fistulas, which always have a blood supply from the external carotid branches and tiny branches from the internal carotid artery to the cavernous sinus that are too small to be occluded with a detachable balloon. The internal carotid artery should never be sacrificed in these cases. Occasionally such fistulas heal spontaneously or can be occluded by embolization of the external carotid branches.

In treating traumatic carotid fistulas with detachable balloons, three different therapeutic approaches should be considered [1-4]: (1) the endoarterial route, (2) the venous route, and (3) direct placement of the balloon in the cavernous sinus at surgery.

Treatment Considerations

Anatomic Peculiarities of the Internal Carotid Artery

A previous intracranial or cervical ligation of the carotid artery precludes the endoarterial route. A wide angle of the origin of the internal carotid artery, almost perpendicular to the common carotid artery, is usually followed by a sharp loop or kink that makes catheterization of the internal carotid artery difficult and risky. Also, a complete loop of the internal carotid below the base of the skull will make the detachment of the balloon much more difficult. Atheromatous stenosis and/or ulcerated plaque at the origin of the internal carotid increases the risk of thrombosis or embolism.

Location of the Fistula and Nature of the Venous Drainage

The exact location of the fistula and its size are demonstrated in most cases by vertebral angiography with compression of the carotid artery in the neck on the side of the fistula. When this fails, more sophisticated techniques can be attempted, such as the use of a double-lumen balloon catheter with the balloon occluding the internal carotid artery as contrast is slowly injected through the second lumen. The venous drainage is often multidirectional: anteriorly to the superior and inferior ophthalmic veins, posteriorly to the superior and inferior petrosal sinus, inferiorly to the pterygoid plexus, superiorly to the sylvian veins, and medially to the contralateral cavernous sinus.

The choice between the endoarterial route and the venous route depends on anatomic considerations. If the fistula is anterior and the venous drainage is totally or mainly anterior to the ophthalmic veins, the patient has severe proptosis and chemosis and risks rapid loss of vision. Retrograde venous navigation through the superior ophthalmic vein is virtually impossible in such cases, making the endoarterial route the preferred alternative. If the fistula is posterior and the venous drainage is mainly or exclusively posterior, the inferior petrosal sinus is dilated and connects with the internal jugular vein. The retrograde venous route is then preferable [1-3].

In most cases both anterior and posterior venous drainage is present. Whenever the inferior petrosal sinus is dilated and the fistula is more posterior than anterior, the venous route should be tried first. However, the failure rate is relatively high, either because it is impossible to enter the inferior petrosal sinus or because the cavernous sinus is compartmentalized and the balloon does not reach the level of the fistula [1].

Direct Puncture of the Carotid Artery or Jugular Vein in the Neck or Puncture of the Femoral Artery or Vein

The femoral approach is usually ideal. It is easy to install an 8 French or 9 French sheath in the femoral artery or vein, and the attending physician is protected from scattered radiation. The cervical approach is mandatory when the femoral route is contraindicated or when tortuous vessels obviate positioning the sheath in the internal carotid artery. Direct insertion of an 8 French or 9 French sheath into the carotid artery is difficult and involves a high risk of dissecting the internal carotid with the guide and dilator. The

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patient must remain intubated for several hours after removal of the sheath in order to guard against the development of a devastating cervical compressing hematoma.

Size and Capacity of the Balloon

The latex balloons have different shapes and sizes. They can be inflated with 0.1–3 ml of liquid, resulting in a balloon diameter between 3 mm and 3 cm. The largest balloon capable of entering the cavernous sinus is generally the best and should be tried first. When the fistula is very large, however, a spherical balloon 2 cm in diameter may bulge through the fistula with a risk of occluding the internal carotid artery. If this is the case, the carotid artery cannot be preserved. The fistula will be cured but the carotid artery will be permanently thrombosed.

Fluid Content of Balloon

Both iodinated contrast materials and polymerizing substances have advantages and disadvantages. A balloon inflated with pure contrast material will progressively deflate, possibly causing a false aneurysm. These pseudoaneurysms are generally asymptomatic, but become symptomatic when very large. If the patient develops oculomotor nerve palsy or retroorbital pain, the pseudoaneurysm must then be treated either with another detached balloon or by permanent occlusion of the internal carotid artery with a balloon detached in the siphon at the level of the neck of the pseudoaneurysm. The advantage of an iodine-inflated balloon is that if oculomotor nerve palsy occurs, balloon deflation will usually signal complete recovery from the palsy.

A balloon inflated with a polymerizing substance will produce better anatomic results with minimal or no residual aneurysm at the level of the fistula. However, the balloon will remain permanently solid, with the concomitant risk of poor or incomplete recovery from oculomotor nerve palsy developing after detachment of the balloon. The risk is probably low when the balloon is equal to or less than 1 cm in diameter, but very high with balloons approaching 2 cm in diameter.

If many balloons have to be detached in a large cavernous sinus, the last balloon should be inflated with silicone to occlude the fistula. The other balloons must be inflated with iodine so that they can shrink and decrease their mass effect. It is desirable to keep the number of detached balloons to a minimum. Latex has higher elasticity than Silastic, and a fistula can be treated with a smaller number of latex than of Silastic balloons.

Failure of Balloon to Enter Cavernous Sinus by the Arterial Approach

The transvenous approach can be used if drainage is through the inferior petrosal sinus. The use of a supermagnet to direct the metallic marker inside the balloon should decrease the number of failures to enter the cavernous sinus. If both the arterial and venous routes are unsuccessful, it may be desirable to occlude the carotid artery at the site of the fistula. If the patient cannot tolerate permanent occlusion of the internal carotid artery, direct exposure of the cavernous sinus at surgery and introduction of the detachable balloon in the cavernous sinus is possible. The other alternative is to perform a surgical external carotid–middle cerebral artery bypass before permanent occlusion of the carotid artery.

If carotid artery occlusion is chosen, it is mandatory to perform contralateral carotid and/or vertebral angiography before detaching the balloon in order to confirm that the fistula does not fill from above. It is sometimes difficult to position the tip of the balloon beyond the fistula, because the balloon may "stick" at this level in the carotid siphon. It could be catastrophic to partly occlude the fistula with the balloon; the carotid artery would be permanently occluded below the fistula and the patient could develop ischemic complications from steal through the fistula.

Surgical Exposure of Cavernous Sinus and Direct Balloon Implantation

If the fistula recurs after intracranial ligation of the internal carotid artery and division of the internal carotid in the neck, and if the internal carotid artery cannot be punctured above the level of the previous ligation, direct surgical exposure of the cavernous sinus is indicated. The internal carotid blood flow is usually reconstituted through different pathways, including the branches of the external carotid artery; the dural branches of the contralateral internal carotid artery; the ophthalmic artery (if the internal carotid artery has been ligated above it); rarely, the posterior communicating artery (if the internal carotid artery has been ligated above it); or, exceptionally, a persistent trigeminal or hypoglossal artery. When the cavernous sinus is directly exposed, an 8 French sheath is introduced into the cavernous sinus, allowing passage of a balloon catheter. The balloon is inflated with iodine under fluoroscopy and detached when the murmur of the fistula has disappeared.

Conclusions

The multiplicity of decisions that the neuroradiologist confronts during balloon treatment of a traumatic carotid-cavernous fistula is related to the uniqueness of individual cases. Careful study of the diagnostic angiograms in each case will aid the physician in avoiding mistakes and in choosing the best approach. The goal of therapy is to cure the patient (i.e., to occlude the fistula) without residual oculomotor nerve palsy and with preservation of the carotid blood flow. In my opinion, the occlusion of traumatic carotid-cavernous sinus fistulas by injection of isobutyl-2-cyanoacrylate [5, 6] is extremely risky, since it is difficult to avoid glue emboli in the middle cerebral artery. The carotid artery cannot be preserved in all cases. Occasionally it is advisable to permanently occlude the artery in preference to attempting to detach many balloons in a huge cavernous sinus. Finally, in rare cases, anatomic injury to the carotid artery precludes any effort to preserve it.

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