Intraluminal occlusion of a carotid-cavernous sinus fistula with a balloon catheter

Technical note

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A technique for intraluminal occlusion of a carotid-cavernous sinus fistula with a balloon catheter is described. Passage of a balloon catheter into the cavernous carotid artery from the cervical carotid usually is easily accomplished. Inflation of the balloon with contrast material allows it to be visualized as the fistula is occluded. The simplicity and effectiveness of this method offer advantages over preexisting ones. Appraisal of its usefulness awaits further clinical trial.

Key Words · carotid artery · cavernous sinus · fistula, carotid cavernous · balloon catheter

Methods developed to eliminate carotid-cavernous sinus fistulas are varied and often have limited success due to unique anatomical and physiological requirements. Exclusion of these fistulas from the cephalic circulation is an unsolved surgical challenge despite the 162 years that have elapsed since Travers first successfully ligated the common carotid artery in 1809. These methods vary from simple carotid artery ligation, to various “trapping” and embolization procedures, to direct repair of the fistula under cardiac standstill. None is uniformly applicable or invariably successful.

Any simple direct method to obliterate the fistula must provide safety to the patient’s cerebral circulation and eye. Ready accessibility of the cervical carotid artery makes this vessel a central element in any technique. Yet control of the distal supraclinoid carotid is critical, both because these fistulas by their sump action may fill from either direction and because propagation of substances beyond the fistula into the cerebral circulation is an ever present danger. Control of the carotid beyond the fistula by craniotomy introduces the risks of surgery in a very difficult area where the circulation is furthermore hyperkinetic. Direct communication between arterial and venous channels accounts for this increased intravascular pressure and flow. An ideal solution, therefore, would involve the cervical carotid artery approach only, and somehow avoid the risks of either not exposing or exposing the supraclinoid carotid, both of which are significant. Intraluminal obliteration of the fistula with a balloon catheter offers this possibility.
Case Report

On August 28, 1969, 2 weeks after returning from Vietnam, a 22-year-old right-handed man was the front seat passenger in a car which blew a tire at 65 mph and rolled over twice. At the Salinas Valley Memorial Hospital, he was comatose with right-sided weakness. There were multiple lacerations of the face and neck and a compound fracture of the mandible. Skull, cervical spine, and chest films were normal. Mandible films showed bilateral fractures. Bifrontal burr holes revealed a swollen brain with very thin subdural blood collections. Tracheostomy was done. Within 24 hours the patient began to respond to simple commands.

Examination. On August 30, 1969, the patient was transferred to the Veterans Administration Hospital, Palo Alto, where he was lethargic, responsive to some auditory stimuli, and followed commands occasionally. Cerebrospinal fluid drained from the left ear; retrotympanic blood appeared on the right. Pupils reacted minimally to light, the left pupil being larger than the right. Gaze was dysconjugate with no eye movement in response to command. The left corneal reflex was decreased. There was left periorbital edema. Purposeful movement was present in all four extremities. There was a right Chaddock's sign.

On September 2, bilateral chemosis with a bruit over a pulsating left eye became evident. The left pupil remained larger than the right. There were subhyaloid and subretinal hemorrhages in both eyes. Angiograms through a retrograde femoral catheterization of both carotid arteries revealed a left carotid-cavernous fistula (Fig. 1). By September 3 a loud systolic bruit was heard over both orbits, which became inaudible with occlusion of the left internal carotid artery. The patient was disoriented, yet responsive. He had bilateral paraparesis and a right extensor plantar response; the right leg was definitely weaker. Retinal hemorrhages remained with a total external and internal ophthalmoplegia. Electroencephalography showed bifrontal delta and theta waves, more pronounced on the left.

Over the subsequent 4 weeks the proptosis and chemosis progressed to complete conjunctival prolapse with recurrent bleeding. Although otorrhea had abated, hearing had decreased on the left with a left peripheral seventh nerve weakness. Surgery was delayed until facial and cervical wounds healed sufficiently to allow a sterile field. On September 30 vitreous hemorrhages occurred. The patient was disoriented, confused, and hallucinatory, with a flattened affect and an expressionless voice.

Operation. On October 1, 1969, a No. 3 F balloon catheter* was introduced through the common carotid artery into the cavernous carotid artery under radiographic control (Fig. 2). The balloon was inflated with 0.15 ml of Renografin which permitted its visualization. The proximal catheter tubing was secured into the wall of the common carotid. Once the balloon was inflated, there was immediate cessation of the bruit. Left external, internal, and common carotid arteries were doubly ligated.

Postoperative Course. In the immediate postoperative period, turgidity and proptosis of both eyes decreased in association with improvement in the patient's level of consciousness. Over the subsequent weeks, his cerebration, sensory, and motor function returned to normal. Bilateral third and sixth nerve function returned. Gradual restoration of visual acuity is occurring with resolution of vitreous hemorrhages. The obliteration of the carotid-cavernous sinus fistula may be seen in the postoperative arteriogram done on October 14 (Fig. 3).

Discussion

Anatomical relationships of the cavernous carotid artery with respect to its branches, its attachments to bone and dura, and its proximity to neural structures and venous sinuses have been described in excellent studies by Parkinson,14 and Schnürrer and Stattin.18 Parkinson describes fistulas occurring either between the cavernous carotid artery itself and the cavernous sinus, or between one of its branches (meningohypophysial, inferior cavernous, capsular) and the cavernous sinus. In the latter type, the divided branch artery allows two sources of fistula. Rich communications among these branches around the sella, a real intercarotid circulus arteriosus, may perpetuate the fistula through one-

* Fogarty arterial embolectomy catheter, made by Edwards Laboratories, Inc., Santa Ana, California 92705.
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Fig. 1. Preoperative angiograms. Upper left: Lateral subtraction study shows the cervical and petrous internal carotid arteries draining into the cavernous carotid artery where fistulous communication with the sinus leads to early venous drainage through the superior and inferior ophthalmic veins and infratemporal pterygoid plexus. The ipsilateral hemisphere is supplied through the supraclinoid carotid artery. Lower left: Towne projection, left injection. Arterial perfusion of the left hemisphere is seen concomitant with filling of the left carotid-cavernous sinus fistula and venous drainage through the left ophthalmic vein and through transellar communication with the right ophthalmic veins. Lower right: Towne projection, right carotid injection, with left carotid cross compression. There is rich perfusion of the left hemisphere and filling of the left supraclinoid carotid (cf. Fig. 3).

half of the divided branch artery, despite successful embolization with or without a trapping procedure on the parent carotid artery. Hayes has diagrammed these anastomotic channels.

Whereas the first and simplest surgical treatment of carotid cavernous fistula has been carotid ligation, the over-all rate of cure is less than 50%. The Hunterian method of remote proximal ligation in the treatment of fistula fails because of retrograde internal carotid artery flow from the supraclinoid portions, with steal of blood from the intracranial circulation and collateral intercarotid artery flow from the normal carotid branches and anomalous ones. The fistula itself usually remains patent. Brooks in 1930 described closure of the fistulous opening with muscle embolized from the cervical carotid. This may be considered ideal in that the abnormality is corrected without compromise to the ipsilateral cephalic circu-
Fig. 2. Diagram of operation. Through an arteriotomy in the common carotid artery immediately proximal to the bifurcation, the balloon catheter is introduced and advanced into the cavernous portion of the internal carotid artery. A purse-string suture placed previously around the arteriotomy, once secured, prevents excess hemorrhage. Cessation of the bruit when the balloon is inflated with contrast material indicates proper placement. Polaroid radiography allows visualization of balloon position. After final adjustment, the nylon catheter is folded on itself, clamped several times, and doubly ligated. Double umbilical tape ligatures are placed around the external, internal, and common carotid arteries. Those ligatures placed around the common carotid secure the catheter in position.

Fig. 3. Postoperative angiograms, 2 weeks after operation. **Left:** Lateral view, right carotid injection, with superimposition of the balloon in the left cavernous carotid artery filled with contrast material (arrow). **Right:** Anteroposterior view, right injection. Balloon is inflated with contrast material within the left cavernous carotid. Note absence of left supraclinoid carotid filling.

lation. But intracranial propagation of the embolus is always a threat. The size of the fistula and embolus must correspond exactly, yet this is determined by the surgeon’s best estimate and thereby is partly a chance event, notwithstanding the successful fistula obliteration with muscle as has been recently described by Wanissorn.23

Hamby and Gardner’s7 supraclinoid carotid ligation in 1933 introduced distal occlusion. Alone or in association with proximal ligation (“trapping procedure”), this technique suffers the same inherent defects of remote proximal ligation. The technique of distal carotid ligation, muscle embolization, followed by proximal carotid ligation, was introduced by Jaeger11 in 1949 and has been popularized more recently by Hamby.6 Among all methods proposed thus far, this heroic procedure qualifies as the most successful, though not invariably the safest, and requires major intracranial surgery. Serious neurological impairment and death have resulted from this procedure.42 In view of the acknowledged disadvantages of each of the above methods, the search for a simple and safe method becomes obligatory.

Open catheters for introduction of foreign bodies into the intracranial circulation have been used previously and include polyethylene tubes5,10 and silastic tubing.12 There are
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usually six or seven sites of major angulation in the internal carotid artery as it passes through the base of the skull to its supraclinoid position. Most small catheters can negotiate these curves through the horizontal portion of the cavernous carotid to the anterior clinoid process. In the past, emboli of gelfoam and acrylic have been directed through such catheters into the cavernous carotid after supraclinoid carotid ligation. Despite previous distal carotid ligation, such free particulate matter may migrate beyond the cavernous sinus in an arteriolized vein into the cerebral circulation. Hence the importance of "controlled embolization" becomes obvious.

The balloon catheter technique for intraluminal occlusion of the carotid-cavernous sinus fistula is characterized in general by its simplicity and safety. Introduction of Renografin into the balloon permits radiographic control over its position in the cavernous carotid. Concurrent inspection for the presence or absence of bruit confirms the immediate therapeutic effect of balloon inflation. The tamponading effect of the inflated balloon may allow control even of those fistulas due to a rent in a branch artery of the cavernous carotid. Whereas proximal ligation must be a component of this procedure, those complications of cerebral ischemia attendant on such proximal ligation alone are averted by excluding the fistula from the intracranial circulation by the balloon.

Preoccupation with methods designed to obliterate the fistula has led to a neglect in stressing the ocular sequelae of the treated and untreated carotid cavernous sinus fistula. Impairment of vision has occurred in 73% of those cases analyzed by Sattler in 1920, and has been emphasized by Walker and Allègre and Holman. That the physiological basis for this deterioration in vision is due to hypoxia of anterior and posterior segments of the eye has been shown by Sanders and Hoyt. With these fistulas, perfusion pressure to choroidal and retinal vascular systems is reduced because the arterial pressure is decreased and the venous pressure elevated. Any surgical procedure that lowers arterial pressure without concomitant reduction in venous intraocular pressure will further embarrass a marginal ocular perfusion and lead to hypoxia. Carotid ligation and trapping procedures bring about these adverse pressure changes, with disastrous consequences to vision. Obliteration of the fistula with a balloon placed within the cavernous carotid artery proximal to the origin of the ophthalmic artery potentially preserves flow through this artery while lowering the venous pressure by obliteration of the fistula.

The commonest element in all methods devised to treat carotid-cavernous sinus fistula is carotid artery occlusion. Whether a patient can tolerate this procedure is not always predictable, even with evidence from panangiography that crossover potential exists within the intracranial circulation. Immediate tolerance to occlusion, furthermore, provides no safeguard against later development of cerebral ischemia with significant neurological sequelae. In this respect, the balloon catheter method offers no advantage over any pre-existing technique.

Although preliminary observations with this catheter chronically implanted in the dog indicate the inertness of the balloon catheter, human tolerance of this catheter is as yet unknown. In view of the successful experience with chronic human implantation of prosthetic valves directly within the bloodstream, and subcutaneous pacemakers, it seems likely that the human body will tolerate this nylon catheter with stainless steel tip and surgical amber bag, well compartmentalized in the cervical carotid artery.

Physical characteristics of the Fogarty arterial embolectomy catheter are not optimally suited to follow the curves of the carotid artery in its passage through the base of the skull. Cannulation of the carotid artery to its horizontal portion within the cavernous sinus is possible in most but not all specimens studied at necropsy. In an elderly patient with a spontaneous carotid-cavernous sinus fistula from rupture of a cavernous-carotid aneurysm, attempted placement at surgery of No. 2F, 3F, 4F, and 6F balloon catheters failed. The inelasticity of the catheter prevented successful negotiation of the circuitous angles of the carotid in this patient. Other catheters have provided similar difficulty.

With the advent of carotid endarterectomy, the balloon catheter has been used to remove atheromatous plaques from the distal carotid artery. By its angulations, its free
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position within a space surrounded by venous channels, its bone attachments as it leaves the carotid canal proximally and as it curves around the anterior clinoid distally, the cavernous carotid artery is especially vulnerable to trauma. These anatomical features probably explain the not infrequent occurrence of carotid-cavernous sinus fistula after use of the balloon catheter for distal carotid endarterectomy. Thus, a therapeutic paradox arises where the obverse effect of the causative agent is curative.

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