ORIGINAL ARTICLE

Endovascular treatment of post-traumatic carotid-cavernous fistulae using latex detachable balloons

P Szkup
MD, FCRad (Diag) SA, MMed (UCT)

Department of Medical Imaging
Royal University Hospital
University of Saskatchewan
Canada

S Beningfield
MB ChB (UCT), FFRad D (SA)

Department of Radiology
Groote Schuur Hospital
University of Cape Town

Abstract

Objective. To determine the efficiency of latex detachable balloons in the treatment of post-traumatic carotid-cavernous fistulae (CCF).

Methods. Management and outcome were reviewed for 34 consecutive patients with post-traumatic CCF personally treated by one of the authors (PS) using latex detachable balloons during the 4-year period 1996 - 2000.

Results. Endovascular embolisation of 34 CCFs was attempted in 33 patients. In 1 patient where the fistula was a result of rupture of an intra-cavernous aneurysm, the fistula thrombosed spontaneously before embolisation was attempted. In the 33 treated patients, the fistula was occluded in 30 cases (91%). Patency of the internal carotid artery was preserved in 16 cases (53%).

Conclusion. A high percentage (91%) of direct CCFs were successfully occluded with latex detachable balloons. There were no permanent neurological complications in any of the patients treated.

Introduction

A carotid-cavernous fistula (CCF) is an abnormal connection between the carotid artery and the surrounding cavernous sinus. CCFs are usually classified in three ways: (*i*) pathologically (or aetiologically), as spontaneous or traumatic; (*ii*) haemodynamically, into high-flow or low-flow; or (*iii*) angiographically, as direct or indirect.

The Barrow angiographic classification is most commonly used. It is based on the pattern of arterial supply and has therapeutic implications.[1-3] This allows CCFs to be placed into one of four angiographic categories as follows:

Type A fistulae (direct) have abnormal connections (or shunts) between the internal carotid artery (ICA) and cavernous sinus.

Types B, C and D are all indirect (or dural) fistulae. The angioarchitecture of these is analogous to dural arteriovenous fistulae (AVFs) occurring in other locations.

Type B fistulae are shunts between meningeal branches of the ICA and the cavernous sinus.

Type C are shunts between meningeal branches of the external carotid artery (ECA) and the cavernous sinus.

Type D are shunts between meningeal branches of both the ECA and the ICA and the cavernous sinus.

Direct connections between the ICA and the cavernous sinus may occur as a consequence of blunt or penetrating trauma, ruptured intracavernous carotid aneurysms, collagen deficiency syndromes (such as Ehlers-Danlos IV syndrome), fibromuscular dysplasia and arterial dissection.[2-4]

Causes of the indirect type are often unknown, but may be related to pregnancy, undisclosed or minor trauma, surgical procedures and cavernous sinus thrombosis.[1,5]

The symptoms caused by direct CCFs are related to the size, location, duration, route of venous drainage and presence of arterial and venous collaterals.

The clinical features of direct, high-flow CCFs include proptosis, conjuctival oedema, orbital bruit, progressive visual deterioration and cranial nerve palsies. Some low-pressure CCFs present with progressive symptoms mainly affecting the eye. Features of indirect CCFs are similar to those of direct CCFs but as indirect CCFs are usually chronic they seldom lead to visual deterioration.

The goals of treatment are the elimination of the fistula, ideally with preservation of the patency of the ICA, at the same time avoiding cranial nerve palsies and other complications (Fig. 1).

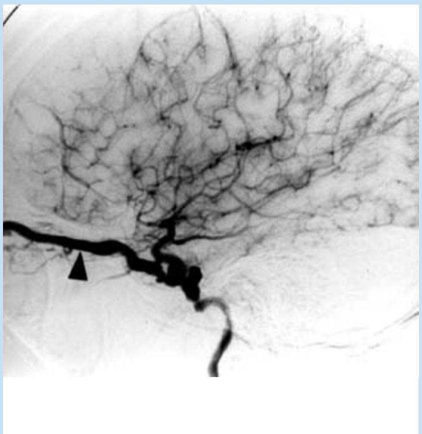

Fig. 1a. Lateral internal carotid angiogram showing fistula with preferential venous drainage via dilated superior ophthalmic vein (arrow).

Fig. 1b. Frontal left internal carotid angiogram showing unusually well demonstrated fistula site (arrow).

The treatment options for CCFs have undergone significant evolution. Surgical and endovascular techniques have been described for the closure of both direct and indirect CCFs. These include surgical carotid artery occlusion, trapping procedures (such as clipping of the supraclinoid and cervical parts of the ICA) and direct surgical exposure of the CCF with surgical closure of the fistula. Embolisation with coils, cyanoacrylate, blood clot and detachable balloons are some endovascular options.[6-9] In 1971 Prolo and Hanberry[7] first reported successful occlusion of CCFs with non-detachable balloons. Although this technique required sacrifice of the ICA, ischaemic complications were less common than encountered with routine carotid ligation.

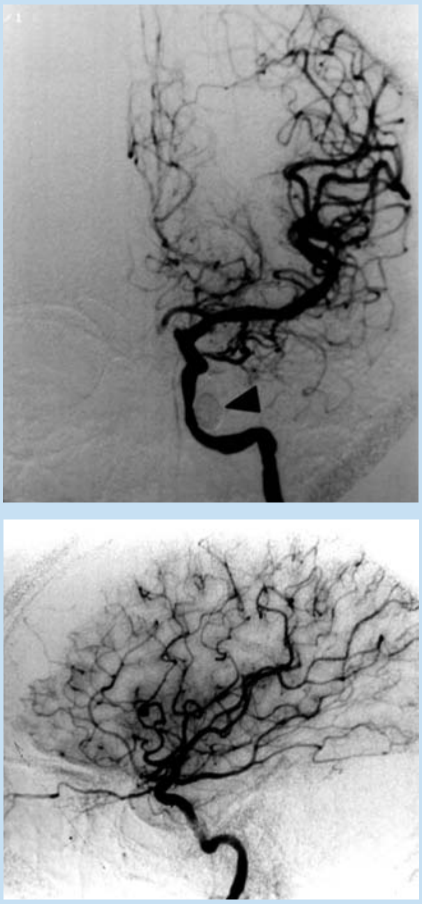

Fig. 1c and 1d. Frontal and lateral internal carotid angiograms following embolisation with one balloon (arrow) and preservation of the carotid artery.

In 1973 Parkinson[6] reported direct surgical repair of a CCF with preservation of the ICA flow, but the procedure was technically difficult, required cardiac arrest and was associated with significant neurological morbidity.

In 1974 Mullan[10] introduced surgical packing of the cavernous sinus using thrombogenic materials such as gelatin sponge ('gelfoam'), oxidised cellulose, cotton or bronze wire placed via surgical transvenous routes. In December 1969, Serbinenko successfully performed occlusion of a direct CCF and the affected ICA using a self-made silicone detachable balloon placed via a common carotid artery puncture.[11,12] This balloon was inflated at the target site with a radio-opaque mixture of polymer and tantalum powder to create a material that gradually became a stable gel within the balloon and distal catheter lumen. This allowed the catheter to be severed using the cutting edge of the arterial needle, leaving the catheter segment still attached to the inflated balloon in the thrombosed arterial lumen.

Unfortunately the silicone polymer proved to be highly viscous, often preventing balloon deflation where the balloon position was not satisfactory on trial inflations. This technique was improved by performing initial test inflation of the balloon with less viscous iodinated contrast material in order to determine whether the position of the balloon was satisfactory. Once correct placement was confirmed, the contrast medium was aspirated and silicone polymer was then injected into the balloon.

Serbinenko subsequently developed a balloon with an ingenious valve mechanism that allowed the balloon to be detached from its delivery catheter by placing traction on the catheter, without the balloon deflating after detachment. From 1969 to 1972, Serbinenko performed 304 permanent carotid artery occlusions with this system, with only 2 deaths.[11,12]

In 1974, Debrun *et al.*[9,13] developed a latex tie-on detachable balloon to occlude direct CCFs. They were able to preserve the ICA in 59% of cases. Subsequently, latex and silicone detachable balloons with internal valves were developed, with various modifications.[14] In 1980, transvenous approaches were developed independently by Debrun *et al.*[15,16] Halbach *et al.*[17] and Higashida *et al.*[18] to treat patients in whom transarterial attempts had failed.

By 1991 Guglielmi introduced retrievable electrolytically detachable platinum coils and these were later used to occlude CCFs.[8] Despite progress in coil technology, transarterial embolisation with detachable balloons is still considered the best initial treatment for direct CCFs.[2,3,16,18]

Patient details and methods

Management and outcome were reviewed for 34 consecutive patients with CCFs personally treated by one of the authors (PS) using detachable latex balloons during the 4-year period 1996 - 2000. These patients were treated at Chris Hani Baragwanath and Groote Schuur hospitals in the departments of radiology of the Universities of the Witwatersrand and Cape Town, South Africa. There were 17 men and 17 women ranging in age from 22 to 56 years, with a mean age of 39 years. Other than in case 4, all patients had direct post-traumatic CCFs (Table I).

A prominent orbital bruit was heard by the patient and/or the doctor, using a stethoscope in every case. The most common initial symptoms were proptosis and chemosis in 31 patients and an isolated abducens nerve palsy on the affected side in 13 patients. Less often, patients complained of headache (11 patients) and visual deterioration (10 patients).

Radiographic evaluation

The initial radiographic evaluation consisted of axial computed tomography (CT) of the head, with and without intravenous iodinated contrast material to evaluate the extent of head trauma. Ideally, evaluation of skull fractures was performed using high-resolution axial and coronal CT through the base of the skull, viewed with bony settings. The presence of a CCF was suspected by detection of any of the following: dilated cavernous sinus, dilated superior ophthalmic vein(s) or the presence of any other prominent draining vein(s).

A 4-vessel cerebral angiogram was then obtained to evaluate the location and extent of any vascular injury, the presence of any collateral supply via the circle of Willis and the pattern of venous drainage. Because most direct CCFs are high-flow fistulae, the cavernous sinus is usually immediately opacified on angiography and the precise communication site is commonly obscured (Fig. 2). The Heuber maneuvre, with injection of the dominant vertebral artery while manually compressing the affected carotid artery is often used for better visualisation of the fistula site. During this maneuvre, the compression of the ipsilateral carotid artery allows flow of contrast medium via the posterior communicating artery into the cavernous part of the ICA and fistula, showing the fistula site more clearly without excessive overlying contrast (Fig. 3).

In all cases, contralateral carotid angiography during compression of the ipsilateral carotid artery was per-

Fig. 2a. Lateral internal carotid angiogram showing direct fistula.

Table I. Aetiology of 33 cases of carotid-cavernous fistulae (*N*)

Blunt trauma	
Motor vehicle accident	17
Blunt assault	6
Penetrating trauma	
Knife stab to orbit	5
Gunshot wound to the head	5

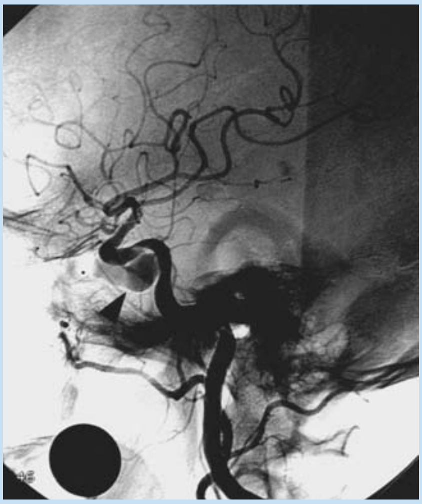

Fig. 2b. Lateral common carotid angiogram following embolisation with one balloon (arrow) and preservation of the carotid artery.

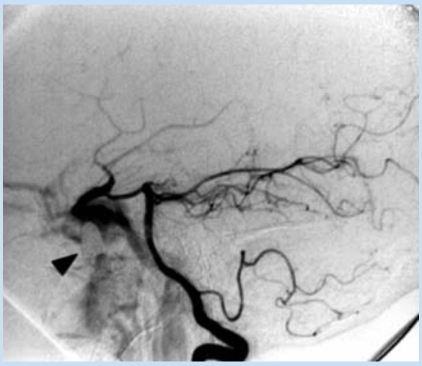

Fig. 3. Lateral vertebral artery angiogram with carotid compression — Heuber maneuvre. Note filling of anterior circulation and fistula via posterior communicating artery. Bullet in the cavernous sinus is visible (arrow).

formed to evaluate the presence or absence of cross-flow via the anterior communicating artery, in case the carotid artery with the fistula had to be occluded during the balloon embolisation. The degree of cross-flow into the anterior and middle cerebral arteries was specifically noted.

Method

Small CCFs may thrombose spontaneously or during diagnostic angiography. This usually only occurs with CCFs with ECA contributions. Manual compression of the ipsilateral ICA or the draining angular vein can also be used to treat slow-flow fistulae. In this series, initial attempts at manual compression of the ICA proved to be ineffective, as has been found with other high-flow CCFs.

All embolisation procedures were performed in the angiography suite by the same radiologist, with the patient under local anaesthesia and sedated as necessary. In 2 cases, patients required deep intravenous sedation performed by an anaesthetist.

A right common femoral artery approach using an appropriately sized vascular introducer sheath was employed in all cases. Eight French (Envoy-Cordis), or 9 or 10- French (Nycomed-Amersham) guiding catheters were used, depending on the size of the balloon used. The 9- French catheter (Nycomed-Amersham) has an internal diameter large enough to accommodate the most commonly used Goldvalve 9 balloon (Nycomed Amersham) with 1.3 ml capacity, and this catheter was therefore used most frequently. The guiding catheter was then positioned in the ICA, at approximately the second cervical vertebral body level. Five thousand units of heparin were then given intravenously to prevent thrombus formation on the catheter and balloon systems.

The detachable Goldvalve balloon system was used in all the cases. The Goldvalve balloon is made of latex with an internal valve to prevent deflation when detached. It also has an internal radio-opaque metal ball in the balloon lumen to permit visualisation on fluoroscopy during positioning. The balloon is available in a variety of sizes and shapes, with a numbering system identifying specific models (Table II). The most commonly used medium-large GVB9 balloon measures 19 x 11 mm when fully expanded, with a capacity of 1.3 ml (Table II). The balloon is manually attached to a coaxial catheter system consisting of paired inner 2-French (red) and outer 3-French (black) catheters (Nycomed-Amersham).

The entire system is then passed through the guiding catheter. The space between the coaxial 2/3 French system and guiding catheter is perfused with pressurised normal saline to prevent thrombus formation. Injections of contrast into the guiding catheter around the 2/3 French coaxial system can be made through a 3-way tap.

Before the balloon is placed intra-arterially, it is tested *in vitro*. Using a provided blunt needle, the balloon is

Table II. Sizes of the latex Goldvalve balloons (Nycomed-Amersham) used

Goldvalve balloon no.	Volume (ml)	Inflated diameter (mm)	No. of balloons used
9	1.3	19 x 11	23
16	0.8	21 x 8	10
12	2.5	22.5 x 14	3
7	1.0	13 x 13	1

filled with contrast medium that is diluted to be iso-osmolar, without exceeding the maximum recommended volume. The inflated balloon is then detached from the needle and checked for integrity of its valve and the absence of wall abnormality. The balloon is then attached to the 2-French delivery catheter that has been previously passed through the 3-French catheter, and the balloon is then allowed to deflate. The balloon attached to the coaxial 2/3-French delivery system is advanced through the guiding catheter under fluoroscopic guidance into the fistula site. It may be partially inflated with iso-osmolar iodinated contrast agent while attempting entry into the fistula. Usually because of the high flow through the fistula, the balloon will spontaneously traverse the tear of the vessel. This is often detected by observing a fluttering motion of the metal marker or balloon on entering the fistula. Once through the fistula, iso-osmolar contrast agent is used to inflate the balloon. When the balloon is inflated in what appears to be the correct position, a diagnostic angiogram is obtained through the guiding catheter to ensure that the fistula is occluded, and ideally that the ICA is patent. The patient is examined neurologically and, if stable, the balloon is detached by traction on the 2-French delivery catheter. This can be combined with counter-traction and stabilisation by advancing the 3-French catheter to the balloon neck. If the ICA has to be sacrificed, the patient is examined for any neurological deficit for 20 minutes with the balloon inflated. If the patient fails this test, the balloon is deflated immediately. After the procedure, the heparin is not corrected with protamine sulfate. The vascular introducer sheath is removed not earlier than 4 hours following heparin administration.

Results

Endovascular embolisation was attempted in 33 of the 34 patients with CCFs. In 1 patient where the CCF was a result of rupture of an intracavernous aneurysm, the fistula thrombosed spontaneously before embolisation was attempted (case 4). In the 33 treated patients, the fistula was occluded in 30 cases (91%) (Table III). In 27 cases, a single detachable balloon was required to close the fistula. In 3 cases, 3 balloons were required to close the fistula (Table IV). Case 20 needed 3 large 1.3 ml balloons to close a fistula following an orbital knife stab wound. Patency of the ICA was preserved in 16 cases (53%).

Endovascular treatment failed to occlude the fistula in 3 patients (9%). In the first case (case 5), a partially inflated balloon was accidentally detached during manipulation in a very tortuous ICA. The balloon lodged in the petrous part of the ICA. The patient was immediately taken for surgery where a trapping procedure with clipping of the supraclinoid part of the ICA was performed, and the fistula subsequently thrombosed. The patient had good cross-flow from the contralateral carotid artery and suffered no permanent neurological deficit. The second patient (case 6) had a very tortuous carotid artery that was not possible to navigate with the balloon. The inferior petrosal sinus was not visualised during diagnostic angiography and as this prevented a venous approach to the fistula, the patient was submitted to surgery where the fistula and ICA were occluded by occluding the supraclinoid and cervical parts of the ICA. In the final patient (case 29) with a mixed direct and indirect CCF following a facial gunshot, the proximal ICA was already occluded by the trauma. The CCF was supplied by the retrograde flow from intracranial arteries. The inferior petrosal sinus was not visualised on angiography of the contralateral carotid artery. An unsuccessful attempt was made to occlude the fistula by means of surgical exposure of the facial and superior ophthalmic veins.

In 1 patient (case 32), 2 initial balloons ruptured during inflation in the cavernous sinus, most likely due to the presence of sharp bony spicules in the cavernous sinus, although high-resolution CT of the base of the skull failed to visualise any such abnormality. The third balloon was placed in a slightly different position in the cavernous sinus, and was subsequently inflated and detached without complication. Transient hemiparesis lasting less than 24 hours occurred in the first patient treated (case 1), and resolved completely with heparin. There was no permanent neurological deficit in any patients treated. Seven patients experienced severe pain during inflation of the balloon in the cavernous sinus, requiring administration of intravenous pethidine. This pain may be related to pressure or displacement of cranial nerves, dura mater or other structures during balloon inflation.

There were no permanent cranial nerve palsies related to the presence of balloons in the cavernous sinus. There was also no clinical evidence of

Case No	Age (yrs)	Sex	Cause	Approach Arterial	Approach Venous	Fistula occluded	ICA Patent	Treatment/ No of balloons
1	22	F	Gunshot	Y		Yes	No	1
2	30	M	Gunshot	Y		Yes	No	1
3	34	M	MVA	Y		Yes	Yes	3
4	55	F	Ruptured aneurysm	Neither approach		Yes	Yes	Thrombosed
5	26	F	MVA	Y		Yes	No	Surgery
6	55	F	MVA	Y		Yes	No	Surgery
7	35	F	MVA	Y		Yes	Yes	1
8	48	F	MVA	Y		Yes	Yes	1
9	36	M	MVA	Y		Yes	Yes	1
10	29	M	MVA	Y		Yes	No	1
11	49	F	MVA	Y		Yes	No	1
12	50	F	MVA	Y		Yes	Yes	1
13	30	M	Assault	Y		Yes	Yes	1
14	31	M	Assault		Y	Yes	Yes	1
15	45	M	MVA	Y		Yes	No	1
16	54	F	MVA	Y		Yes	No	1
17	46	M	MVA	Y		Yes	Yes	1
18	52	F	Assault	Y		Yes	Yes	1
19	37	F	Stab wound	Y		Yes	No	3
20	25	M	Stab wound	Y		Yes	No	3
21	35	M	Assault	Y		Yes	Yes	1
22	41	F	Assault	Y		Yes	No	1
23	40	M	Gunshot	Y		Yes	No	1
24	35	M	Stab wound	Y		Yes	No	1
25	29	F	Assault	Y		Yes	Yes	1
26	38	M	Stab wound	Y		Yes	Yes	1
27	41	F	Stab wound	Y		Yes	No	1
28	39	M	Gunshot	Y		Yes	No	1
29	40	M	Gunshot		Y	No	No	1
30	30	M	MVA	Y		Yes	Yes	1
31	50	M	MVA	Y		Yes	Yes	1
32	49	F	MVA	Y		Yes	Yes	1
33	42	F	MVA	Y		Yes	Yes	1
34	39	F	MVA	Y		Yes	No	1

Table III. Summary of 34 patients with carotid-cavernous fistulae (in chronological order)

MVA = motor vehicle accident; ICA = internal carotid artery.

Table IV. Patients requiring more than one balloon to occlude the fistula

Case no.	Balloon type	No. of balloons used
3	GVB 16	3
19	GVB 9	3
20	GVB 9	3

nerve compression where more than 1 balloon was placed in the cavernous sinus. Two patients became restless during balloon placement and required deep sedation by the anaesthesiologist.

All patients were followed up clinically with neurological and ophthalmological examinations performed on an outpatient basis. An average follow-up of 5 months was used to ensure that the fistula remained clinically closed, although poor patient compliance limited this duration. The outcomes of all 34 patients are summarised in Table III. Technical problems that occurred during embolisation are summarised in Table V.

Discussion

CCF has evolved from being an untreatable condition to a readily curable one over the past 35 years. The early treatment by proximal occlusion or trapping of the ICA has fallen into disfavour because of the high associated incidence of complications and incomplete closure of the fistula.[6,10,20] Serbinenko[11] and Debrun *et al.* [13,15,16,20] pioneered techniques of closing these fistulae with detachable latex or silicone balloons while preserving the ICA in the majority of cases. Large series have proved the effectiveness of endovascular balloon embolisation,[3,4,12,15,21,22] which is now the treatment of choice for this entity.

The overall results of the 33 patients treated by the endovascular approach in this series show that the fistula was successfully occluded in 30 cases (91%), preserving the carotid artery in 16 cases (53%). These results compare reasonably with those of other centres (Table VI). The largest series of 482 patients is from China[23] where 100% success and 84% ICA preservation were achieved.

In 14 of the successfully embolised cases where the ICA could not be preserved in the present series, 9 fistulae were the result of stab wounds or gunshots. This could suggest that gunshots and stab wounds may cause larger tears in the carotid artery. In 1 case (case 20), an antelope's horn caused an orbital stab wound. Large tears in the carotid artery could also be responsible for herniation of the balloon from the cavernous sinus into the ICA, resulting in a parent vessel occlusion (Fig. 4).

The presence of cross-flow via the anterior communicating artery is vital to determine with a cross-compression angiogram. It is also critical when ICA occlusion is considered to examine the patient neurologically for at least 20 minutes while the bal-

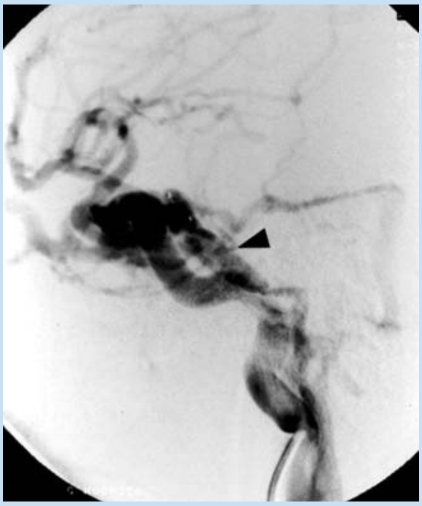

Fig. 4a. Lateral internal carotid angiogram showing fistula and dilated inferior petrosal sinus (arrow). The origin of the fistula was most likely from the posterior aspect of the cavernous part of the carotid artery. Transarterial placement of the balloon was unsuccessful despite multiple attempts.

Table V. Technical problems during embolisation (grouped by type of problem)

Case No.	Problems	Outcome
5	Balloon accidentally detached in the ICA	Surgery — trapping procedure
6	Attempt at embolisation failed due to the tortuous ICA	Surgery — trapping procedure
29	Facial and ophthalmic veins approach failed	Lost to follow-up
30	Spasm of the ICA during placement of 9-French guiding catheter	Second attempt uncomplicated
32	Two balloons ruptured during inflation in the cavernous sinus	Third balloon succeeded
12	9- French guiding catheter kinked at the origin of the left CCA	More rigid 10-French catheter (Cook) was used
18	9-French guiding catheter kinked at the origin of the left CCA	More rigid 10-French catheter (Cook) was used
31	9-French guiding catheter kinked at the origin of the left CCA	More rigid 10-French catheter (Cook) was used
32	9-French guiding catheter kinked at the origin of the left CCA	More rigid 10-French catheter (Cook) was used
21	Severe pain during inflation of the balloon in the cavernous sinus	Deep sedation
25	Severe pain during inflation of the balloon in the cavernous sinus	Deep sedation
3	Partially inflated balloon accidentally detached in the cavernous sinus	Two balloons required to occlude the fistula, ICA preserved
28	Balloon migrated deeper into the cavernous sinus shortly after detachment	Second balloon used to close the fistula
29	Facial and ophthalmic venous approaches failed	

ICA = internal carotid artery; CCA = common carotid artery.

Fig. 4b. Lateral internal carotid angiogram following placement of single balloon (arrow) via the inferior petrosal sinus, closing the fistula with preservation of the internal carotid artery.

loon is inflated. Endovascular embolisation of the CCF should therefore be performed under local anaesthesia, allowing continous neurological monitoring of the patients. However, angiographic and clinical (neurological) assessment prior to permanent ICA occlusion is far from ideal and does not prevent delayed ischaemic complications. Carotid artery occlusion in patients without CCFs is associated with a 5 - 22% rate of neurological ischaemic complications, despite a clinically tolerated test occlusion.[24,25] In an effort to reduce the morbidity of carotid artery occlusion, several quantitative blood-flow imaging techniques are available, including transcranial Doppler sonography, Tc-99m hexamethyl-propylene-amine oxime (HMPAO) SPECT perfusion imaging, xenon CT perfusion, perfusion CT, perfusion MRI, diffusion-weighted MRI and contrast-enhanced fluid-attenuated inversion recovery (FLAIR) MRI imaging.[24,25] The sensitivity of the balloon test occlusion can be further increased by performing hypotensive test occlusion.[24] Practically, the initial test is often cerebral angiography performed during cross-compression, which aids in determining the presence of collateral circulation via the circle of Willis.

No neurological deficit was observed in all 14 patients where the ICA had to be sacrificed in this series. Overall, there was no permanent neurological deficit in any patient treated. The patient with a CCF may be at less risk from carotid occlusion because of the haemodynamics involved.

Of the 34 cases of CCF, 31 fistulae were less than 4 months old while the remaining 3 were over 6 months old. There were no complications

Table VI. CCF embolisation — comparative results from different centres

Autbor	No. of cases	Results	Balloon type	Complications (*N*)
Debrun *et al.*[13] (1978)	17	100% -CCF occluded 70% -ICA preserved	Latex	III n. palsy (1)
Debrun G *et al.*[16] (1981)	54	98% - CCF occluded 59% -ICA preserved	Latex	III n. palsy (1) Middle cerebral artery infarcts (2)
Norman D, Newton T[29] (1983)	10	90% - CCF occluded 40%- ICA preserved	Silicone	None
Larsen D, Higashida R, Halbach V (1989)	206	92% - CCF occluded 88% - ICA preserved	Silicone	III n. palsy (1) Ischaemic stroke (5)
Joseph S, Rao V (1993)	25	80% - CCF occluded 64% - ICA preserved	Silicone	Death (1)
Lewis A *et al.*[3] (1995)	100	86% - CCF occluded 75% - ICA preserved	Latex Silicone	Death (1) Permanent neurological complications (4)
Wu Z *et al.*[23] (2000)	482	100% - CCF occluded 84% - ICA preserved	Latex Silicone Coils	Not stated

observed during the treatment of those of over 6 months duration, despite the potential risks involved in treating longstanding fistulae. Established fistulae may impair the brain's ability to autoregulate its own perfusion. Abrupt closure of these longstanding fistulae can therefore sometimes result in overperfusion, termed 'normal perfusion pressure breakthrough',[26] first described by Spetzler *et al.*[27] This may also occur during occlusion of cerebral arteriovenous malformations. The incidence is small for CCFs (1.2%), but higher for chronic vertebral fistulae (15%).[26]

All 33 fistulae were treated electively. There was no need for any urgent intervention. The usual indications for urgent treatment of CCFs are: (*i*) haemorrhage or epistaxis; (*ii*) cerebral ischaemia due to vascular steal by the fistula from the other cerebral arteries; (*iii*) marked aneurysmal dilatation of the cavernous sinus, which may result in fatal subarachnoid hemorrhage; (*iv*) prominent, abnormal venous drainage into cortical veins, which could produce venous hypertension and parenchymal hemorrhage; and (*v*) rapidly progressive visual deterioration, potentially leading to blindness.[2,4]

Technical aspects

In all of these cases, latex Goldvalve balloons were used. The most frequently used balloon was the GVB 9 balloon of 1.3 ml volume, measuring 19 x 11 mm when fully inflated. Both silicone (Target-Boston Scientific, Fremont, CA) and latex balloons are commonly used for endovascular embolisation and their safety as biomedical materials has been confirmed.[28-30] The relative advantages and disadvantages of latex versus silicone balloons are not clearly defined.[29] Latex Goldvalve balloons are far less expensive than silicone balloons. Latex balloons have the advantage of greater distensibility and can therefore be inflated to larger size. Often a single balloon is sufficient to close the fistula. Latex balloons have proved to be more thrombogenic than silicone balloons, and endothelialisation and thrombus formation occur more rapidly with latex than with silicone balloons.[22,26] This is thought to be related to the surface structure of the latex balloons[26] and local tissue reaction around the latex balloon.[26,29] When the surface of latex and silicone balloons is examined under electron microscopy, the silicone balloon has a smooth, even surface with a homogeneous structure, whereas the latex balloon is rough and porous with numerous large deep craters. This irregular surface may cause turbulent flow and thrombosis, entrapping blood cells and platelets.[28] Latex balloons also induce a mild to moderate degree of local tissue reaction. This could be advantageous as it may promote further thrombosis.[29]

There is some concern regarding latex allergy, following several reported fatalities due to allergic reactions to rectal latex balloons inserted during barium enemas.[28] However, there is no clinical evidence that latex balloons in the cerebral vasculature can cause these allergic reactions.[22]

The balloon should remain inflated for approximately 1 week to guarantee its fibrous attachment to the vascular wall and permanent occlusion of the fistula.[22] Presumably, the vascular obstruction and irritation caused by the balloon initiates the sealing process. The haemostatic plug that forms should develop into an organised thrombus. As this clot organises further over several days, it is transformed into a scar attached to the vessel wall. This ultimately keeps the balloon in place. Ideally the Debrun latex balloon remains inflated for 3 - 5 weeks. Silicon detachable balloons with integrated valves remain inflated for months. [22,28,29,31] As yet, there are no long-term follow-up studies of latex Goldvalve balloons. When the balloon deflates rapidly, venous pouches or false aneurysms frequently form. These can grow silently, reaching sizes as large as 4 - 5 cm without producing any oculomotor nerve palsy or other problems.[16]

Anatomical factors play a dominant role in balloon delivery. In 1 patient (case 6), the procedure had to be abandoned due to a very tortuous carotid artery, and in another patient (case 5) the partially inflated balloon was accidentally detached during manipulation within a tortuous carotid artery. Use of large balloons requires large 9 or 10- French guiding catheters to be introduced into the ICA. These catheters can cause dissection or spasm of the vessel. They may also kink as they bend to enter the common carotid or brachiocephalic artery.

Transvenous embolisation via the inferior petrosal sinus or superior ophthalmic vein remain an alternative but potentially difficult route (Fig. 4). The venous drainage from the cavernous sinus is normally variable and can be diverted by the presence of a fistula. Anatomically, the cavernous sinus is usually drained by the contralateral cavernous sinus, the superior ophthalmic vein, the sphenoparietal sinus, the pterygoid venous plexus, and the superior and inferior petrosal sinuses (Fig. 5).[32] The lack of inferior petrosal sinus visualisation during angiography does not necessarily indicate its occlusion or absence. Direct catheterisation of the inferior petrosal sinus, whether angiographically demonstrated or not, may be technically difficult due to the small calibre of the often tortuous vessel, and carries a risk of perforation with subsequent subarachnoid haemorrhage.[3,17] It is extremely difficult to navigate a catheter with a balloon into or through the partitions of the cavernous sinus to the fistula site.

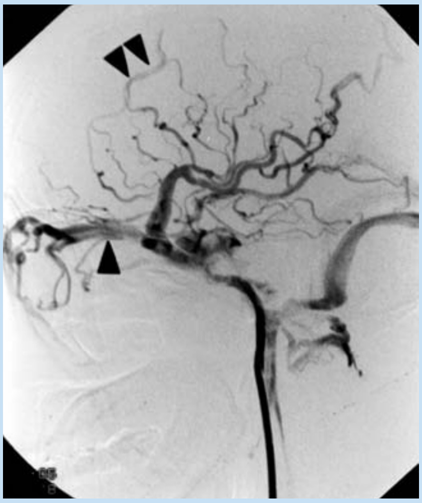

Fig. 5a. Lateral internal carotid angiogram showing fistula with venous drainage into the superior ophthalmic vein (arrow) and cortical veins (double arrows).

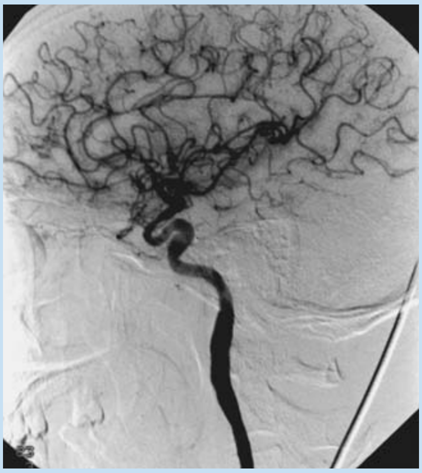

Fig. 5b. Lateral internal carotid angiogram following embolisation, showing fistula occluded and carotid artery preserved.

Another pitfall of either approach is converting the cavernous sinus into an aneurysm by blocking all venous drainage without occluding the fistula. Occluding posterior venous drainage can result in the diversion of flow into the superior ophthalmic vein and an abrupt loss of vision. Occluding the anterior drainage may increase cortical or petrosal venous drainage and could cause cerebral or brainstem venous hypertension or haemorrhage.[3,17]

Electrolytically detachable coils such as Guglielmi detachable coils (GDCs) and pushable, fibre-coated micro-coils can be used in the presence of difficult anatomy to occlude the CCF from the arterial side. They can also be employed from the venous side to navigate into and through the septated cavernous sinus.[33,34] GDC coils are especially useful for CCFs caused by ruptured intracavernous aneurysms or where use of balloons can be very dangerous, such as in patients with Ehlers - Danlos syndrome.[8,19,34,35] Coils can also be helpful when balloons cannot enter the fistula, as sometimes occurs after placement of a number of balloons narrows the entry into the fistulae. Other detachable coils and endovascular stents are promising new devices that may increase the rate of fistula occlusion and ICA preservation.

In the meantime, transarterial detachable balloons remain the treatment of choice for direct CCFs.[2,3,17,19,30,32]

Conclusion

From this analysis of the 34 cases of CCF treated over 4 years, the following conclusions can be drawn: (*i*) a high percentage (91%) of direct CCFs were successfully occluded with detachable balloons; (*ii*) in 53% of cases the ICA was preserved; (*iii*) the latex Goldvalve balloons used in all cases proved to be very effective; and (*iv*) there were no permanent neurological complications in any of the patients treated.

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