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Dissertation for Master of Medicine in Diagnostic Radiology

ENDOVASCULAR TREATMENT OF POST-TRAUMATIC CAROTID-CAVERNOUS FISTULAE WITH LATEX DETACHABLE BALLOONS

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INTRODUCTION

Carotid cavernous fistula (CCF) is an abnormal connection between the carotid artery and the cavernous sinus (Fig. 1). The CCF's are usually classified in three ways:

1. Pathologically, as spontaneous or traumatic;
2. Hemodynamically, into high-flow or low-flow; or
3. 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 CCF's to be placed into one of four angiographic categories:

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

Type B,C,D are all indirect (or dural) fistulae. The angioarchitecture of these is analogous to dural arterio-venous fistulae (AVF's) occurring in other locations.

Type B fistulae are shunts between meningeal branches of the internal carotid artery (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 ECA and 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), fibro-muscular dysplasia and arterial dissection (2-4).

Causes of the indirect type are often unknown, but may be related to the pregnancy, undisclosed or minor trauma, surgical procedures and cavernous sinus thrombosis (1,5,6).

The symptoms caused by direct CCF's 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 CCF's include proptosis, conjuctival oedema, orbital bruit, progressive visual deterioration and cranial nerve palsies. Some low pressure CCF's present with progressive symptoms mainly affecting the eye. Features of indirect CCF's are similar to those of direct CCF's but as indirect CCF's are usually chronic they seldom lead to visual deterioration.

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

The treatment options for CCF have undergone significant evolution. Surgical and endovascular techniques have been described for the closure of both direct and indirect CCF's. These include surgical carotid 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 (7-12). In 1971 Prolo and Hanberry first reported successful occlusion of CCF's with nondetachable balloons. Although this technique required sacrifice of the ICA, ischemic complications were less common than encountered with routine carotid ligation (9).

In 1973 Parkinson reported direct surgical repair of a CCF with preservation of the ICA, but the procedure was technically difficult, required cardiac arrest and was associated with significant neurological morbidity (8).

In 1974 Mullan introduced surgical packing of the cavernous sinus using thrombogenic materials such as gelatin sponge ("Gelfoam"), oxidized cellulose, cotton or bronze wire placed via a surgical transvenous route (13).

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 (14,15).

This balloon was inflated at the target site with a radiopaque 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 on trial inflations was not satisfactory. This technique was improved by instead performing prior test-inflation of the balloon with the 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 balloon.

Serbinenko subsequently developed a balloon with an ingenious valve, that allowed the balloon to be detached from its delivery catheter by placing traction on the catheter, with the balloon remaining inflated after detachment.

From 1969 to 1972, Serbinenko performed 304 permanent carotid artery occlusions with this system, with only two deaths (14,15).

In 1974, Debrun developed a latex tie-on detachable balloon (Fig. 3) to occlude direct CCF's. He was able to preserve the internal carotid artery in 59% of cases (11,16). Subsequently, latex and silicone detachable balloons with internal valves were developed, with various modifications (Fig. 2) (17).

In 1980, transvenous approaches were independently developed by

Halbach and Debrun to treat patients in whom transarterial attempts had failed (18-22).

By 1991 Guglielmi introduced retrievable electrolytically detachable platinum coils and later used them to occlude CCF's (10,12,23). Despite this progress in coils, transarterial embolisation with detachable balloons is still considered the best initial treatment for direct CCF's (2,3,19,21).

PATIENTS DETAILS AND METHODS

The management and outcome of 34 consecutive patients with CCF's personally treated by the author with detachable latex balloons during the four year period 1996-2000 are reviewed. These patients were treated at Chris Hani – Baragwanath and Groote Schuur Hospitals and the Departments of Radiology of the Universities of Witwatersrand and Cape Town.

There were 17 males and 17 females 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 CCF's (Table 1).

A prominent orbital bruit was heard by the patient and/or the doctor with 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).

Table 1.

Aetiology of 33 cases of carotid-cavernous fistulae

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

Radiographic evaluation

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

A four-vessel cerebral angiogram was then obtained to evaluate the location and extent of any vascular injury, the presence of collateral circulation via the circle of Willis and the pattern of venous drainage. Because most direct CCF's are high-flow fistulae, the cavernous sinus is usually immediately opacified on angiography and the precise communication site is commonly obscured. The Heuber maneuver, with injection of the dominant vertebral artery while manually compressing the affected ipsilateral carotid artery is often used for better visualisation of the fistula site. During this maneuver, the compression of the ipsilateral carotid artery allows flow of contrast medium via the posterior communicating artery into the cavernous part of internal carotid artery and subsequently the cavernous sinus, via the fistula more clearly depicting the fistula site.

In all cases, contralateral carotid angiography during compression of the ipsilateral carotid artery was performed to evaluate the presence or absence of cross flow via the anterior communicating artery, in case the carotid artery had to be occluded during the balloon embolisation. The degree of cross-flow into the anterior and middle cerebral arteries was specifically noted.

Small CCF's may thrombose spontaneously or during diagnostic angiography. This usually only occurs with CCF's 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 CCF's

Technical aspects

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

A right common femoral artery approach using a 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 (Nycomed-Amersham) catheter has an internal diameter large enough to accommodate the most commonly used balloon (Goldvalve Balloon (GVB 9) (Nycomed Amersham) capacity 1.3ml), 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 (Fig. 2). The balloon is available in a variety of sizes and shapes, with a numbering system identifying specific models. The most commonly used medium-large GVB9 balloon measures 19x11mm when fully expanded, with 1,3ml. (Table 4). 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. Injections of contrast into the guiding catheter around the 2/3 French coaxial system can be made through a 3-way tap (Fig.

5). Before the balloon is placed intraarterialy, it is tested in vitro. Using a provided blunt needle, the balloon is 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 t+1Xhrough 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 as they enter into 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 stabilization 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 correct with protamine sulfate. The vascular introducer sheath is removed not earlier than four hours following heparin administration.

RESULTS

Endovascular embolisation was attempted in 33 of the 34 patients with CCF's. In one 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 2). In 27 cases, a single detachable balloon was required to close the fistula. In 3 cases, 3 balloons were required to close the fistula. Case 20 needed 3 large 1.3ml 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 (a trapping procedure with clipping of the supraclinoid part of the ICA), 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 impossible to navigate with the balloon. The inferior petrosal sinus was not visualised during diagnostic angiography and the patient was therefore 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 one patient (case 32), two initial balloons ruptured during inflation in the cavernous sinus, most likely to be due to the presence of sharp bony fragments in the cavernous sinus. High resolution CT of the base of the skull however 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 could be related to pressure or displacement of cranial nerves, dura 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 nerve compression where more than one balloon was placed in the cavernous sinus. Two patients become restless during balloon placement and required deep sedation by the anaesthetist.

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. Technical problems that occurred during embolization are summarized in Table 3.

The outcomes of all 34 patients are summarized in Table 2.

Table 3.

Technical problems during embolisation

CASE NO.	PROBLEMS	OUTCOME
5	Balloon accidentally detached in the ICA	Surgery – trapping procedure
6	Attempt embolisation failed due to the tortous 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 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 cavernous sinus shortly after detachment	Second balloon used to close the fistula

Table 2: Summary of 34 patients with carotid-cavernous fistulae (in chronological order) MVA = motor vehicle accident

CASE NO	AGE	SEX	CAUSE	APPROACH ARTERIAL	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			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 4:

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

GVB no.	**Volume**	**Inflated diameter**	**No. of balloons used**
9	1,3ml	19x11mm	23
16	0,8ml	21x8mm	10
12	2,5ml	22,5x14mm	3
7	1,0ml	13x13mm	1

Table 5:

Patients where more than one balloon was used to occlude the fistula.

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

DISCUSSION

Carotid-cavernous fistula has evolved from being an untreatable condition to curable one over the past 35 years. The early treatment by proximal occlusion or trapping of the internal carotid artery has fallen into disfavor because of the high associated incidence of complications and incomplete closure of the fistula (7,8,13,24). Serbinenko and Debrun pioneered techniques of closing these fistulae with detachable latex or silicone balloons while preserving the ICA in the majority of cases (14,16,18,19,24). Large series have proven the effectiveness of endovascular balloon embolization (3,4,15,18,25-27), 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 (91%) cases, preserving the carotid artery in 16 cases (53%). These results compare reasonably with those of other centers (Table 6). The largest series of 482 patients is from China (28) where 100% success and 84% ICA preservation were achieved. In 14 successfully embolised cases where the ICA could not be preserved, 9 fistulae were the result of stab wounds or gunshots. This suggests that gunshots and stab wounds may cause larger tears in the carotid artery. In one case (case 20) a gemsbok horn was used to cause an orbital stab wound. Large tears in the carotid artery could be also responsible for herniation of the balloon from the cavernous sinus into the ICA, resulting in a parent vessel occlusion (Figure 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 balloon is inflated. Endovascular embolisation of CCF should therefore be performed under local anesthesia, allowing continous neurologic monitoring of the patients.

However, angiographic and clinical (neurological) assessment prior to permanent ICA occlusion is far from ideal and does not prevent delayed ischemic complications. Carotid artery occlusion in patients without CCF is associated with a 5% to 22%

rate of neurologic ischemic complications, despite a clinically tolerated test occlusion (29,30). In an effort to reduce the morbidity of carotid artery occlusion, several quantative blood flow imaging techniques are available including transcranial Doppler sonography, Tc-99m hexamethyl-propylene-amine oxime, (HMPAO) SPECT perfusion imaging, xenon CT perfusion, CT perfusion, perfusion MRI, diffusion

-weighted MRI and contrast enhanced fluid-attenuated inversion recovery (FLAIR) MRI imaging (29,30). The sensitivity of the balloon test occlusion can be further increased by performing hypotensive test occlusion (29).

Practically the initial test is often cerebral angiography performed during cross-compression, which can aid in determining the presence of collateral circulation via the circle of Willis. No neurological deficit was observed in all 14 patients where the internal carotid artery 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 observed during the treatment of those of over 6 months duration, despite the potential risks involved in treating long-standing fistulae. Established fistulae may impair the brains ability to autoregulate its own perfusion. An abrupt closure of these long standing fistulae can therefore sometimes result in overperfusion, termed "normal perfusion pressure breakthrough" (31), first described by Spetzler (32). This may also occur during occlusion of cerebral arterio-venous malformations. The incidence is small for carotid cavernous fistulae (1.2%), but higher for chronic vertebral fistulae (15%) (31).

All 33 fistulae were treated electively. There was no need for any urgent intervention. The usual indications for urgent treatment of CCF are:

1. Hemorrhage or epistaxis,
2. Cerebral ischemia due to vascular steal by the fistula from the other cerebral arteries,
3. Marked aneurysmal dilatation of the cavernous sinus, which may result in fatal subarachnoid hemorrhage,
4. Prominent, abnormal venous drainage into cortical veins, which could produce venous hypertension and parenchymal hemorrhage and
5. 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 1,3ml volume, measuring 19x11mm when fully inflated. Both silicone and latex balloons are commonly used for endovascular embolization and their safety as biomedical materials have been confirmed (33-35). However, neither latex nor silicone detachable balloons are approved by the Food and Drug Administration of the USA, despite nearly 30 years of use.

The relative advantages and disadvantages of latex versus silicone balloons are not clearly defined (34). Latex Goldvalve balloons are far less expensive than silicone balloons (Target-Boston Scientific, Fremont CA). 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 proven to be more thrombogenic than silicone balloons, and endothelialization and thrombus formation occurs more rapidly with latex than with silicone balloons (27,31). This is thought to be related to the surface structure of the latex balloons (31) and local tissue reaction around latex balloon (31,34).When the surface of latex and silicone balloons are examined under electron microscopy, the silicone balloon has a smooth, even surface with a homogenous 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 (33). Latex balloons also induce a mild -to-moderate degree of local tissue reaction. This could be advantageous as it may induce further thrombosis (34).

There is some concern regarding latex allergy, following several reported fatalities due to allergic reactions to rectal latex balloons inserted during barium enemas (33). However, there is no clinical evidence that latex balloons in the cerebral vasculature can cause these allergic reactions (27).

The balloon should remain inflated for at least approximately one week to guarantee its fibrous attachment to the vascular wall and permanent occlusion of the fistula (27). Presumably, the vascular obstruction and irritation caused by the balloon initiates the sealing process. The haemostatic plug that forms should develop into an organized thrombus. As this clot organizes 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 (27,33,34,36). There are as yet no long term 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 to 5 cm without producing any oculomotor nerve palsy or other problems (19).

Anatomical factors play a dominant role in balloon delivery. In one 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 internal carotid artery. These can cause dissection or spasm of the vessel. They may also kink as they enter the common carotid or brachiocephalic artery. Transvenous embolization via the inferior petrosal sinus or superior ophthalmic vein remain an alternative but potentially difficult route. 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 contra-lateral cavernous sinus, the superior ophthalmic vein, sphenoparietal sinus, pterygoid venous plexus, superior and inferior petrosal sinuses (37). The lack of inferior petrosal sinus visualization during angiography does not necessary indicate its occlusion or absence. Direct catheterization of the inferior petrosal sinus, whether angiographically demonstrated or not, may be technically difficult due to the small caliber of the often tortuous vessel, and caries a risk of perforation with subsequent subarachnoid hemorrhage (3,20). It is extremely difficult to navigate a catheter with a balloon into or through the partitions of the cavernous sinus to the fistula site.

The pitfalls of the transvenous approach include converting the cavernous sinus into an aneurysm by blocking venous drainage, without occluding the fistula. Occluding posterior venous drainage can result in the diversion of flow into the superior ophthalmic vein, and a worsening of vision loss. Occluding the anterior drainage may increase cortical or petrosal venous drainage and could cause cerebral or brainstem venous hypertension or haemorrhage (3,20).

Electrolytically detachable coils such as Guglielmi Detachable Coils (GDC) and pushable, fiber-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 (12,22,38,39). GDC coils are especially useful for CCF's caused by ruptured intracavernous aneurysms or where use of balloons can be dangerous, such as in patients with Ehlers –Danlos syndrome (10,23,39,40). They 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 carotid-cavernous fistulae (2,3,20,23,35,37).

Table 6.
Comparative results for CCF embolisation from different centers.

AUTHOR	NO. OF CASES	RESULTS	BALLOON TYPE	COMPLICATIONS
1. Debrun G (1978)	17	100% -CCF occluded 70% -ICA preserved	Latex	III n. palsy -1
2. Debrun G Lacour P (1981)	54	98% - CCF occluded 59% -ICA preserved	Latex	III n. palsy -1 Middle cerebral artery infarcts -2
3. Norman D Newton T (1984)	10	90%- CCF occluded 40%- ICA preserved	Silicone	None
4. Larsen D Higashida R Van V Halbach (1989)	206	92% - CCF occluded 88% - ICA preserved	Silicone	III n. Palsy -1 Ischemic stroke -5
5. Joseph S. Rao V (1993)	25	80% - CCF occluded 64% - ICA preserved	Silicone	Death - 1
6. Lewis A Tomsick T (1995)	100	86% - CCF occluded 75% - ICA preserved	Latex Silicone	Death - 1 Permanent neurological complications – 4
7. Wu Z Zhang Y (2000)	482	100%-CCF occluded 84% - ICA preserved	Latex Silicone Coils	Not stated

CONCLUSION

From this analysis of the 34 cases of carotid-cavernous fistulae treated over 4 years, the following conclusions can be drawn:

1. A high percentage (91%) of direct CCFs were successfully occluded with detachable balloons.
2. In 53% of cases the internal carotid artery was preserved
3. The latex Goldvalve balloons used in all cases proved to be very effective.
4. There were no permanent neurological complications in any of the patients treated.

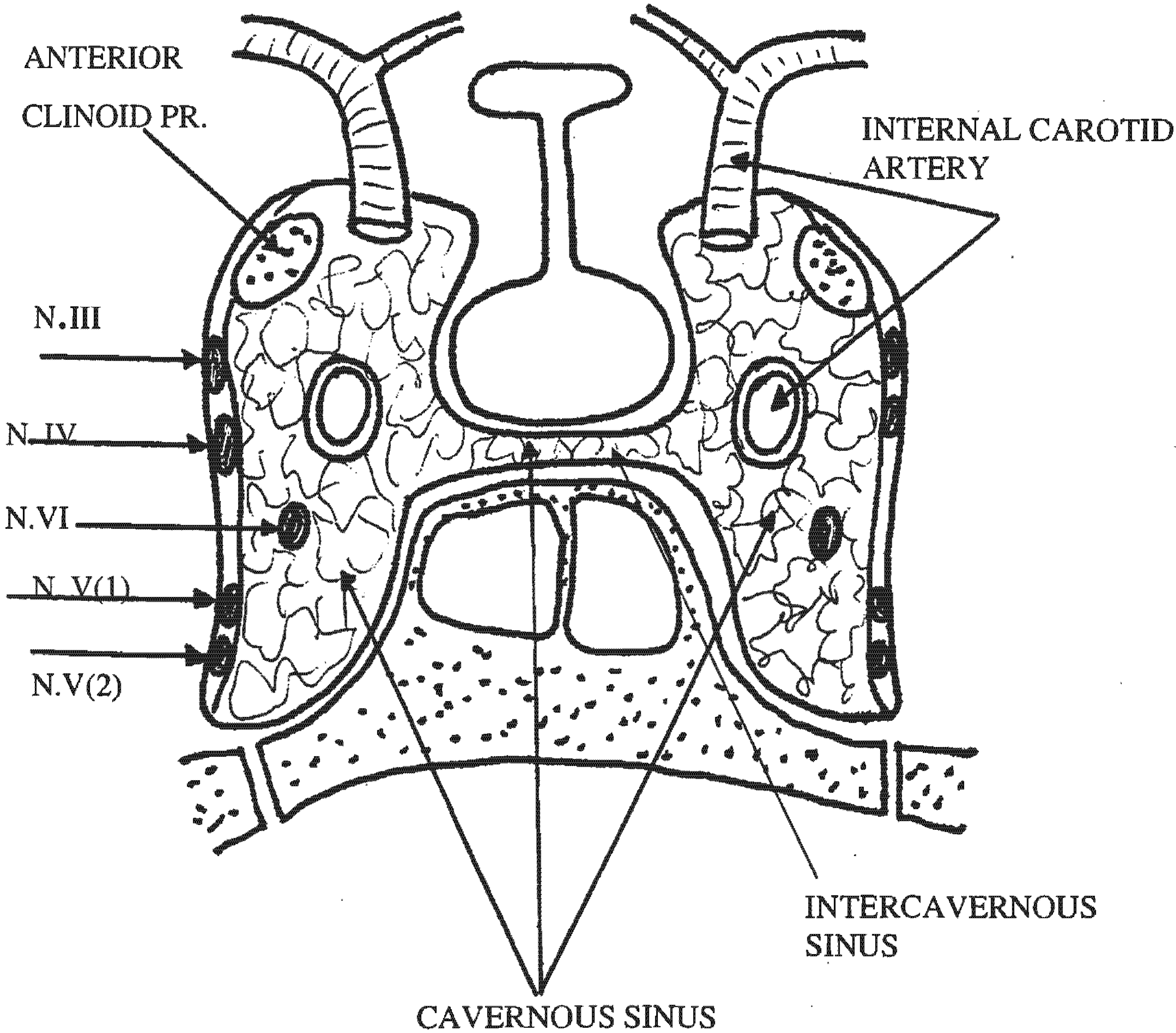

Figure 1. Cavernous sinus and related structures in coronal plane.

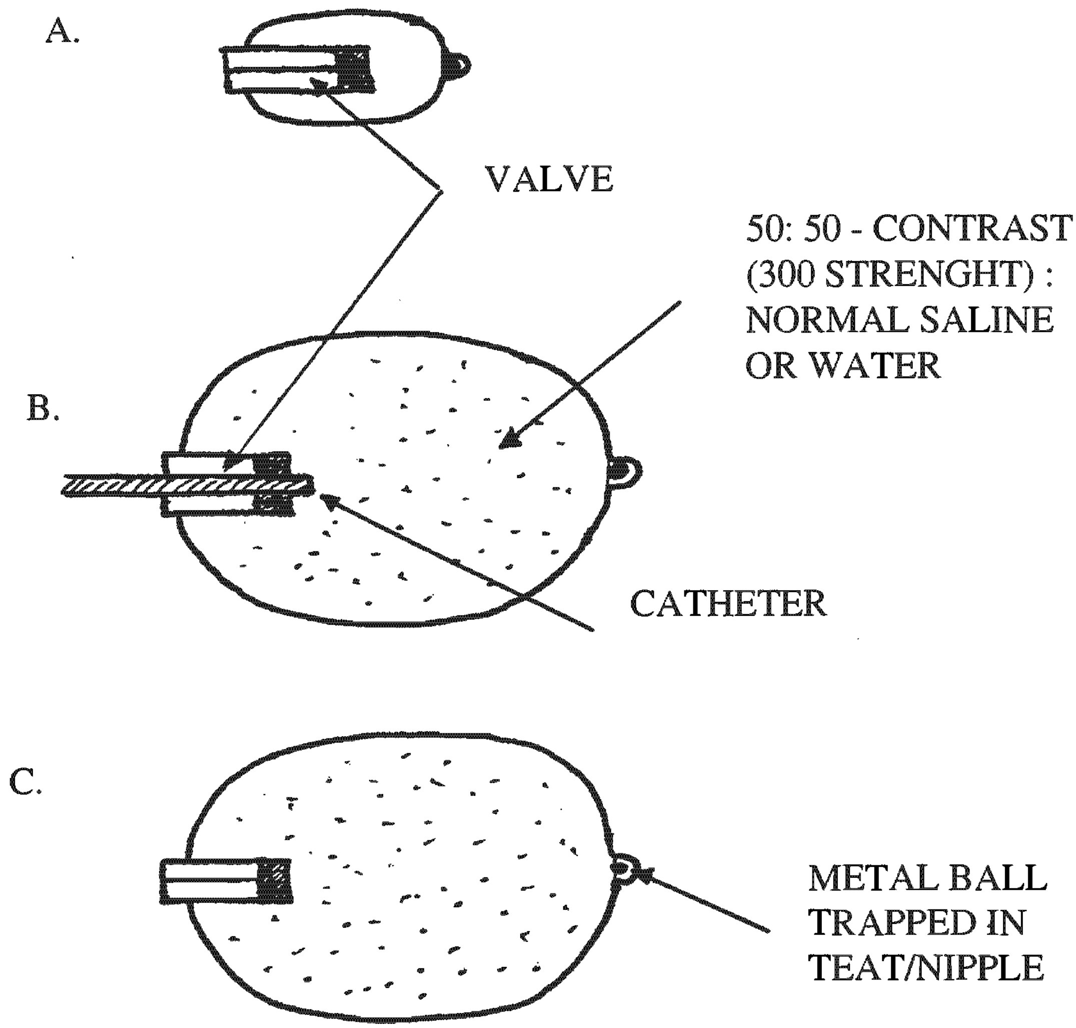

Figure 2.
Schematic illustration of Goldvalve balloon.

A. Collapsed balloon.

B. Balloon is inflated with 50:50 isoosmolar contrast and normal saline or water.

C. Catheter is withdrawn from the inflated balloon.

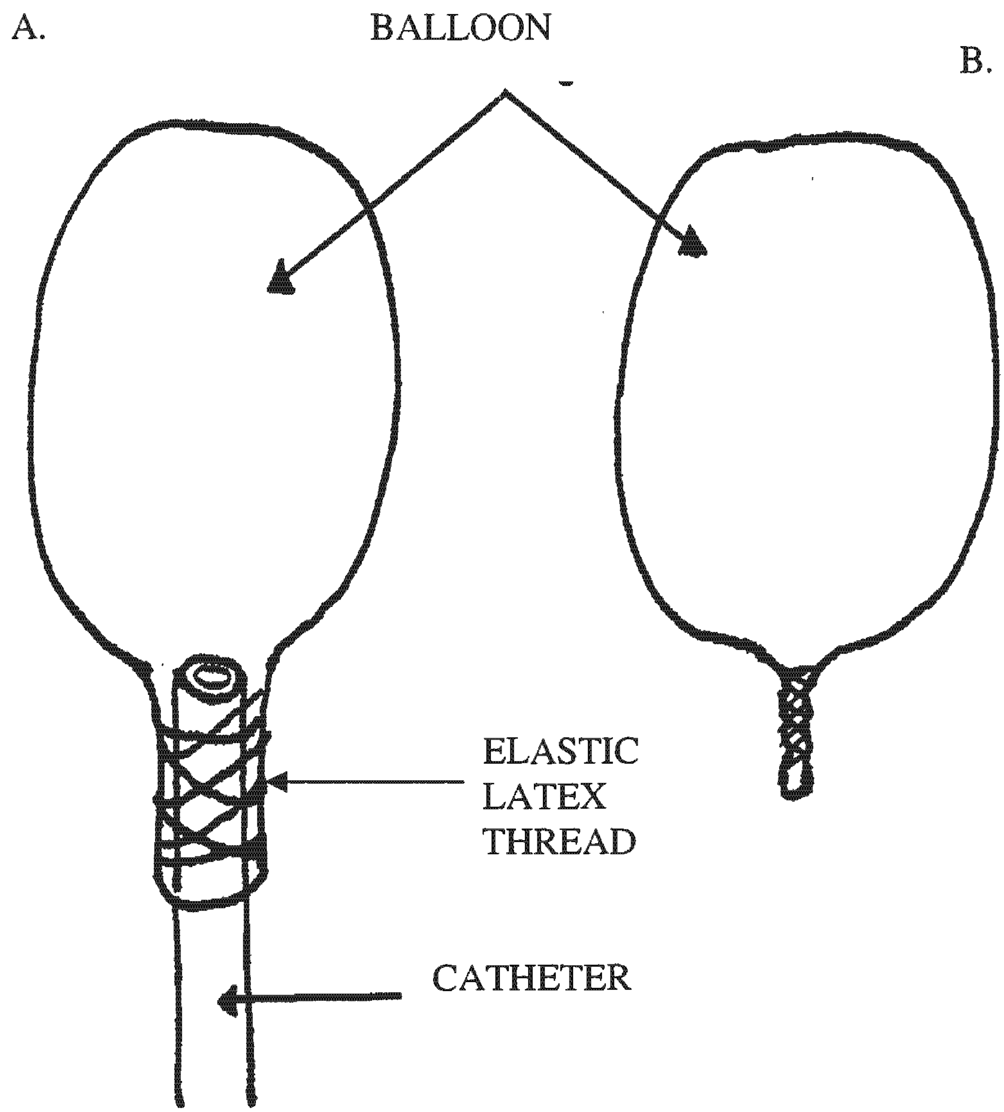

Figure 3.

A. Latex conventional tie-on Debrun detachable balloon is tied onto the tip of the catheter by latex thread.

B. After detachment latex threads contracts and seals neck.

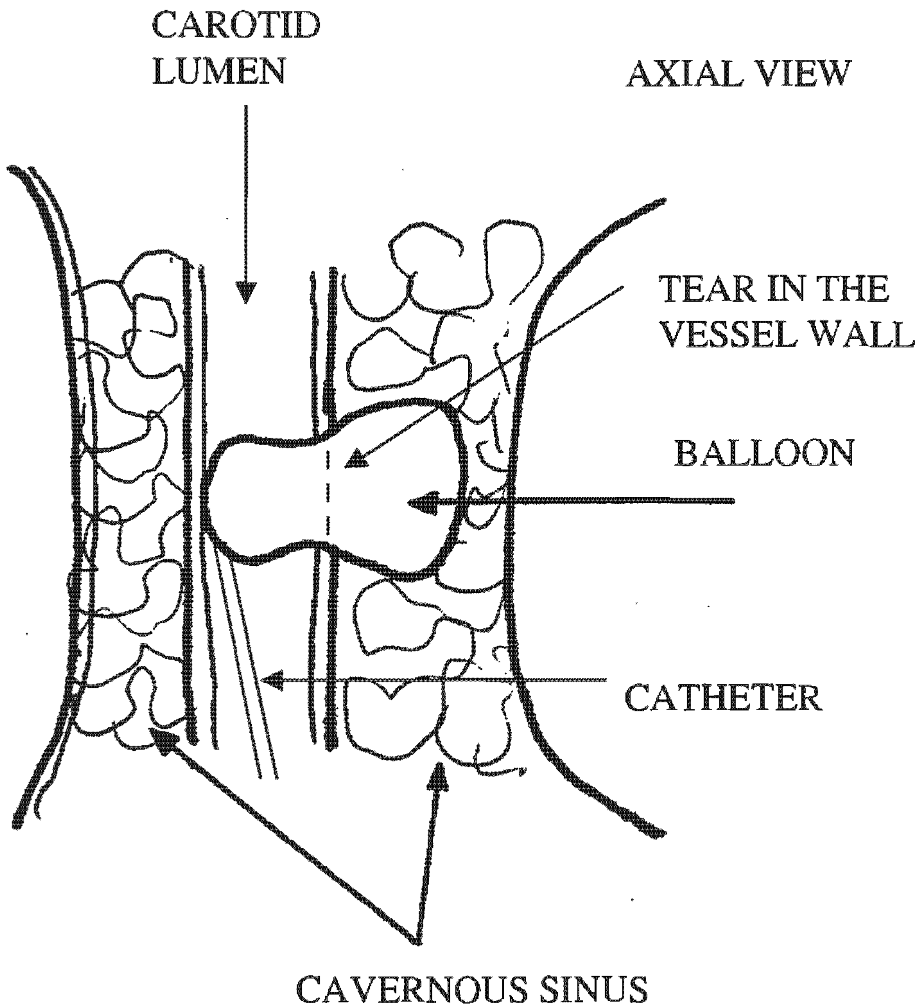

Figure 4.

Illustration of herniation of the balloon from the cavernous sinus, back into ICA via large tear in the vessel wall.

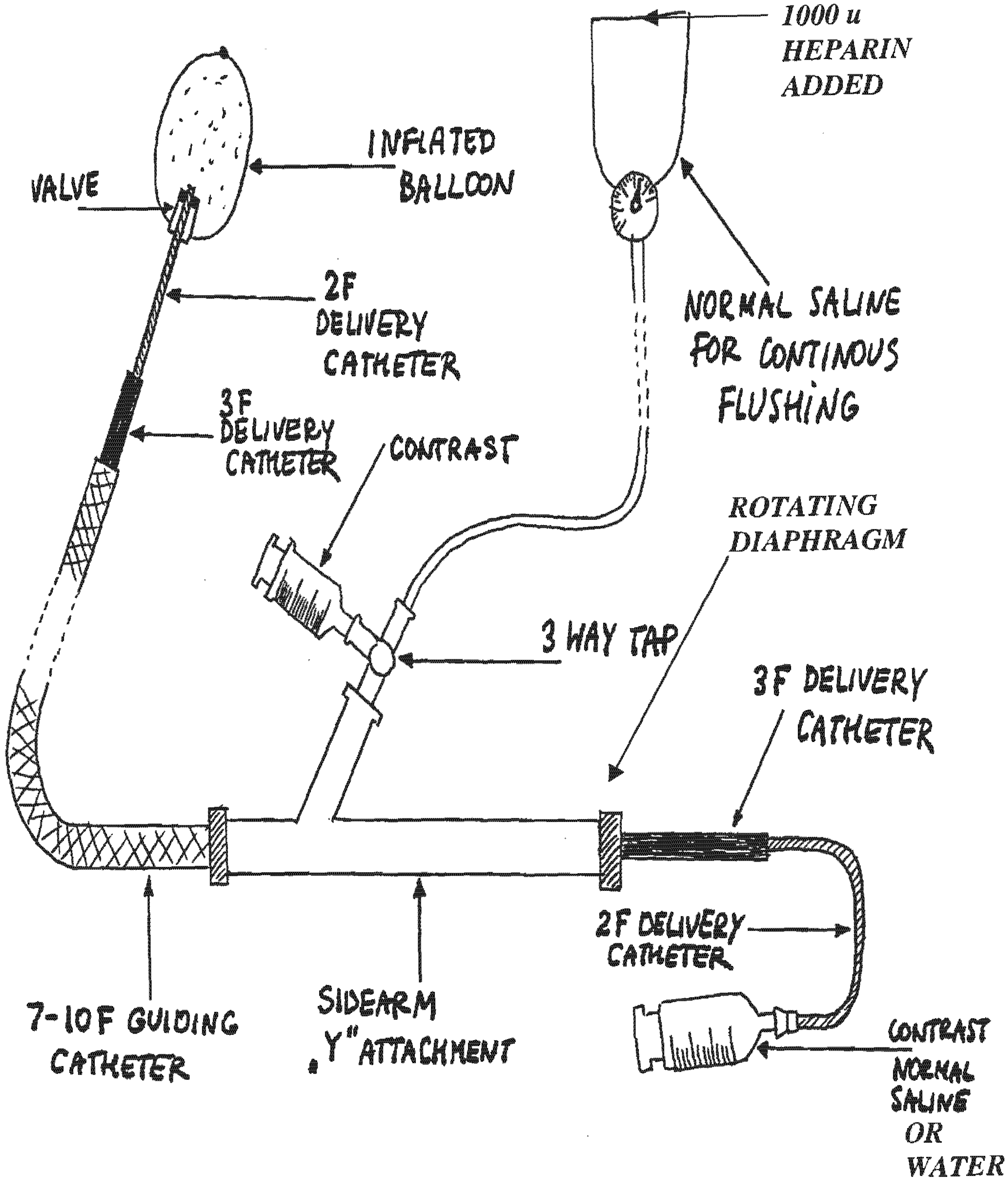

Figure 5. Balloon catheter delivery unit.

REPRESENTATIVE CASES

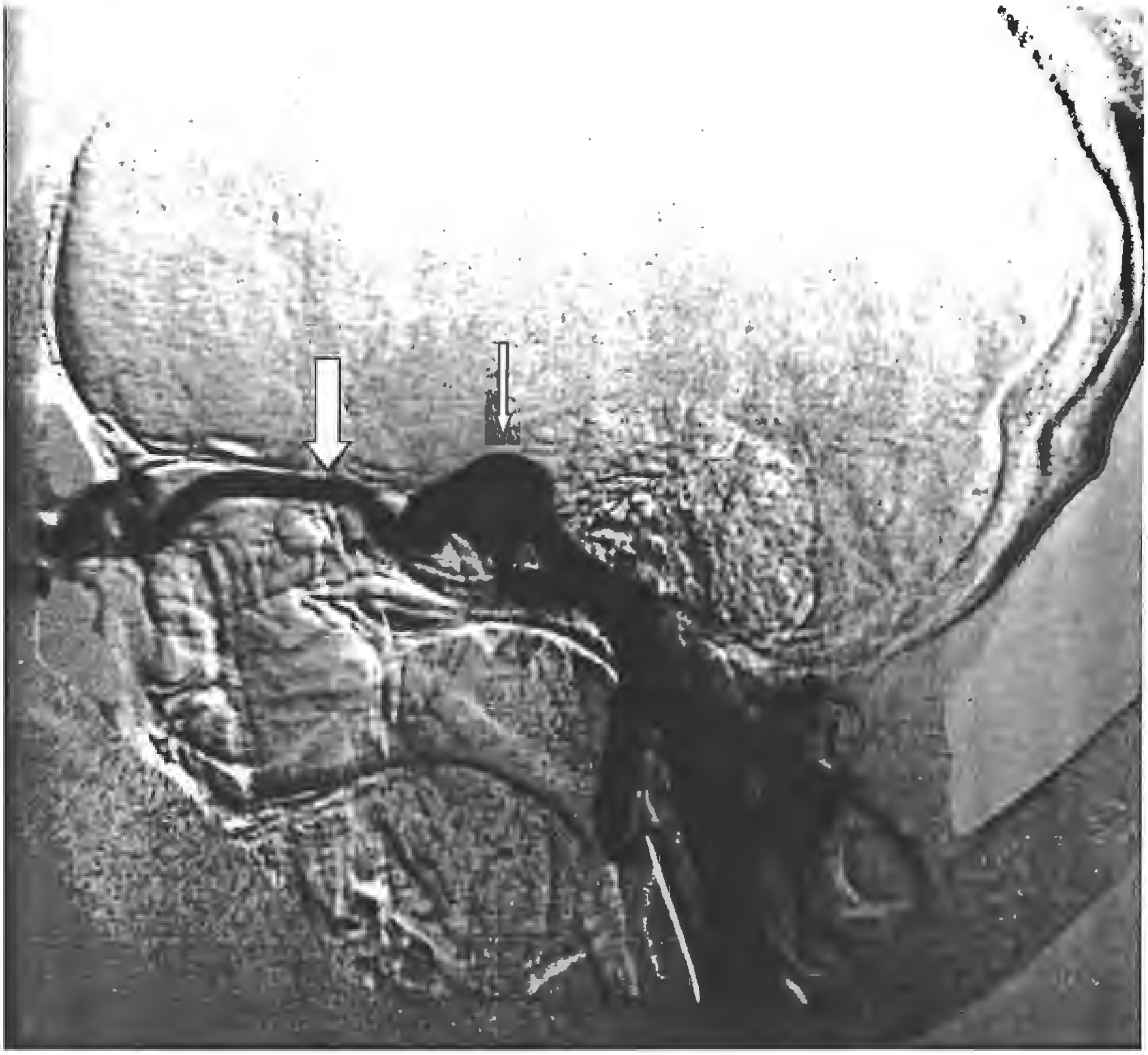

FIGURE 6 (A). Case 3. Lateral right carotid angiogram showing site of large fistula (small white arrow), with dilated superior ophthalmic vein (broad arrow) and inferior petrosal sinus (thin arrow).

FIGURE 6 (B). Case 3. Frontal right internal carotid angiogram following embolization, showing fistula occluded and internal carotid artery preserved. Balloon position indicated (arrow)

FIGURE 6 (C) Frontal X ray of case 3 with two latex balloons (white arrows) placed within the right cavernous sinus and one partially inflated balloon (thin arrow) that has migrated into the proximal part of the inferior petrosal sinus

FIGURE 7 (A). Case 2. Lateral left internal carotid (thin white arrow) angiogram showing fistula with venous drainage predominantly into the inferior petrosal sinus (broad white arrow) . Bullet is also visible within the cavernous sinus (thin black arrow).

FIGURE 7 (B) Case 2. Frontal internal carotid angiogram following embolization of the fistula and occlusion of the left internal carotid artery. Bullet in the left cavernous sinus is visible (thin arrow). Note retrograde flow in distal left internal carotid artery (broad arrow) due to ophthalmic artery flow, but no filling of fistula.

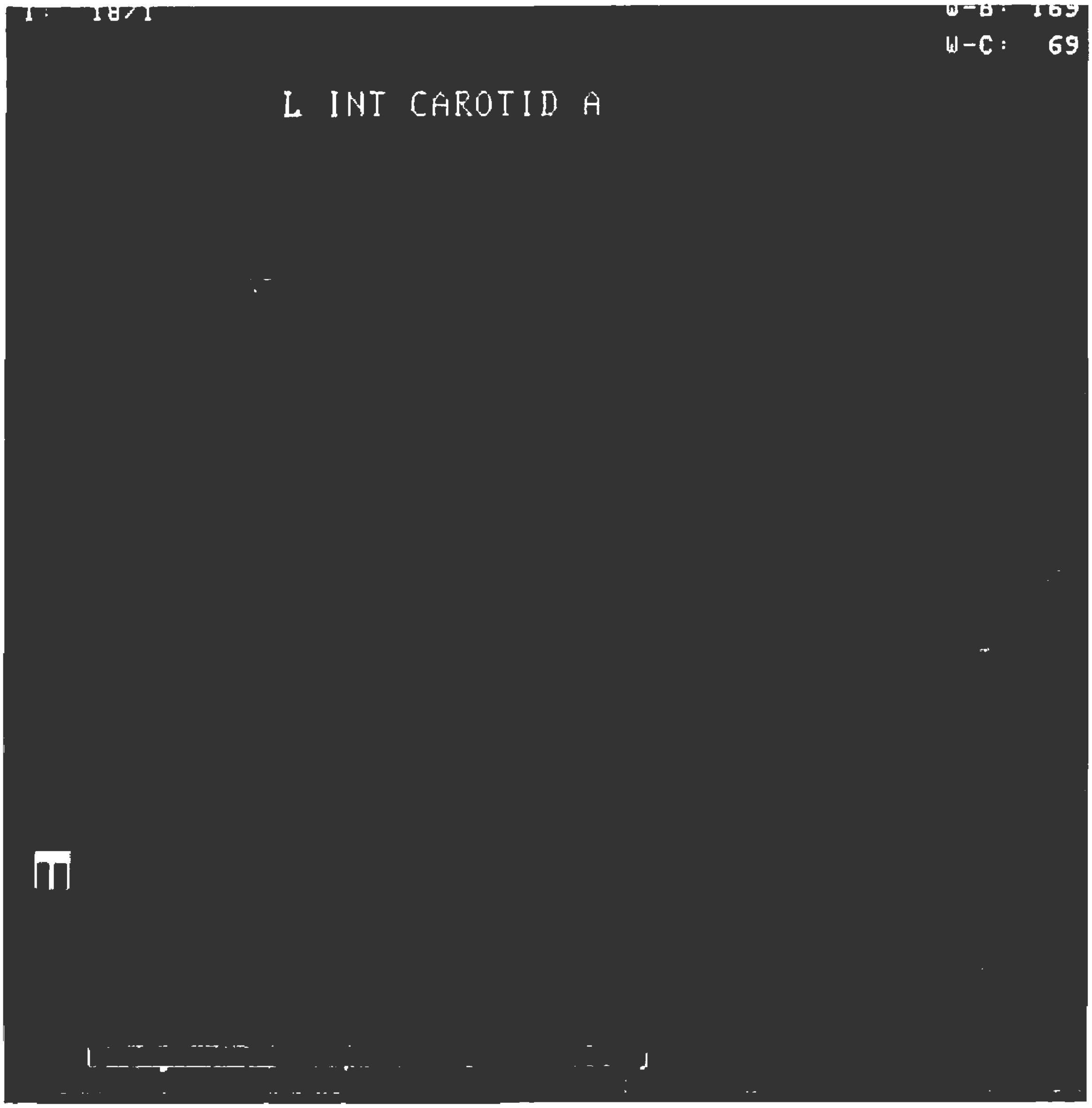

FIGURE 8 (A) Case 11. Lateral left internal carotid angiogram showing fistula into cavernous sinus (broad arrow), dilated superior ophthalmic vein (double arrows) and dilated facial vein (thin arrow).

FIGURE 8 (B) Case 11. Frontal right carotid angiogram following left internal carotid occlusion and closure of fistula (poor filling of the left middle cerebral artery may be due to posterior communicating artery inflow

FIGURE 8 (C). Case 11. Lateral vertebral (double arrows) angiogram following embolization of fistula with the balloon (thin arrow) with left internal carotid occlusion. Note filling of anterior circulation (thin white arrow) via posterior communicating artery (broad white arrow).

FIGURE 9 (A) Case 8. Lateral left internal carotid angiogram showing large fistula with venous drainage into superior ophthalmic vein (thin arrow), inferior petrosal sinus(double white arrows), pterygoid plexus (white arrow) and cortical veins (double black arrows).

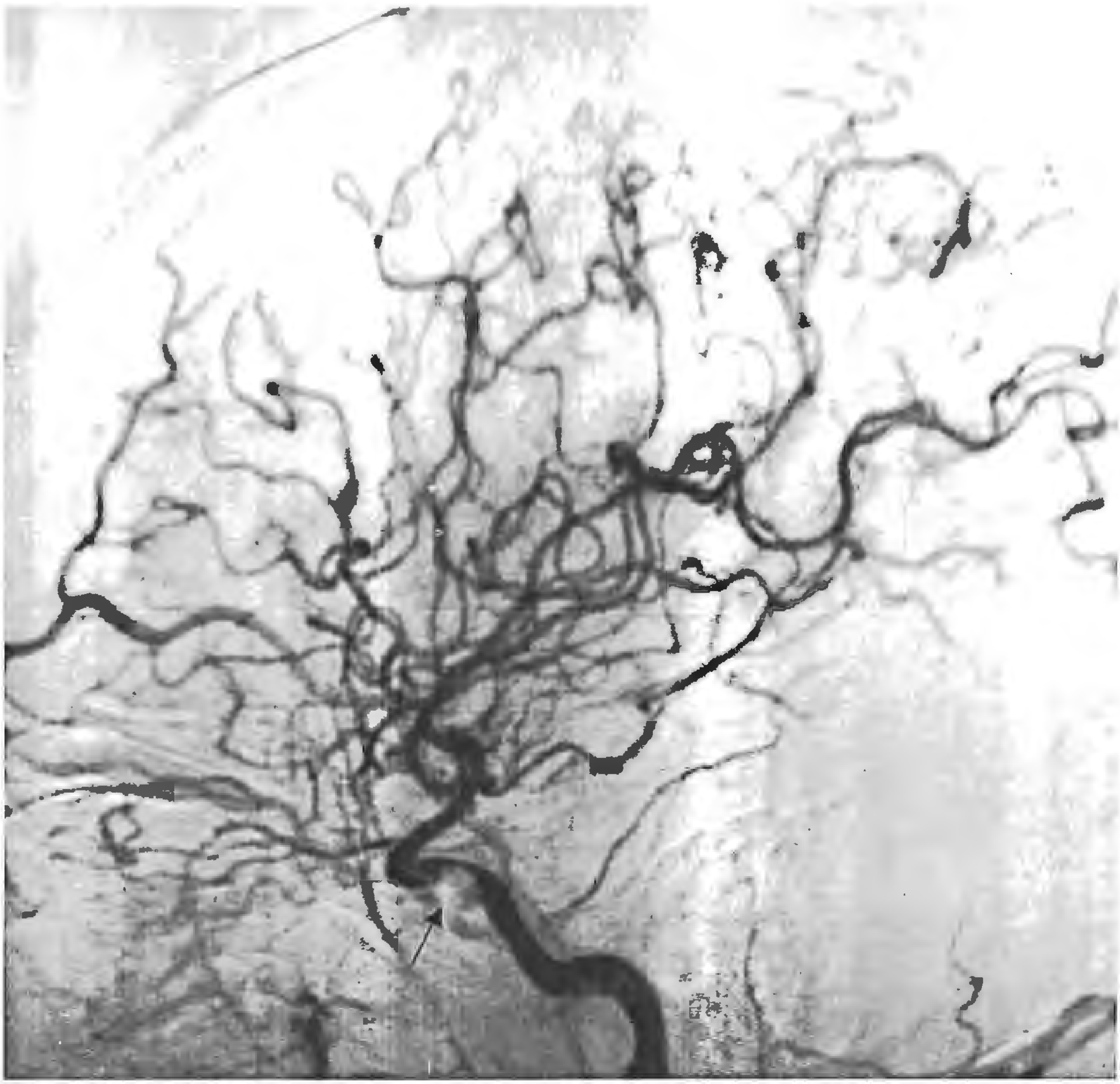

FIGURE 9 (B) Case 8. Lateral left internal carotid angiogram following embolization of the fistula with preservation of the carotid artery. Apparent filling defect (arrow) in the carotid artery may be caused by subtracted contrast material within the balloon placed in the cavernous sinus, although partial balloon protrusion into the internal carotid artery lumen may also be present.

FIGURE 10 (A) Case 13. Lateral left internal carotid angiogram showing fistula (thin arrow) with preferential venous drainage via dilated superior ophthalmic vein (broad arrow).

FIGURE 10 (B) Case 13. Frontal left internal carotid angiogram showing unusually well demonstrated fistula site (arrow).

FIGURE 10 (C) Case 13. Frontal left internal carotid angiogram following embolization of the fistula with one balloon (arrow) and preservation of the carotid artery. Note slight irregularity of internal carotid artery due to spasm following manipulations.

FIGURE 11 (A) Case 14. Lateral left internal carotid angiogram showing large fistula (broad arrow) and dilated inferior petrosal sinus (arrow). The origin of the fistula was most likely from the posterior aspect of the cavernous part of carotid artery.Transarterial placement of the balloon was unsuccessful despite multiple attempts.

FIGURE 11 (B).Case 14. Lateral left internal carotid angiogram following placement of single balloon via the inferior petrosal sinus, closing the fistula with preservation of the internal carotid artery.

FIGURE 12. Case 5. Lateral left internal carotid angiogram showing large fistula, with markedly dilated superior ophthalmic vein (white arrow). Partially inflated balloon was accidentally detached during manipulation within tortuous internal carotid artery (thin arrow) and ended up in petrous segment of ICA

FIGURE 13. Case 6. Frontal carotid angiogram showing fistula with drainage via both cavernous sinuses (white arrows). Attempts to occlude the fistula were unsuccessful due to the tortuous internal carotid artery (thin arrow). Patient was referred for surgery.

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