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Endovascular management of carotid-cavernous fistulas

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【Abstract】 **Objective** To investigate endovascular treatment of traumatic direct carotid-cavernous fistulas (CCF) and their complications such as pseudoaneurysms. **Methods**: Over a five-year period, 22 patients with traumatic direct CCFs were treated endovascularly in our institution. Thirteen patients were treated once with the result of CCF occluded, 8 twice and 1 three times. Treatment modalities included balloon occlusion of the CCF, sacrifice of the ipsilateral internal carotid artery with detachable balloon, coil embolization of the cavernous sinus and secondary pseudoaneurysms, and covered-stent management of the pseudoaneurysms. **Results** All the direct CCFs were successfully managed endovascularly. Four patients developed a pseudoaneurysm after the occlusion of the CCF with an incidence of pseudoaneurysm formation of 18.2% (4/22). A total number of 8 patients experienced permanent occlusion of the ICA with a rate of ICA occlusion reaching 36.4% (8/22). Followed up through telephone consultation from 6 months to 5 years, all did well with no recurrence of CCF symptoms and signs. **Conclusion** Traumatic direct CCFs can be successfully managed with endovascular means. The pseudoaneurysms secondary to the occlusion of the CCFs can be occluded with stent-assisted coiling and implantation of covered stents. (J Intervent Radiol, 2007, 16: 4-9)

【Key words】 Carotid-cavernous fistula; Trauma; Endovascular managemeat

Cavernous sinuses are a paired structure, 2 cm long and 1 cm wide, within the sphenoid bone in the anterior portion of the middle cranial fossa. Located on either side of the sella turcica and the pituitary gland, these sinuses extend anteriorly from the superior orbital fissure to the petrous portion of the temporal bone posteriorly. The cavernous sinus contains some important vascular and neural structures including a portion of cranial nerves III, IV, V, and the sympathetic plexus as well as a segment of the internal carotid artery (ICA) and its intracavernous branches (1,2). Direct carotid-cavernous fistulas (CCFs) are high-flow shunts with a direct connection between the intracavernous ICA and the cavernous sinus, usually arising from trauma or a ruptured aneurysm. The goal of treatment is to eliminate the fistula with concurrent preservation of the ICA. With continuous and, recently, rapid evolution of endovascular technology, numerous direct CCFs have been successfully treated through endovascular means (3-7). Here we report our experience in managing direct CCFs endovascularly.

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Materials and methods

From August 1999 to January 2005, twenty-two consecutive patients with traumatic direct CCFs were treated in our institution. There were 16 males and 6 females with an age range of 4 to 71 years (mean 38 years). Clinical findings included exophthalmos and chemosis (in all 22 patients), diplopia and increased ocular pressure (in 15), decreased visual acuity and orbital bruit (in 15), orbital pain (in 9) and ptosis (in 4). Oculomotor and trigeminal nerve deficits

Table The diagnostic and therapy outcome of CCF in 22 cases

Patient/age/sex	location of CCF	therapy	number of treating	Pseudoaneurysm	follow-up time	results
1/41/m	right	balloon	1	no	5years	occlusion
2/15/m	left	ICA sacrifice	1	no	5years	occlusion
3/42/m	right	balloon, ICA sacrifice	2	yes	5years	occlusion
4/42/m	right	balloon, ICA sacrifice	2	no	5years	occlusion
5/49/f	left	balloon	2	yes	4years	occlusion
6/5/f	right	balloon, ICA sacrifice	2	no	4years	occlusion
7/24/m	left	ICA sacrifice	1	no	4years	occlusion
8/71/m	right	ICA sacrifice	1	no	3years	occlusion
9/29/f	right	balloon	1	no	3years	occlusion
10/46/m	right	balloon	1	no	3years	occlusion
11/48/m	bilateral	balloon, coil, covered-stent	3	yes	0.5years	occlusion
12/28/m	right	balloon	1	no	1.5years	improved
13/32/m	right	balloon	1	no	1.5years	occlusion
14/21/m	left	balloon	1	no	1.5years	occlusion
15/37/m	right	balloon	1	no	1year	improved
16/49/f	right	balloon	1	no	1year	occlusion
17/41/m	left	balloon	1	no	1year	occlusion
18/45/f	bilateral	balloon	1	no	1year	improved
19/47/f	left	balloon, ICA sacrifice	2	no	1year	occlusion
20/33/m	right	balloon, coil	2	no	0.5year	occlusion
21/34/m	right	balloon, covered-stent	2	yes	0.5year	occlusion
22/51/m	right	balloon	2	no	0.5year	occlusion

occurred in 4 and 2 patiens respectively. The CCF was on the right side in 14 cases, on the left in 6 and on bilateral sides in 2 (Table).

All patients were treated endovascularly through transarterial embolization of the fistula. Thirteen patients were treated once with the result of CCF occluded, 8 twice and 1 three times. Treatment modalities included detachable-balloon occlusion of the CCF, sacrifice of the ipsilateral internal carotid artery with detachable balloon, coil embolization of the cavernous sinus and pseudoaneurysms, and covered-stent management of the pseudoaneurysm.

Transarterial embolization was usually performed with detachable balloons after the diagnostic angiography in the same session. Following systemic heparinization (5000 U leading dose and then 1000 U/h), a 8 F guiding catheter was placed in the ICA of the diseased side for passing the coaxial balloon assembly. Thereafter, a latex balloon (Ingenor Medical System, Paris, France) mounted on the tip of a 3 F microcatheter was then slowly navigated through the guiding catheter into the ICA. By gentle inflation and deflation of the balloon and careful manipulation of the microcatheter, the balloon was negotiated across the fistula into the cavernous sinus by the blood flow. The balloon was then progressively inflated and dilated with nonionic iodine contrast material (Omipaque 300, Sanofi Winthrop, New York), and ICA angiography was performed after each inflation to determine the extent of closure of the CCF and the patency of the ICA. If the control angiography showed complete closure of the CCF without parent artery occlusion, the balloon would be detached subsequently by gently pulling the microcatheter under fluoroscopic monitoring. Several detachable balloons may be needed to occlude a large fistula. In the case of ICA sacrifice, a detachable balloon would usually be navigated through the guiding catheter to the place of the fistula or a little farther with the detachable balloon remaining within the ICA. Then, the balloon was progressively inflated until the ICA was totally occluded. Afterwards, a second detachable balloon would be sent to the proximal place of the first balloon and inflated so as to enforce the effect of ICA occlusion. In this way, the ICA as well as the fistula would be completely occluded.

Results

Three patients were treated successfully with permanent occlusion of the ICA alone using detachable balloons, and nineteen were treated with detachable balloon embolization of the fistulas. Of the nineteen patients, ten were treated only once with 7 occluded and three improved. The CCFs in another 4 patients recurred and were totally occluded in a second procedure with ICA sacrifice in all 4 patients (Fig.1). One patient was treated intentionally in two different sessions of endovascular procedure with the result of the CCF occluded. The remaining 4 patients developed a pseudoaneurysm after the first detachable balloon embolization resulting in the occlusion of the fistula, with the pseudoaneurysm requiring a second or even a third endovascular intervention. Two pseudoaneurysms were treated using covered stents with concurrent preservation of the ICA (Fig.2), one was embolized with a detachable balloon of the pseudoaneurysm cavity and the remaining one treated with ICA sacrifice, with the results of all pseudoaneurysms disappeared.

Coils were used together with detachable balloons in one patient to occlude the cavernous sinus. In one case, coils were used in stent-assisted technique to obliterate a pseudoaneurysm (Fig.2). In another patient, N-butyl-cyanoacrylate (NBCA) was employed to embolize an indirect CCF secondary to the occlusion of bilateral CCFs (Fig.3).

Altogether, 5 patients were recurrent after the first intervention with a recurrent rate of CCF accounting for 22.7% (5/22). A pseudoaneurysm formed in 4 patients, all secondary to the deflation of the detached balloon and the occlusion of the fistulas, with an incidence of pseudoaneurysm formation of 18.2% (4/22). A total number of 8 patients experienced permanent occlusion of the ICA with a rate of ICA occlusion reaching 36.4% (8/22).

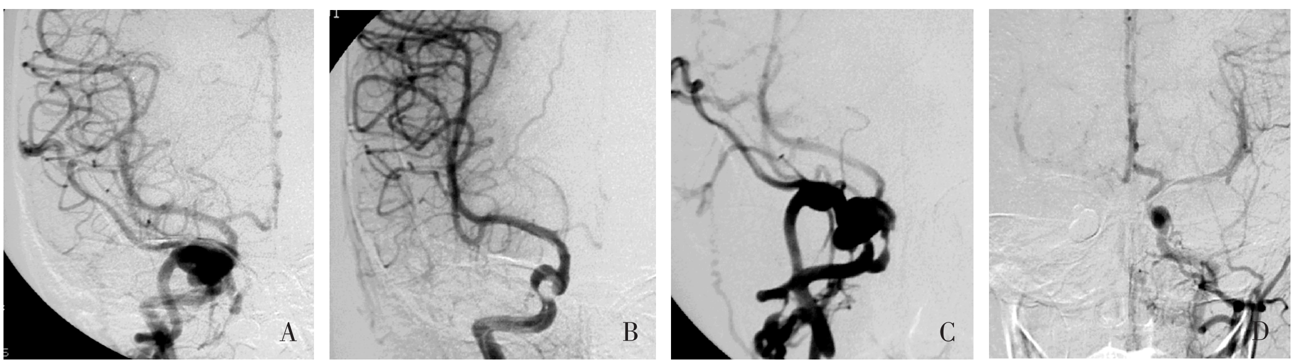

Fig.1 **A**: 4-year-old girl had a traumatic CCF on the right side. Injection through the right ICA revealed a direct CCF with venous drainage primarily through the ophthalmic vein; **B**: The detachment of a detachable balloon within the right cavernous sinus led to the complete obliteration of the fistula with concurrent compromise of the ICA; **C**: Half a month later, the CCF was recurrent due to the premature rupture of the balloon within the cavernous sinus; **D**: The right ICA was successfully sacrificed using two balloons with one detached within the right cavernous sinus and the other in the right ICA proximal to the fistula. Injection through the left ICA showed that the right anterior cerebral artery was supplied by the left ICA

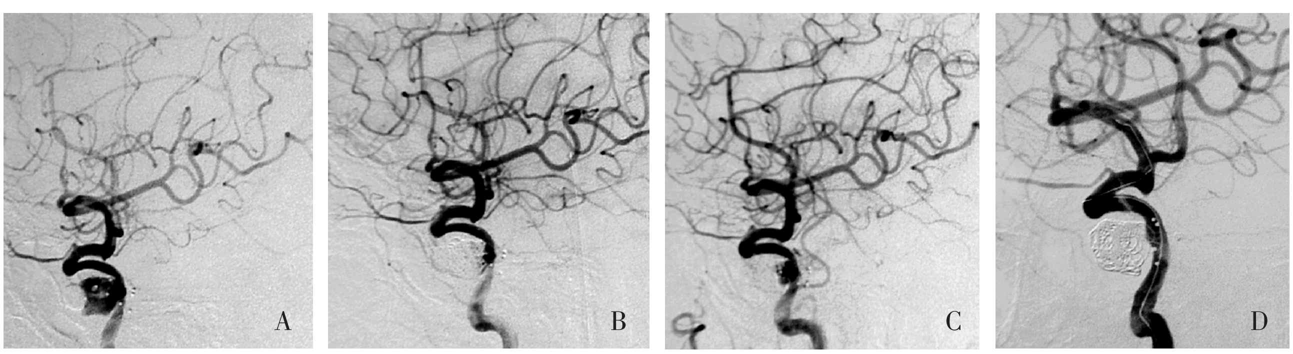

Fig.2 A 50-year-old man had traumatic bilateral CCFs that had been successfully treated with detachable balloon embolizaiton. **A**: One and a half month after the embolization, a pseudoaneurysm was formed on the intracavernous portion of right ICA; **B**: Embolization with stent-assisted technique resulted in the total obliteration of the pseudoaneurysm; **C**: Follow-up cerebral angiography five months after the stent-assisted embolization demonstrated recurrence of the pseudoaneurysm due to coil compression; **D**: Following the placement of a covered stent, the pseudoaneurysm was completely occluded

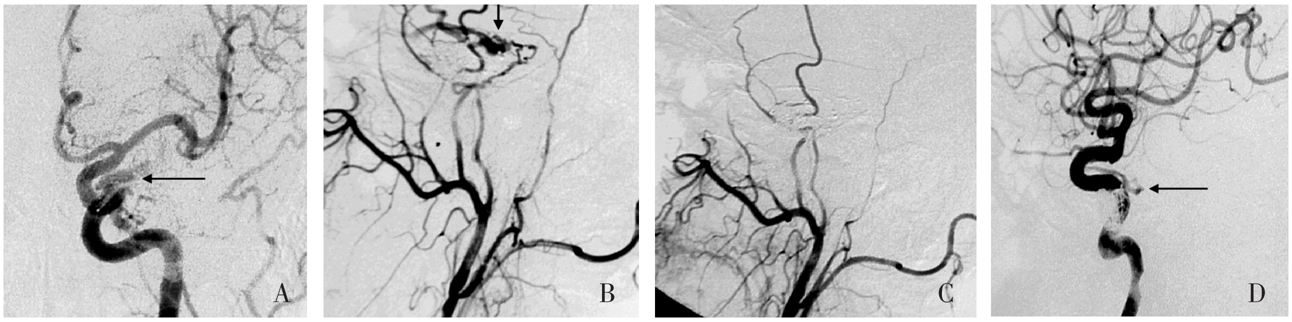

Fig.3 The patient was the same as in Fig.2. Over half a year after the embolization of bilateral CCFs with detachable balloons, the patient developed an indirect CCF on the left side ;**A&B** : Injection of the left ICA and ECA revealed the development of a Barrow Type D CCF (arrow) supplied by some little branches of both ICA and ECA ;**C** :Embolization with NBCA was performed through the ECA branches of both left middle meningeal and maxillary arteries and resulted in the occlusion of the fistula ;**D** :The fistula was still supplied by little branches of the left ICA (arrow)

Followed up through telephone consultation from 6 months to 5 years, all did well with no recurrence of CCF symptoms and signs.

Discussion

Transarterial detachable balloon embolizaiton remains the best initial therapy for direct CCFs in spite of the development of transvenous approaches and improved techniques in cranial base surgery (1,3,6,8-13). Although the efficacy and safety of detachable balloon occlusion of direct CCFs have been well established, this technique has required occlusion of ICA in a substantial percentage of patients (3,9,13). Lewis et al (3) reported a rate of ICA patency of 71% to 81% in using detachable balloons made by different companies. In our series, the rate of ICA patentcy was 63.6% (1-36.4%) which was relatively smaller. Under certain circumstances, preservation of the ICA is impossible if the CCFs were treated only through transarterial route with use of detachable balloons alone. First, if there is a large tear of a nearly complete transection of the ICA, it is nearly impossible to preserve the ICA with detachable balloons. Occlusion of the fistula requires simultaneous occlusion of the ICA. Second, the balloon may protrude into the ICA lumen and create a significant stenosis (Fig.1) which can greatly reduce blood flow through the ICA and create turbulence around the balloon, resulting in a risk of thromboembolism. The balloon may also shift, leading to ICA occlusion, or may migrate into the distal cerebral vasculature. In these situations, occluding the ICA may be a better choice of management. Balloon rupture caused by a bony fragment may also promote occlusion of the ICA. The rate of permanent ICA sacrifice in our series was relatively higher (36.4%) compared with other reports (9,13,14) because we employed only transarterial approach to embolize the fistulas. The approach of transvenous embolization of the cavernous sinus would probably achieve a higher rate of ICA patency. Furthermore, early in our experience with detachable balloons, we often occluded the ICA when the fistula persisted or recurred. Sometimes when patients were referred from far-away places, we chose to occlude the ICA rather than accept an imperfect or incomplete closure or potentially subject the patients to another procedure.

When occluding the CCFs especially larger ones including those involving bilateral ICAs, one important issue we should take into consideration is to avoid hyperperfusion syndrome caused by abrupt occlusion of the blood shunt through larger fistulas. If a large fistula was abruptly completely obliterated, the cerebral perfusion pressure might increase suddenly due to closure of large shunts of blood flow and serious complications like intracranial hemorrhage might take place. In patient 11 with bilateral fistulas, we attempted in the first place to completely occlude the bilateral fistulas in one session of procedure. However, the patient suddenly felt uncomfortable with vomiting and tachycardia only after total embolization of the left smaller fistula and placement of a detachable balloon within the right cavernous sinus. So, the procedure was emergently stopped and another procedure was arranged for complete obliteration of the right larger fistula. The patient had a one-week interval for adaptation before the second procedure and no severe complications occurred except slight to mild headache caused by hyperperfusion resulted from occlusion of large blood shunt. Since then，we adopted a strategy to embolize in two or more sessions a large fistula to avoid severe complications possibly resulting from abrupt occlusion of large shunts of blood blow through the bigger fistula. Case 20 had a large fistula and we decided to occlude it in two different sessions. We first delivered 6 detachable coils within the cavernous sinus and then，three detachable balloons were detached within the same cavernous sinus， which did not result in total occlusion of the large fistula. The 6 coils together with three detached balloons had reduced the fistula to a smaller one. When the patient had adapted to the hemodynamic change brought about by partial embolizaiton of the fistula， a second embolization procedure may be carried out to totally obliterate the fistula without possible severe sequela. In this patient，the second procedure with detachable balloon embolization of the fistula allowed the patient two months for adaptation and the large fistula was completely occluded with no sequela.

There is a certain incidence of pseudoaneurysm which usually develop a few weeks after embolization either because of deflation or migration of the detached balloons (4,11). They are generally asymptomatic and may decrease in size and spontaneously seal off. However， large pseudoaneurysms may induce trigeminal pain or oculomotor palsy， necessitating occlusion with a second detached balloon or permanent sacrifice of the ICA. Pseudoaneurysms occurred in 14 of 74 (18%) patients in the series by Tsai et al (15)， and Higashida et al (16) reported an incidence of pseudoaneurysm of 2.8% (5/181). In our series，the incidence of pseudoaneurysm was 18.2% (4/22)， with three pseudoaneurysms causing trigeminal pain and one causing oculomotor palsy. All these pseudoaneurysms happened secondary to deflation of the balloon and at a time when the fistula had disappeared. One pseudoaneurysm was successfully managed with one detachable balloon， one with ICA sacrifice and a third with covered-stent implantation. The remaining pseudoaneurysm was treated initailly with stent-assisted technique and then，with covered-stent implantation when it recurred due to coil compaction over half a year later. Covered stents were employed in this series to occlude two pseudoaneurysms with satisfactory results. Because of the fragile wall and numerous lobulations of some pseudoaneurysms，endovascular management with covered stents would be a better choice than with detachable coils. The Polytetrafluoroethylene (PTFE)-covered stent has been developed by MicroPort Medical (Shanghai) Co. Ltd，Shanghai，China. This kind of covered stent is specially designed for intracranial vasculature with good longitudinal flexibility. It can pass through the tortuous segment of ICA and be used in intracranial vasculature. It is closely compressed against a non-detachable balloon. After the combination of the un-detachable balloon and the PTFE-covered stent is accurately placed in the desired location，the balloon is distended and the stent is expanded on the wall of ICA. Withdrawal of the non-detachable balloon will conclude the process of PTFE-covered stenting and the pseudoaneurysm or any defect will be covered by the PTFE-stent. Utility of covered stents has been reported with good results in treating extracranial and intracranial aneurysms and arteriovenous fistulas including CCFs (17-18). But the current generation of covered stents designed for coronary use is rather stiff and difficult to navigate in tortuous vessels particularly in the intracranial vasculature. The PTFE-covered stent，developed by MicroPort Medical (Shanghai) Co. Ltd，Shanghai，China，has overcome the shortcoming of stiffness and can be navigated through very tortuous intracranial vasculature because it has sufficient longitudinal flexibility.

The causes of recurrence of direct CCFs are thought to include premature balloon deflation， balloon migration and rupture of the detached balloon by a bony fragment (3,4) with the most common causes being balloon deflation and migration. In the current study，five patients recurred. Two was due to premature deflation and two to puncture of a bony fragment. The fifth patient (case 11) developed left indirect dural CCF (Type D) after the total obliteration of bilateral direct CCFs. The development of indirect CCF was probably because of the presence or reopening of the normal anatomosis between intracavernous external and internal carotid arteries. After the development of the left indirect CCF, we chose to embolize the fistula through the meningeal artery of the left external carotid artery with NBCA. The fistula through the left external carotid artery branches was occluded but small branches of the ipsilateral internal carotid artery still supplied the fistula (Fig.3). However, the indirect CCF was almost totally occluded, as expected, through thrombosis of the cavernous sinus within several months´ time.

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