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Endovascular treatment of basilar tip aneurysms associated with moyamoya disease

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Abstract We report the efficacy and safety of endovascular treatment of basilar tip aneurysms (BTA) in five patients with moyamoya disease. The patients underwent intra-aneurysmal embolisation with detachable platinum coils. Three BTA presented with subarachnoid haemorrhage (SAH); the other two were asymptomatic. In four cases, one embolisation procedure produced >95% angiographic obliteration of the aneurysm. In the other patient, 80–90% obliteration was achieved initially, but due to growth of the residual aneurysm, the procedure was repeated 7 months later. Two patients experienced transient oculomotor paresis as a procedure-related complication. Mean follow-up was 43.6 ± 34.0 months (range 8–92 months). One patient died of putaminal haemorrhage unrelated to the aneurysm 15 months after embolisation. The other four had no subsequent SAH and survived without sequelae. Endovascular embolisation using detachable platinum coils proved to be a safe and efficient treatment modality for BTA associated with moyamoya disease.

Keywords Basilar tip aneurysm · Moyamoya disease · Embolisation

Introduction

Moyamoya disease is a slowly progressive occlusive disease involving the internal carotid arteries [1, 2]. In 5–15% of patients there are associated intracranial aneurysms [3, 4, 5], preferentially located at the tip of the basilar artery [5, 6, 7]. Morbidity following direct clipping of basilar tip aneurysms (BTA) is high [6, 8, 9], but due to advances in endovascular techniques, these aneurysms can now be approached in different ways [7]. We used soft platinum coils to treat five patients with moyamoya and a BTA and discuss the efficacy and safety of intra-aneurysmal embolisation.

Materials and methods

We treated two men and three women (Table 1), whose ages ranged from 31 to 52 years (mean 43.6 ± 9.0 years). Three presented with SAH, World Federation of Neurosurgeons (WFNS) scale 1 (two patients) and 4 (one), thought attributable to the BTA. One of the other two patients had a putaminal haemorrhage shown angiographically not to be related to the BTA and in the other the BTA was detected incidentally on inspection of angiograms obtained after

Table 1 Summary of patients who underwent endovascular treatment

Patient, age (years), sex	Carotid angiography moyamoya staging		Size of aneurysm (mm)		Presentation (WFNS grading)	Previous ischaemic symptoms
	Right	Left	Maximum	Neck		
1. 38, F	2	3	8	2.8	Subarachnoid haemorrhage (1)	Transient right arm paresis
2. 46, F	5	4	8	2.8	Subarachnoid haemorrhage (1)	None
3. 51, M	3	3	5	4	Cerebral haemorrhage unrelated to aneurysm	None
4. 31, M	3	3	5	2.5	Subarachnoid haemorrhage (4)	None
5. 52, F	3	2	3.5	2	None relevant	Transient left hemiparesis

prior superficial temporal-middle cerebral artery anastomosis. The aneurysms ranged from 3.5 to 8 mm (mean 5.9 ± 2.0 mm) in diameter. On angiography we staged the moyamoya disease from 2 to 5 [10].

During the procedure, all patients received propofol (1–2 mg/kg/h) to keep the head immobile. Heparin (5,000–9,000 units) was used to prolong the activated coagulation time to approximately twice the base value. Guglielmi electrically detachable platinum coils (GDC) were deployed in four patients and Interlocking detachable coils (IDC) were used in patient 1 who was treated before GDC became available in Japan. The coils were introduced into the aneurysm via a microcatheter. The balloon-assisted technique was used in patient 3 whose aneurysm had a relatively large orifice, and in patient 2 for the second embolisation (Table 2).

We closely monitored the patients' neurological condition after embolisation. CT was obtained at least once a month for the first 4 months after treatment. The first follow-up angiograms were obtained between 3 and 6 months after treatment (Table 3).

Table 3 Follow-up data

Patient	Follow-up (months)	Subarachnoid haemorrhage after embolisation	Status at latest follow-up (Activities of daily living score)
1	92	No	1
2	58	No	1
3	15	No	Died of unrelated cerebral haemorrhage
4	45	No	1
5	8	No	1

Results

After one embolisation procedure, >95% angiographic obliteration of the aneurysm was confirmed in four patients (Fig. 1). On follow-up angiograms there was no reappearance of the aneurysmal lumen. Patient 2 underwent two procedures; the first resulted in 80–90% occlusion and a second, performed 7 months later due to enlargement of the residual lumen, produced >95% obliteration. The lumen in this patient had grown to 3.5 mm and lumen/neck ratio became relatively small (3.5/2.8 mm), we used the balloon-assisted technique.

Transient right mydriasis occurred intraoperatively in patient 1 and disappeared spontaneously within an hour. In patient 2, a left oculomotor paresis observed 2 days after the procedure was successfully treated with a tapering dose of corticosteroids (maximum 40 mg prednisolone/day). In the other three cases, there were no procedure-related complications. None of the three

Table 2 Immediate results of endovascular treatment. *IDC* interlocking *GDC* Guglielmi detachable coils

Patient	Type of coil	Size (mm)×length (cm) of coils (number used)	Degree of obliteration on angiography (%)	Procedure-related complications
1	IDC	6×10 (1), 5×10 (1), 5×15 (1), 4×8 (2)	>95	Transient intraoperative mydriasis
2	GDC	7×25 (1), 5×10 (1), 3×6 (1), 3×6(1), 2×8 (1), 2×4 (1)	80–90	Transient oculomotor paresis
	GDC	3×6 (1), 2×3 (1)	>95	None
3	GDC	4×4 (1), 3×3 (1), 2×4 (2), 2×2 (2)	>95	None
4	GDC	5×15(1), 3×8(1), 3×6(1), 2×4 (1)	>95	None
5	GDC	3×6 (1), 2×4 (1)	>95	None

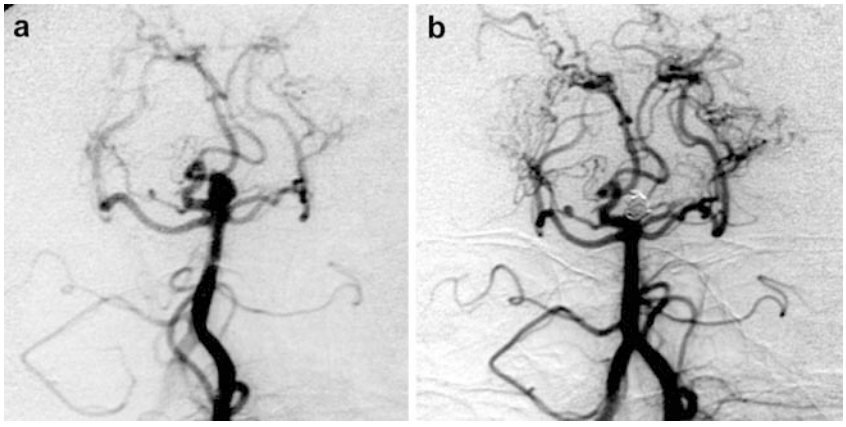

Fig. 1a, b Case 4. **a** Digital subtraction angiography (DSA) reveals a basilar tip aneurysm (diameter 5 mm). There were moyamoya vessels arising from the posterior cerebral arteries. **b** Postembolisation DSA showing almost complete obliteration of the aneurysm and patency of the arteries surrounding it

patients who presented with SAH had symptomatic vasospasm.

Follow-up ranged from 8 to 92 months (mean 43.6 ± 34.0 months). Patient 3 died of another intracerebral haemorrhage 15 months after embolisation. The other four patients resumed their independent daily lives without neurological symptoms. At the latest follow-up, their ability to pursue the activities of daily living was graded as normal or nearly normal.

Discussion

Maki and Nakata [11] were, in 1965, the first to report an intracranial aneurysm associated with moyamoya disease. The prevalence of intracranial aneurysms in this disease is around 10% [3, 4, 5]. According to Kawaguchi et al. [5], the distribution of these aneurysms on the circle of Willis, the basal ganglia, and the collateral vessels is 3:1:1. They are encountered more often in the posterior than in the anterior circulation [5, 6, 7]. It has been suggested that increased blood flow through the vertebrobasilar system, the major source of collateral circulation in moyamoya disease, intensifies haemodynamic stress on arterial walls and may result in the formation of saccular aneurysms [12, 13].

Treatments for these aneurysms include direct clipping and extra-intracranial revascularisation surgery [5, 14]. Direct clipping is difficult and hazardous. Dural and arachnoid incisions may disturb collateral flow through anastomotic vessels [8, 15] and intraoperative compression of ischaemic cerebral cortex or temporary clipping of the parent artery may result in irreversible brain damage [9]. The stiffness of the carotid artery may preclude adequate retraction [7] and abnormal intertwined vessels in the basal cisterns can hinder the approach [6, 8]. In addition, the already compromised cerebral blood flow may be further disturbed by intra- and perioperative cardiovascular and ventilatory instability [16, 17, 18]. These complications preclude surgery in approximately half of patients with moyamoya and intracranial aneurysms and lower the rate of successful neck clipping to 20% [5].

Endovascular procedures using soft platinum coils have become an alternative for treating aneurysms in patients considered ineligible for general anaesthesia and craniotomy and for aneurysms difficult to reach by craniotomy [19, 20]. Because of the difficulties encountered in direct aneurysm clipping, the endovascular treatment of BTA in patients with moyamoya disease presents a welcome alternative. Massoud et al. [7] reported two BTA associated with moyamoya disease, treated by endosaccular embolisation. One patients was successfully treated, but the other had a large aneurysm and died 1 month after embolisation. Two subsequent Japanese reports documented excellent results [21, 22] and our endovascular treatment of five patients with associated BTA also yielded excellent outcomes: four were able to resume their normal lives without post-treatment aneurysmal bleeding.

Further aggravation of cerebral ischaemia, which is inherent in moyamoya disease and already exacerbated by SAH, may result in immediate neurological morbidity. Maintaining normal blood pressure and normal $PaCO_2$ levels is therefore mandatory during endovascular treatment. Our use of propofol (1–2 mg/kg/h) did not induce cardiovascular or respiratory instability and was useful for the temporary prevention of head movement. Because the posterior cerebral arteries are the major source of collateral flow to the anterior circulation in moyamoya disease, obliteration of these arteries could lead to catastrophic results. Thus, dislodging of coils from the aneurysm lumen must be avoided and we therefore used the balloon-assisted technique in two patients [23]. Because even transient obstruction of parent arteries during balloon inflation may result in irreversible brain damage due to the pre-existing ischaemia, the balloon was inflated for the shortest possible time, under adequate heparinisation.

As the very long-term efficacy of endosaccular obliteration of intracranial aneurysms with platinum coils remains to be established, patients who receive this treatment should be closely followed. The very recent introduction of novel coils [24, 25, 26] may improve the safety and promote wider use of this treatment for intracranial aneurysms in patients with moyamoya disease.

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