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Stenting for vertebrobasilar dissection: a possible treatment option for nonhemorrhagic vertebrobasilar dissection

Yong Sam Shin · Ho Sung Kim · Sun Yong Kim

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Abstract
Introduction It has been reported that stent placement may improve compromised blood flow resulting from vertebrobasilar dissection. In this study the technical feasibility, safety, as well as short-term outcome of stent placement for the treatment of nonhemorrhagic vertebrobasilar dissection was retrospectively investigated.
Methods Ten patients (eight men, two women; age range 36 to 45 years) with nonhemorrhagic vertebrobasilar dissection were treated by stenting. Nine lesions were located at the vertebral artery (VA) (one bilateral case) and two at the basilar artery. Seven patients presented with ischemic symptoms and three with headache. Among the nine VA dissections, eight lesions involved the posterior inferior cerebellar artery (PICA). Angiographic findings included abrupt or irregular vessel narrowing with aneurysmal dilatation in nine lesions and irregular bulbous aneurysmal dilatation in two lesions.
Results Placement of a stent-within-a-stent was performed in six lesions and single stent in five lesions. Initial treatments were technically successful in all patients. Follow-up was performed using digital subtraction angiography (six patients) or CT angiography (two patients). Successful occlusion or decreased contrast filling of the aneurysm sac was noted in six patients (seven lesions), increased aneurysm sac filling in one patient, and parent artery occlusion in one patient. PICA flow was preserved in all those with follow-up (1 week to 17 months).
Conclusion Stent placement is technically feasible and safe for the treatment of vertebrobasilar artery dissection, especially for preserving PICA and/or major perforating arteries. However, a study with a larger population and longer follow-up is necessary for validation of the efficacy of this treatment modality.

Keywords Vertebrobasilar dissection · Stenting · Ischemia

Y. S. Shin
Department of Neurosurgery,
Ajou University College of Medicine,
Suwon, Kyonggi-Do, Republic of Korea

H. S. Kim · S. Y. Kim (✉)
Department of Diagnostic Radiology,
Ajou University College of Medicine,
San 5, Wonchon-Dong, Yeongtong-Gu,
Suwon, Kyonggi-Do, Republic of Korea
e-mail: kimsun@ajou.ac.kr

Introduction

Intracranial vertebrobasilar artery (VBA) dissection is classified into three major clinical types: subarachnoid hemorrhage (SAH), headache, and nonhemorrhagic ischemic symptoms. SAH, from dissecting aneurysms of the intracranial VBA, are increasingly reported. Aggressive treatments including internal trapping have been implemented due to their tendency for early rebleeding and a fatal natural course [1]. Intracranial VBA dissections, initially presenting without SAH, have been more frequently identified since the introduction of advanced diagnostic imaging modalities including MR angiography and multidetector CT angiography. These dissections are considered to be benign in nature [2]. However, the natural history of and management policies for nonhemorrhagic VBA dissections are not well delineated [3, 4].

The therapeutic management of patients presenting with nonhemorrhagic VBA dissection remains controversial. Surgical and endovascular treatment are generally performed in patients who have dangerous lesions liable to rupture or who have persistent symptoms of ischemia despite adequate anticoagulation. However, in patients with nonhemorrhagic

VBA dissection, aggressive surgical treatment and/or endovascular trapping as well as proximal occlusion of the parent artery are not routinely considered primary treatment.

Recently, stent placement for VBA dissection has been increasingly reported in selected patients [5–10]. The advantages of stent-assisted angioplasty include exclusion of plaque and a dissected false lumen from the true vessel lumen, as well as prevention of vessel recoil and rupture with preservation of the parent artery. We treated ten patients with nonhemorrhagic VBA dissection thought to be at risk of impending ischemic stroke using placement of a stent or a stent-within-a-stent.

Materials and methods

Patient selection

During the period between March 2001 and May 2005, 50 consecutive patients were diagnosed with a VBA dissection based on clinical and imaging findings. Among them, 40 patients were excluded including those with a hemorrhagic presentation and those with a nonhemorrhagic presentation treated with other modalities such as conservative treatment, surgery or endovascular occlusion. Finally, 11 patients with VBA dissection of whom 10 presented with ischemic symptoms without SAH were treated using angioplasty and intraluminal stent placement. Informed consent was obtained from patients or their relatives. Patients with VBA dissection were considered eligible for stent placement only if they had failed optimal medical therapy, were unable to undergo anticoagulation, or if they had no other therapeutic option with an acceptably low risk. The specific indications included the presence of transient ischemic attacks despite anticoagulant or antiplatelet therapy. The angiographic indications for stenting in nonhemorrhagic VBA dissection was as follows: (1) the angiogram showed irregular aneurysmal dilatation prone to rupture, and (2) the lesion involved the posterior inferior cerebellar artery (PICA) and the parent artery required preservation due to its dominance.

Clinical and imaging data

We evaluated the clinical data, radiological findings, and clinical and imaging outcomes of ten consecutive patients. There were eight males and two female patients, ranging in age from 32 to 45 years (mean age 40.1 years). The dissection was caused by trauma in one patient; in the remaining patients, there were no obvious causes identified. Seven patients presented with ischemic symptoms including lateral medullary syndrome and three with headache. Among nine vertebral artery (VA) dissection lesions, seven lesions involved the PICA. All lesions involved dominant VAs and one patient had bilateral lesions.

The imaging diagnosis was performed using a 16-channel multislice CT, MR images and conventional rotational angiographic findings. Nine lesions were located at the VA and two at the basilar artery. Angiographic findings revealed the pearl and string sign in five lesions, the string sign with aneurysmal dilatations in three lesions, a double lumen in two lesions and fusiform aneurysmal dilatation in one lesion.

Endovascular procedure

All patients underwent complete digital subtraction angiography of both anterior and posterior cerebral circulations. Stenting procedures were performed under local anesthesia. All patients underwent thorough cerebral angiography with an emphasis on defining the following lesional and anatomical characteristics: vessel reference diameter, lesion length, eccentricity, and the presence of perforating vessels or branches within the lesion or adjacent vessel segments. A 6F guiding catheter (Envoy; Cordis Endovascular, Miami Lakes, Fl.) was advanced into the affected VA or the dominant VA in cases of basilar dissection via the transfemoral approach. After positioning of the guiding catheter, the patients received 5,000–10,000 IU heparin intravenously to attain an activated clotting time (ACT) of more than 200 s. A microcatheter (Prowler 14; Cordis Endovascular) was directed into the lesion using a 0.014-inch guidewire (Transcend, Boston Scientific, Fremont, Calif.). The true lumen was cannulated and a microcatheter was positioned into the distal posterior cerebral artery. A 300-cm exchange microguidewire (Choice PT Extrasupport, Boston Scientific) was introduced through the microcatheter into the distal posterior cerebral artery. A variety of sizes of (normally undersized) balloon-expandable coronary stents were used. ArthosPico stents, (AMG International, Germany) were used in 10 of 11 lesions and S670 (AVE, Medtronic, Minneapolis, Minn.) was used in one procedure. The stents were advanced and deployed at the lesion and inflated to optimal or suboptimal balloon pressure. After deployment, the balloon was withdrawn. Control angiography was performed immediately and 30 min after the procedure. If the patient was neurologically and hemodynamically stable, the arterial sheath was removed and the puncture site treated with a suture-mediated closure system (The Closer S; Perclose, Redwood City, Calif.).

Postprocedural management and follow-up

Patients were sent to the neurological intensive care unit for observation and intensive monitoring to prevent high blood pressure. Heparin was continued for 24 h after the

procedure, and aspirin and clopidogrel were subsequently started. Aspirin 100 mg once daily was continued as permanent medication. Additionally, 75 mg clopidogrel was given once daily for 12 months. All patients had a neurological examination before and 24 h after the procedure. All of the patients were followed at outpatient clinics and were asked to return for follow-up angiography between 6 months and 1 year after treatment.

Results

Successful stent placement was achieved in all patients. Patient age, sex, presenting symptoms, dissection site, side affected, and length of follow-up are summarized in Table 1. A double stent (stent-within-a-stent) and multiple stents were placed in seven lesions and a single stent in four lesions. Multiple stents and a stent-within-a-stent were intentionally used in patients with a longer lesion and/or accelerated aneurysmal thrombosis. Among the 10 patients with 11 lesions in which stent placement was attempted, the overall technical success rate, for reaching the target lesion and obtaining good preservation and/or restoration of the blood flow of parent arteries, was 100%. In one patient (patient 1), acute occlusion of the VA was noted; it was reopened with an intravenous infusion of 10 mg abciximab (ReoPro; Eli Lilly/Centocor, Vernier, Switzerland). All of eight patients with aneurysmal dilatation (pseudolumen) showed decreased contrast filling to the aneurysm. However, various degrees of contrast filling were still observed in the angiogram that immediately followed the procedure.

Angiographic follow-up was performed in six patients, and CT angiographic follow-up in two patients (at 1 week to 17 months). VA occlusion was noted in one patient (patient 1). No aneurysm filling was noted in five patients (six lesions); decreased but notable contrast filling to the aneurysm sac through the stent was noted in one patient (patient 3), and increased aneurysm sac filling in one patient (patient 8). Among the seven lesions with PICA involvement, PICA flow was preserved in all five of those with follow-up. In patient 1, the VA was occluded at 1 week on the follow-up angiogram; however, the patient remained asymptomatic during follow-up. There were no instances of postprocedural ischemic attacks, new neurological deficits, or new minor or major strokes prior to patient discharge or during the follow-up period.

Case illustrations

Patient 4

A 43-year-old man presented with left lateral medullary infarction (Fig 1a). Digital subtraction angiography showed a right VA dissection with proximal aneurysmal dilatation (Fig 1b–d). The dissecting segment involved the origin of the right PICA. Because the angiogram showed very irregularly shaped aneurysmal dilatation, and the dissecting segment involved a PICA origin, angioplasty with stenting was selected to maintain VA and PICA flow and induce aneurysm thrombosis. According to the protocol for intracranial stent placement in our hospital, the patient received clopidogrel (75 mg twice daily) and aspirin (325 mg twice daily) orally beginning 2 days before the procedure. The procedure was performed with the patient under local anesthesia. A 3×18 mm ArthosPico (AMG International, Germany) stent was initially deployed to cover the dissected segment. Additionally, an overlapping 3×18 mm ArthosPico stent was carefully positioned to traverse the first stent and was then deployed. After deployment, the VA and PICA flow were preserved and restored. The size of the aneurysm was unchanged, but the late-phase images revealed some stagnation of contrast material (Fig 1e,f). Neither technical complications nor neurological sequelae were observed. Arteriography was performed 17 months after stent placement; it revealed no aneurysm filling with full restoration of the VA with good PICA flow (Fig 1g,h). The patient remained stable during the follow-up and there was no recurrent ischemic attack.

Patient 8

A 36-year-old previously healthy man without any medical history was admitted because of aggravating posterior headache for 6 days. He was normal on neurological examination. A nonenhanced CT scan showed no evidence of SAH. A 16-channel multislice CT and MR angiography disclosed bilateral VA dissection, resulting in aneurysmal dilatation. Diagnostic cerebral angiography was performed the following day, and the bilateral VA angiogram confirmed fusiform dilatation with an intimal flap at the left VA and vessel irregularity at the right VA (Fig 2a–d). Endovascular treatment with stent placement was planned; the potential risk of stent placement for VA was explained to the patient and informed consent was obtained.

Under local anesthesia, 3×24 and 3×18 mm ArthosPico stents were overlapped at the left VA and a 3×24 mm ArthosPico stent was deployed at the right VA. Both VA and PICA flow were well preserved and minimal contrast filling was noted at the left VA aneurysm (Fig. 2e,f). The patient was stable without any neurological deficit. A follow-up angiogram was performed at 12 months after stent placement. The left VA arteriogram showed consistent aneurysm filling with good VA and PICA flow. A right VA arteriogram showed increased aneurysm flow through the stent (Fig 2g,h). The patient remained stable and was discharged with a scheduled follow-up angiogram in 1 year.

Table 1 Summary of patients with nonhemorrhagic vertebrobasilar dissection

No.	Sex	Age (years)	Angiographic finding	Symptom	Location	Treatment	Stent		Initial angiographic result	Complications	Follow-up
							Type[a]	Size (mm)			
1	M	39	Pearl and string sign (PICA proximal)	TIA	Right vertebral artery	Stent only	S670	3×25	Partial preservation of parent artery. Aneurysm filling decreased	In-stent thrombus – recanalized	Angiography 1 week. Occlusion of right VA
2	F	38	Double lumen	Headache	Basilar artery	Stent only	Arthos	3×14	Preservation of parent artery	No	CT angiography 10 months. Very good patency
3	F	39	Fusiform aneurysmal dilatation (PICA involve)	Headache	Left vertebral artery, right vertebral artery (not treated)	Stent-in-stent	Arthos	3.5×14, 3.5×10	Preservation of parent artery. Aneurysm filling decreased	No	Angiography 3 months, 16 months. Very good patency; aneurysm filling decreased
4	M	43	Pearl and string sign (PICA involve)	Stroke	Right vertebral artery	Stent-in-stent	Arthos	3×18, 3×18	Preservation of parent artery. Aneurysm filling decreased	No	Angiography 17 months, Very good patency; no aneurysm filling
5	M	42	Double lumen	Stroke	Basilar artery	Stent only	Arthos	3×18	Preservation of parent artery	No	Angiography 4 months. Very good patency
6	M	45	Pearl and string sign (PICA involve)	Stroke	Right vertebral artery	Stent-in-stent	Arthos	3×24, 3×18	Preservation of parent artery. Aneurysm filling decreased	No	Angiography 2 months. Very good patency; aneurysm filling decreased. CT angiography 10 months. very good patency; no aneurysm filling
7	M	40	Pearl and string sign (PICA involve)	TIA	Right vertebral artery	Tandem stent	Arthos	3×24, 3×18	Preservation of parent artery. Aneurysm filling decreased	No	CT angiography 7 days. very good patency; no aneurysm filling
8	M	36	String sign with aneurysm dilatation (Bilateral L>R) (PICA involve)	Headache	Both vertebral artery	Stent-in-stent (left), stent only (right)	Arthos	3×24, 3×18 (left), 3×24 (right)	Preservation of parent artery. Aneurysm filling decreased	No	Angiography 12 months. very good patency; aneurysm filling increased
9	M	43	String sign with aneurysm dilatation (PICA involve)	Stroke	Left vertebral artery	Stent only	Arthos	3×18	Preservation of parent artery. Aneurysm filling decreased	No	
10	M	36	Pearl and string sign (PICA involve)	Stroke	Right vertebral artery	Stent-in-stent, tandem stent	Arthos	3.5×24, 3.5×18	Preservation of parent artery. Aneurysm filling decreased	No	

[a] *S670* S670 stent (AVE, Medtronic, Minneapolis, Minn.); *Arthos* ArthosPico stents (AMG International, Germany)

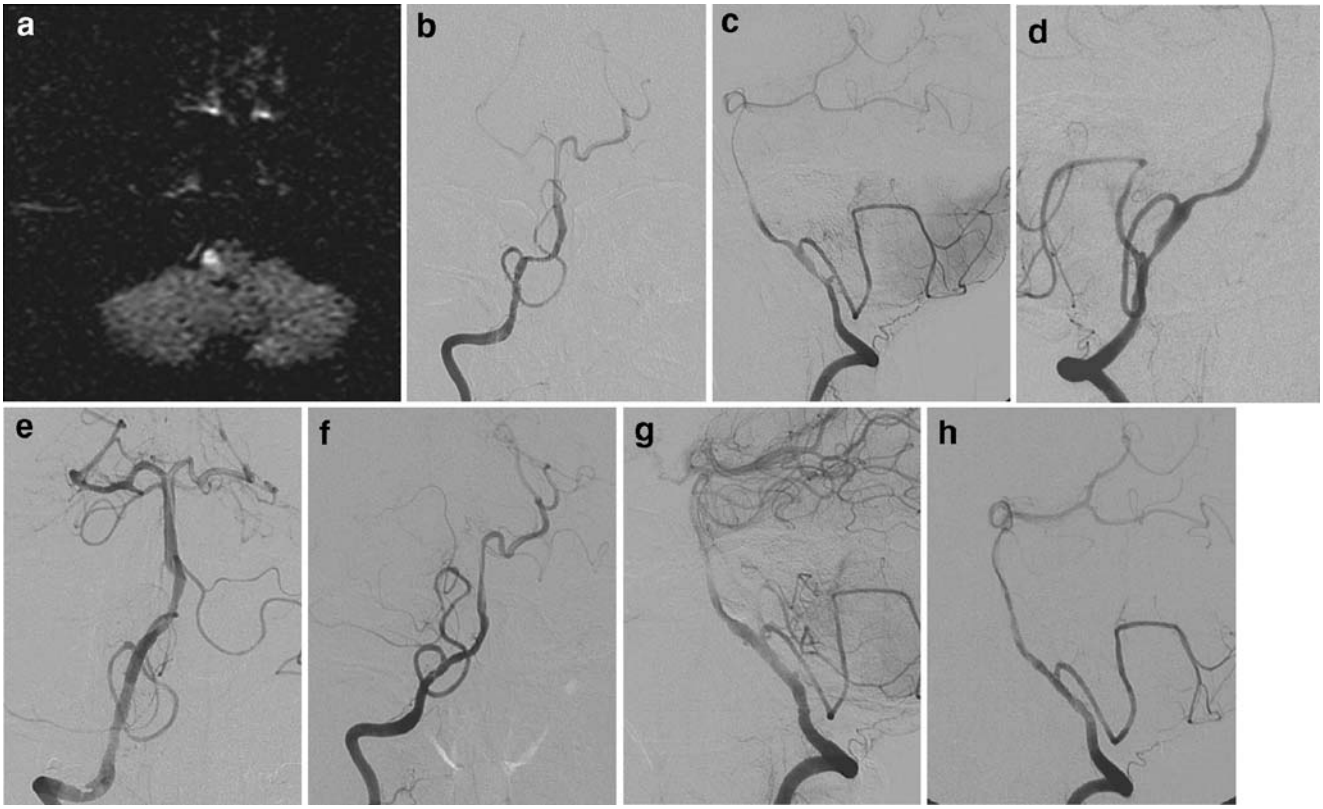

Fig. 1 Patient 4. **a** Diffuse weighted MRI image obtained on admission shows a high signal intensity lesion on the right medulla corresponding to a lateral medullary infarction . **b**–**d** Initial angiograms reveal concentric luminal narrowing with intramural hematoma of the right VA with PICA involvement. **e**, **f** Follow-up angiograms acquired immediately after insertion of a tandem intracranial stent (3×18 mm) demonstrate augmentation of the stenotic lumen. **g**, **h** Follow-up angiograms acquired 17 months after the procedure reveal good patency and maintained luminal integrity

Discussion

In patients with arterial dissection with a stenoocclusive pattern, subintimal hematoma and intimal flap may cause luminal narrowing and flow restriction [11–13]. Some dissections may heal spontaneously with reconstitution of the vessel lumen; others can cause ischemic symptoms or stroke as a result of stenosis or occlusion of the parent vessel, or by perforating or circumflex vessels such as the PICA.

Kitanaka et al. [14] reported six consecutive patients with intracranial VA dissection presenting with brain-stem ischemia without SAH who were treated nonsurgically with blood pressure control and bed rest; five patients received follow-up review with serial angiography. No further progression of dissection or associated SAH occurred in any of the patients, and all patients returned to their previous life style. In the serial angiograms of five patients, the findings continued to change during the first few months after onset. Four patients ultimately showed "angiographic cure," while fusiform aneurysmal dilatation of the affected vessel persisted in one patient. In one patient, arterial dissection was visualized on the second angiogram despite negative initial angiographic findings. Nakagawa et al. [4] also reported a good result with conservative treatment in 17 patients with unruptured VA dissection.

Some patients who present with non-SAH have been reported to suffer progression of the dissection and die as a result of a SAH [15, 16]. Naito et al. [3] reported that the risk of bleeding from an unruptured VA dissection is higher than previously thought. Therefore, they suggest that endovascular treatment should be considered for patients with VA dissections with relatively large or growing aneurysmal dilatation. Iihara et al. [17] reported seven patients with nonhemorrhagic VA dissection who had progressive enlargement of aneurysmal dilatation at short-term angiographic follow-up and recurrent ischemic symptoms. They recommended follow-up angiography for VA dissections in those with nonhemorrhagic dissection during the early stage (<3 weeks) after presentation and, if subsequent formation of aneurysms is documented, therapeutic intervention is necessary to prevent rebleeding.

Surgical and endovascular treatment should be reserved for patients who have dangerous lesions liable to rupture, or persistent symptoms of ischemia despite adequate anticoagulation. Therefore, the management of vertebrobasilar

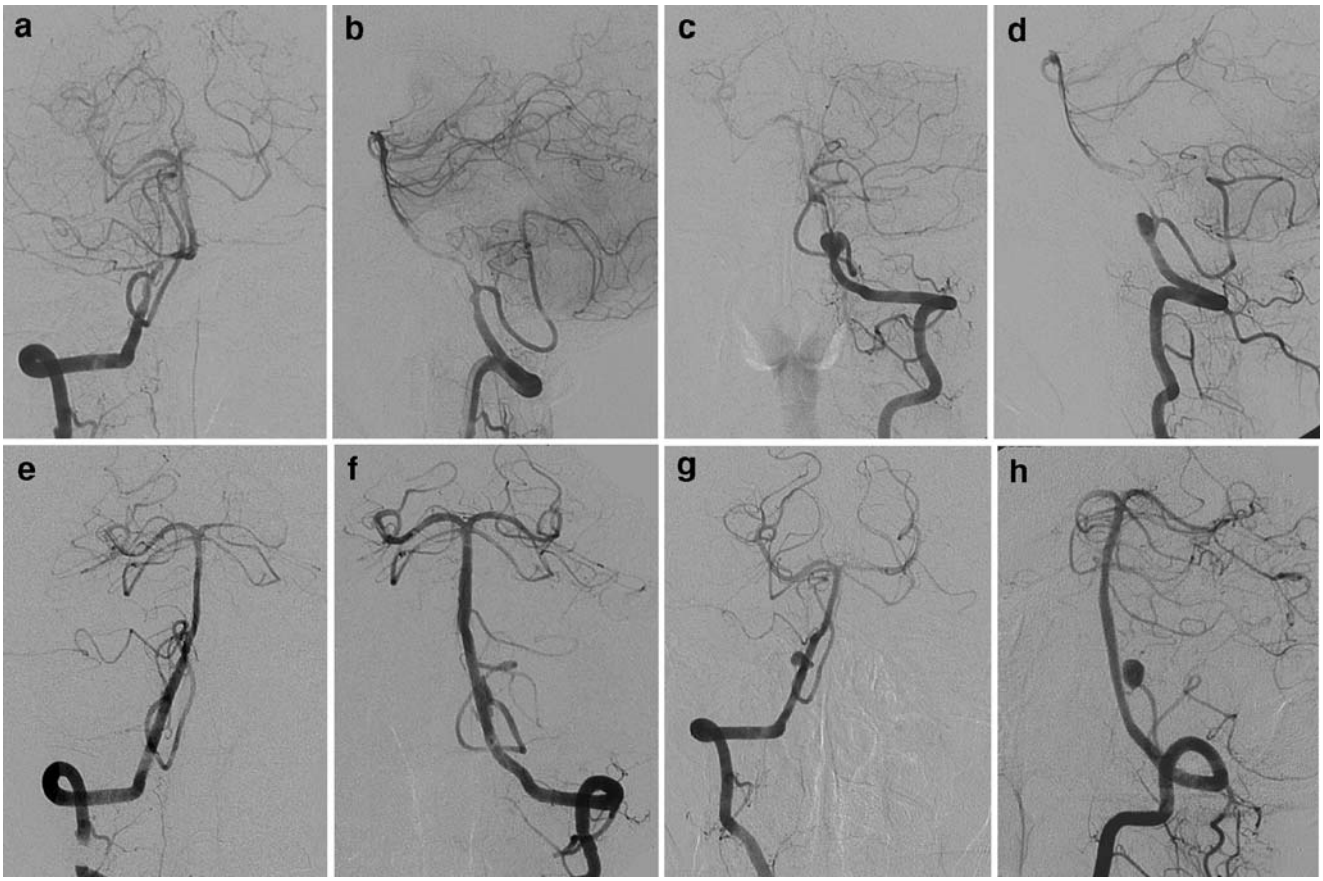

Fig. 2 Patient 8. **a–d** Initial angiograms show bilateral intracranial VA dissection with irregular luminal narrowing, proximal to distal, of the PICA on the right VA (**a**, **b**) and aneurysmal dilatation at the origin of the PICA with severe distal stenosis on the left VA (**c**, **d**). **e**, **f** Angiograms acquired after deployment of bilateral stents demonstrate restoration of luminal integrity in both VAs with a remaining minimal bulbous configuration at the origin of the PICA on the left VA. **g**, **h** Follow-up angiograms acquired after 1 year reveal aneurysmal dilatation at the site of the PICA origin on both VA

dissection must be carefully tailored to the needs of the individual patient giving consideration to the manner of presentation and angiographic findings.

For arterial dissection with subintimal hematoma, stent placement may attach the intimal flap to the tunica media and compress the subintimal hematoma, resulting in restoration of blood flow into small perforating branches as well as a normal arterial luminal caliber. If patients present with progressive stroke despite adequate conservative treatment including anticoagulation, or have dangerous angiographic findings such as aneurysm formation a dissecting segment with PICA or vital perforating branches, primary stenting should be considered as a treatment option. However, treatment of VA dissection involving the PICA is still controversial, and indeed challenging. If trapping, by surgical or endovascular procedures, is performed for these lesions, revascularization of the PICA such as occipital artery-to-PICA anastomosis and side-to-side PICA anastomosis is required. However, these procedures are technically demanding and are associated with a substantial morbidity rate. Endovascular stent placement with preservation of the parent artery entails a lower risk than surgical treatment.

Mehta et al. [10] reported three patients with intracranial dissecting VA aneurysms treated with an endovascular stent-within-a stent technique. Since then, double stenting has been reported as a feasible treatment option for VA dissecting aneurysms without sacrificing parent arteries. Benndorf et al. [8] reported a patient with a ruptured dissecting VA aneurysm treated with double stent placement. They suggested that reduced stent porosity, caused by overlapping stents, results in significant hemodynamic change inside the aneurysmal sac which may accelerate intraaneurysmal thrombosis, helping to achieve a more rapid complete occlusion compared to placement of a single stent. We treated five patients with VA dissection with the stent-within-a-stent technique; among four patients with follow-up, there was no aneurysm filling in one, decreased aneurysm filling in two, and increased aneurysm filling, through double stents, in one (patient 8).

Stent-supported coil embolization is referred to as an endovascular reconstructive technique in contrast to the

deconstructive surgical or endovascular techniques involving parent vessel occlusion. Recently, the use of stent-supported coil embolization, with preservation of the parent vessel lumen, has been described in a small number of patients [18–20]. This technique offers the advantage of parent vessel preservation, which obviates the need to consider whether collateral blood flow is sufficient to allow parent vessel sacrifice without neurological deficit. However, the dissection involves the PICA and the stent-supported coil embolization may occlude the PICA.

Isolated spontaneous basilar artery dissection is very rare and usually fatal [21–24]. In the setting of basilar dissection either with progressive severe neurological deficit or with dissecting pseudoaneurysm and SAH, the appropriate treatment of the acute basilar dissection is very challenging and difficult but might be life-saving. Conservative management or surgical treatment has been followed by disappointing results [21, 23, 24]. As Willing et al. [9] mentioned in a previous report, endovascular intervention of any type in a basilar dissection can be extremely risky, particularly if a false lumen is incorrectly cannulated. In a vessel with critical side branches such as the basilar artery, such a procedure should be attempted with meticulous angiography for delineation of the relationship of both true and false lumens. If any doubt exists, placement in the true lumen should be confirmed by injection with a microcatheter at the site of the proposed deployment before advancing the stent delivery system. In our experience, we have treated two patients with basilar dissection with primary stenting. In spite of the many technical difficulties and potential risk, stent placement may be the only promising and effective method for treatment of acute basilar artery dissection.

Although, we have not experienced arterial rupture using balloon-mounted stents, the use of recently available self-expandable stents, such as Neuroform (Boston Scientific, Fremont, Calif.) or Wingspan (Boston Scientific) might present a lower risk of hemorrhage than balloon-expandable stent devices.

With the current information available, including the results of this study, we cannot present definitive answers to the questions of which patients are appropriate for the stenting procedures and at what point they should undergo such intervention. At this point, we have not experienced symptomatic complications and the short-term results have been excellent. Therefore, stent placement for the treatment of vertebrobasilar dissection should be tailored to individual patients with the following criteria: (1) an angiogram that shows irregular aneurysmal dilatation liable to rupture; (2) recurrent ischemic symptoms in spite of adequate medication; (3) lesions involving the PICA and parent arteries should be preserved due to dominance; and (4) unstable basilar artery dissection.

The potential benefits of endovascular stenting in patients with nonhemorrhagic vertebrobasilar dissection cannot be determined from our data. A randomized controlled trial is needed to compare endovascular stenting and its natural course with medication only to determine the clinical effects.

In conclusion, stent placement for the treatment of vertebrobasilar dissection presenting with nonhemorrhagic symptoms is technically feasible and safe. Stenting procedures including placement of multiple stents can be used in selected patients with vertebrobasilar dissection; vertebral dissection involving the PICA and/or the VA should be preserved due to its dominance or basilar artery dissection. However, long-term results of stenting after vertebrobasilar dissection are unknown, and the indications for the stenting require further study.

Conflict of interest statement We declare that we have no conflict of interest.

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