Clinical Article

Endovascular Treatment of Vertebral Artery Dissecting Aneurysms That Cause Subarachnoid Hemorrhage: Consideration of Therapeutic Approaches Relevant to the Angioarchitecture

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Objective: Intracranial ruptured vertebral artery dissecting aneurysms (VADAns) are associated with high morbidity and mortality when left untreated due to the high likelihood of rebleeding. The present study aimed to establish an endovascular therapeutic strategy that focuses specifically on the angioarchitecture of ruptured VADAns.

Methods: Twenty-three patients with ruptured VADAn received endovascular treatment (EVT) over 7 years. The patient group included 14 women (60.9%) and 9 men (39.1%) between the ages of 39 and 72 years (mean age 54.2 years). Clinical data and radiologic findings were retrospectively analyzed.

Results: Four patients had aneurysms on the dominant vertebral artery. Fourteen (61%) aneurysms were located distal to the posterior inferior cerebellar artery (PICA). Six (26%) patients had an extracranial origin of the PICA on the ruptured VA, and 2 patients (9%) had bilateral VADAns. Eighteen patients (78%) were treated with internal coil trapping. Two patients (9%) required an adjunctive bypass procedure. Seven patients (30%) required stent-supported endovascular procedures. Two patients experienced intra-procedural rupture during EVT, one of which was associated with a focal medullary infarction. Two patients (9%) exhibited recanalization of the VADAn during follow-up, which required additional coiling. No recurrent hemorrhage was observed during the follow-up period.

Conclusion: EVT of ruptured VADAns based on angioarchitecture is a feasible and effective armamentarium to prevent fatal hemorrhage recurrence with an acceptable low risk of procedural complications. Clinical outcomes depend mainly on the pre-procedural clinical state of the patient. Radiologic follow-up is necessary to prevent hemorrhage recurrence after EVT.

Key Words: Vertebral artery dissecting aneurysm · Subarachnoid hemorrhage · Endovascular treatment.

INTRODUCTION

Intracranial vertebral artery dissecting aneurysms (VADAns) are rare, with an incidence of 0.001% to 0.0015% in the general population. VADAns account for approximately 3% of all spontaneous subarachnoid hemorrhages (SAH). Ruptured VADAns are associated with dismal clinical outcomes with rebleeding rates as high as 71.4% and mortality rates of 46.7% following rebleeding. Patients are especially likely to present with rebleeding in the first 24 hours, and there is a high risk of rebleeding within the first week after the initial ictus if patients remain untreated. Therefore, the early treatment of VADAns with concurrent SAH is imperative to the improvement of clinical outcomes.

Conventional surgical treatments for VADAns include proximal occlusion of the ipsilateral vertebral artery (VA) and trapping the affected VA segment with or without bypass surgery. Although proximal occlusion of the VA has lower postoperative complications and is a simpler surgical procedure, some reports state that regrowth or rebleeding of the VADAn can occur even after the surgical procedure due to the maintenance of blood flow from the contralateral VA. Trapping of the affected segment has been accepted as an appropriate management strategy to prevent rebleeding. However, ischemic complications and lower cranial nerve palsy may occur following the blockade of VA blood flow and the perforating arteries that arise from the
of complications, they still have ischemic risks comparable to sur-

Although these treatments are effective and safe with a low risk

ent study aimed to establish an endovascular therapeutic strate-

involvement, bilateral presentation, and V A dominance. The pres-

However, there is still an insufficient understanding of EVT for

treatment of V ADAns, especially those with accompanying PICA

ed coil embolization and stent-only techniques with advanced in-

ed endovascular procedures. One patient with a PICA-involved

results, including both

surgical measures. Nevertheless, recent attempts to use stent-assist-
ed coiled embolization and stent-only techniques with advanced in-

graphic findings, was recorded as fusiform dilatation in 5 pa-

graphic findings of the arterial and venous anatomy. When the quality of the

image was poor, a diagnostic DSA was performed again under
general anesthesia prior to EVT. Electrolytically detachable coils
(Target® detachable coil, Boston Scientific, Fremont, CA, USA)
were used for arterial occlusion. Stents (Neuroform, Boston Sci-

tific, Fremont, CA, USA and Enterprise, Cordis Endovascu-

lar, Miami Lakes, FL, USA) were deployed when trapping of the

VA would be expected to create an ischemic incident or when
flow preservation of a neighboring PICA on the dissecting VA
was necessary. Once the dissecting segment was secured, either
with the deconstructive or reconstructive EVT, management for
the SAH followed standard of care. Heparinization was discon-
tinued immediately after EVT and anti-platelet agents were orally
administered for 6 months after EVT when stents were used.

RESULTS

The clinical and radiological data from our 23 patients are
summarized in Table 1, 2. Ten patients (45%) had poor clinical
grades (HHG IV or V) and 16 patients (70%) had intraventricu-
or intraparenchymal hemorrhages (FG IV). Four patients
had ruptured aneurysms on the dominant side of the VA, where-
as 2 patients had ruptured aneurysms on the non-dominant VA.
The other 17 patients had even balanced VAs on DSA. Two pa-
tients had VADAnS that extended up to the vertebrobasilar junc-
tion (VBJ). Fourteen aneurysms were located in a supra-PICA
area, 1 in an infra-PICA area, 5 in a PICA-involved segment,
and 3 in an irrelevant PICA area. Nine VADAnS were on the
right and 14 were on the left. Two female patients had bilateral
VADAnS. The diagnosis of dissection, based on classical angiog-
graphic findings, was recorded as fusiform dilatation in 5 pa-
tients, “pearl and string” sign in 14 patients, and irregular luminal
stenosis in 4 patients. There were 6 patients with extracranial or-
iginS of the PICA (ECOPICA) lesions, and 1 patient exhibited a
double origin of the PICA lesion.

Eighteen patients (78%) were treated with an internal trapping
(partial or total) procedure using detachable coils, including 12
of 14 patients with supra-PICA lesions, 1 patient with an infra-
PICA lesion, 1 of 3 patients with non-PICA lesions, and 4 or 5
patients with PICA-involved lesions. Two patients with PICA-
involved lesions had partial internal trapping of the ruptured VA
segment with PICA preservation, and were treated with surgical
trapping for the remaining dissected segment after occipital ar-
tery (OA)-PICA bypass surgery the following day. Two of the 5
patients with PICA-involved lesions were treated using a stent
procedure, which included consecutive stent-assisted coiling and
stent-assisted trapping. Seven patients (30%) had stent-support-
ed endovascular procedures. One patient with a PICA-involved
lesion had internal trapping of the ruptured segment of the VA

MATERIALS AND METHODS

From June 2006 to December 2013, 725 patients with spon-
taneously ruptured intracranial aneurysms were surgically or
endovascularly treated at our institution. Of these patients, 23
had ruptured VADAnS and enrolled in our study. SAH was con-

cfirmed by computed tomography (CT) scans, and contrast-en-

hanced three-dimensional CT angiography (3D-CTA) was per-

formed to assess cerebral vasculature anomalies. This retrospec-
tive analysis included 9 men and 14 women whose age ranged from
39 to 72 years (mean 54.2 years). Two female patients had bilat-
eral VADAnS, one of which eventually resulted in an SAH and
the other of which required a staged subsequent EVT due to the
fear of a future rupture resulting from hemodynamic augmenta-
tion after occlusion of the ruptured VA. All patients were treat-
ed within the first day of hemorrhage. Presenting symptoms in-
cluded headache and vomiting, decreased consciousness, and
cranial nerve palsy. Two patients experienced cardiopulmonary
arrest after their clinical deterioration. The clinical status of the
patients at admission was recorded according to the Hunt-Hess
grading (HHG) system, and the Fisher grading (FG) system was
used to evaluate the amount of blood on CT. All patients under-
went 4- vessel digital subtraction angiography (DSA). The diag-
nosis of dissection was based on classical angiographic findings,
such as fusiform dilatation, the “pearl and string” sign, subinti-
mal flap, and irregular luminal stenosis.

We adopted EVT as the first-line treatment. The procedure
performed depended on patient status, location of the dissec-
tion, composition of the related vessels, and collateral circulation.
EVT was performed on the day of admission immediately after
the diagnostic DSA. EVT was performed under general anesthe-
sia in all patients except for one who required instantaneous
sacrifice of the affected VA due to a worsening clinical status. The
collateral circulation was evaluated based on an elaborate analy-
sis of the arterial and venous anatomy. When the quality of the
image was poor, a diagnostic DSA was performed again under
general anesthesia prior to EVT. Electrolytically detachable coils
(Target® detachable coil, Boston Scientific, Fremont, CA, USA)
under local anesthesia due to a poor clinical condition, therefore, the PICA origin could not be determined.

Three of the 4 patients with ruptured dissecting aneurysms on the dominant VA had stent-assisted coiling procedures to preserve the VA flow. One patient had ipsilateral VA trapping after an OA-PICA bypass to preserve the PICA flow because the contralateral VA was not severely hypoplastic. Ventricular or lumbar cerebrospinal fluid drainage occurred in 17 patients (74%) with acute hydrocephalus or thick intraventricular hematoma, and 2 patients (9%) required a permanent ventriculoperitoneal shunt for delayed communicating hydrocephalus.

Clinical outcomes were favorable for 15 of 23 patients (65%); 13 patients (17%) had good recovery, and 2 patients (4%) had moderate disability. Outcomes were unfavorable for 8 patients (35%); 4 patients (17%) had severe disability, 1 patient (4%) entered a persistent vegetative state, and 3 patients (13%) died. All 3 patient deaths could be attributed to the severity of the initial clinical status (Hunt-Hess IV). The complete occlusion of the dissected arterial and aneurysm segment was achieved in 21 of 23 patients (91%). Two patients (1 with stent-assisted coiling and 1 with internal trapping) had near-complete occlusions on angiography, and one required additional endovascular coiling during the follow-up period.

There were 5 complications in our study: 2 patients developed rebleeding at the end of the coiling procedure, 1 patient developed symptomatic medullary infarction, and 2 patients experienced recanalization of the VADAn after the first EVT. Rebleeding during the endovascular procedure was managed with an additional compact coil insertion or rescue stent placement and reversal of the anticoagulant.

Illustrative cases

Case 1
A 52-year-old woman presented with decreased consciousness after a sudden headache and vomiting. A brain CT indicated a dense SAH and 3D-CTA revealed dilatation and narrowing of the left VA, indicating a possible dissection. An emergency
cerebral DSA was conducted, and a vertebral angiogram (VAG) indicated that the left VA dissection produced multiple dilata-
tions and stenosis (Fig. 1A, B). Both VAs had similar diameters. The proximal VA-DAn included the origin of the PICA (Fig. 1C) and the distal VA-DAn was hypothesized as the source of the SAH. Under general anesthesia, the ruptured distal VA-DAn was internally trapped (Fig. 1D, E); the proximal part of the VA-DAn was then surgically trapped after OA-PICA bypass surgery the next day (Fig. 1F, G). A postoperative angiogram demonstrated a completely occluded VA-DAn and well-preserved PICA flow (Fig. 1H). The patient recovered well with no neurologic deficits after 2 procedures.

Case 2
A 43-year-old woman had a sudden headache and vomiting. A brain CT indicated a dense SAH, and 3D-CTA revealed a dil-
atation and narrowing of the right VA, indicating a possible dis-
section. The diameters of both VAs were similar. The proximal VA-DAn included the origin of the PICA, and the central VA-DAn was hypothesized as the source of the SAH (Fig. 2A, B). Under general anesthesia, the ruptured distal VA-DAn was internally trapped (Fig. 1D, E); the proximal part of the VA-DAn was then surgically trapped after OA-PICA bypass surgery (Fig. 2C). After the stent insertion, tighter coil packing of the ruptured portion of the VA-DAn occurred. A postoperative VAG demonstrated a completely occluded VA-DAn and well-preserved PICA flow through the stent, and the patient recovered well with no neurologic deficits (Fig. 2D). After 7 months, the VA-DAn recanalized. The recanalized VA-DAn was treated with additional coil via the contralateral VA (Fig. 2E). The final angiogram revealed a complete occlusion of the VA-DAn and patent PICA flow (Fig. 2F).

Case 3
A 44-year-old woman presented with a sudden onset of head-
ache, vomiting, and disturbance of consciousness. A brain CT revealed an SAH, and a 3D-CTA revealed bilateral VA-DAn (Fig. 3A). The VAG demonstrated that both aneurysms were located distal to the PICA (Fig. 3B), and the left VA-DAn had a bleb-like lesion, which was considered to be the source of the SAH (Fig. 3C). The ruptured left VA-DAn was internally completely trapped with detachable coils (Fig. 3D, E) immediately. Staged intervention was performed 1 week later. In order to preserve the flow, the right VA-DAn was treated using an endo-
vascular stent-within-a-stent construct with 2 self-expandable intracranial stents. Although the control angiography revealed that the stents failed to completely exclude the aneurysm, definite stagnation of the contrast inside the aneurysm was achieved (Fig. 3F, G). The patient’s postoperative course was uneventful, and she was discharged in excellent neurological condition.

Table 2. Outcomes and complications of ruptured vertebral artery dissecting aneurysms by treatment method

| Case | Treatment modalities                        | Angiographic outcomes* | Clinical outcomes | Complications               |
|------|--------------------------------------------|------------------------|------------------|-----------------------------|
| 1    | Partial trapping, surgical trapping after OA-PICA bypass | Complete                | GR               |                             |
| 2    | Trapping                                   | Complete                | SD               |                             |
| 3    | Trapping                                   | Complete                | GR               |                             |
| 4    | Trapping                                   | Complete                | GR               |                             |
| 5    | Partial trapping, surgical trapping after OA-PICA bypass | Complete                | GR               |                             |
| 6    | Stent assisted coiling                      | Near complete           | GR               | Recanalization              |
| 7    | Stent assisted coiling f/b rescue stent     | Complete                | Death            | Aneurysm rupture            |
| 8    | Trapping                                   | Complete                | PVS              |                             |
| 9    | Trapping                                   | Complete                | MD               | Focal medullary infarction  |
| 10   | Trapping                                   | Complete                | GR               |                             |
| 11   | Stent (contralateral) assisted trapping     | Complete                | GR               |                             |
| 12   | Trapping                                   | Complete                | SD               |                             |
| 13   | Trapping                                   | Complete                | GR               |                             |
| 14   | Trapping                                   | Complete                | SD               |                             |
| 15   | Trapping                                   | Complete                | GR               |                             |
| 16   | Stent assisted coiling f/b double stent     | Complete                | GR               |                             |
| 17   | Stent assisted coiling                      | Complete                | GR               |                             |
| 18   | Trapping                                   | Complete                | Death            |                             |
| 19   | Trapping                                   | Complete                | GR               | Aneurysm rupture            |
| 20   | Trapping                                   | Complete                | Death            |                             |
| 21   | Trapping                                   | Complete                | MD               |                             |
| 22   | Stent assisted coiling                      | Complete                | SD               |                             |
| 23   | Stent assisted trapping                     | Complete                | GR               | Recanalization              |

*pDegree of occlusion in angiographic findings, †Recanalization during follow-up required additional endovascular treatment. OA: occipital artery, PICA: posterior inferior cerebellar artery, GR: good recovery, MD: moderate disability, SD: severe disability, PVS: persistent vegetative state
cept for mild diplopia. A 6-month follow-up VAG demonstrated that the left VA remained occluded. The right VA was remodeled and reconstituted, and the blood flow was preserved normally (Fig. 3H).

DISCUSSION

The undefined neck and fragile aneurysm wall of VADAns create an innate pathologic nature, including technical difficulties and risks of rupture when applying a microsurgical neck clip or performing endovascular coil embolization. To prevent the ruptured VADAn from rebleeding, surgical or endovascular proximal occlusion and external or internal trapping are safe and effective management strategies. However, these destructive techniques increase the risk of ischemic complications resulting from occlusion of the VA, PICA, and perforating arteries, which have a significant impact on the clinical outcome. Revascularization and reconstructive treatments, including bypass surgery, stent-assisted coiling, and multiple stenting are necessary to prevent and minimize ischemic complications. To achieve the best treatment results, which include complete obliteration and preserved blood flow patency, precise treatment planning should occur following careful inspection of angiographic architecture in each individual case. We considered the angioarchitecture of VADAns in relation to the PICA location, VA dominancy, and bilateral lesions, as described in Fig. 4.

We designed the treatment strategy to preserve PICA flow patency if needed, because the PICA is the major artery supplying the posterior inferior cerebellar hemisphere, inferior portion of the vermis, and lower medulla. The VADAns were divided into 3 categories, according to the location of the VADAn from the origin of the PICA: supra-PICA, infra-PICA, and PICA-involved. Twelve of the 14 patients who had supra-PICA lesions with sufficient contralateral VA flow were treated with internal trapping, and the affected segments were successfully occluded. Anatomically, many perforators originate from the distal VA to the VBJ. Therefore, longer sections of internal trapping in the distal VA segment were more prone to the fatal occlusion of perforators that supply the medulla oblongata. However, we attempted to occlude the affected ruptured VADAn segments over as long a section as possible. Due to the underlying nature of dissection, we hypothesized that the actual dissected vessel wall may be longer than the angiographic feature, and that the complete occlusion of the dissected site could therefore prevent rebleeding. Fortunately, there was no medullary infarction or any ischemia resulting from the occlusion of the perforating arteries when trapping occurred in cases of supra-PICA lesions. Of the 12 cases where internal trapping was used, 1 case involved stent-assisted trapping. In this case, the dissected section was just distal to the PICA, so we decided to deploy the stent from the VA to the PICA in order to preserve PICA flow. Several authors have reported the efficacy and safety of VA-PICA stenting with no stent occlusion, and midterm follow-up angiography revealed that PICA flow was patent without stenosis or occlusion.

Fig. 1. Radiological findings of internal trapping and bypass surgery of a ruptured left vertebral artery dissecting aneurysm (VADAn). A and B: Two dilatations and a stenosis (arrowheads) of the left vertebral artery (VA) are revealed on the right vertebral angiogram (VAG) frontal view (A) and the left VAG lateral view (B). These radiological findings reveal a VADAn with proximal and distal parts. C: A three-dimensional rotational angiogram shows the proximal part of the VADAn, including the origin of the posterior inferior cerebellar artery (PICA, arrow). Because of its irregular and lobulated features, the distal part of the VADAn is considered to be ruptured. D and E: The ruptured distal VADAn is successfully internally trapped with detachable coils (asterisks). F and G: Performing the surgical interventions of trapping with clip ligations to prevent rupture of the proximal part of the VADAn and occipital artery (OA)-PICA anastomosis to preserve PICA flow. H: The left external carotid angiogram shows well-preserved blood flow of PICA supplied from the OA-PICA anastomosis.
There was only 1 infra-PICA VADAn case that was treated with internal trapping in this study. Similar to our results, other studies have found that infra-PICA lesions are relatively rare compared to supra-PICA lesions, and internal trapping has provided reliable management in cases with sufficient blood flow from the contralateral VA.

The treatment of PICA-involved VADAn remains difficult and controversial. Some authors argue that PICA occlusion does not result in severe disability, due to sufficient collaterals; however, the ideal treatment for a PICA-involved aneurysm is trapping and PICA reconstruction. Therefore, endovascular segmental occlusion using coils, followed by PICA-to-PICA side anastomosis or OA-PICA revascularization, has been performed in many cases. In our study, 2 patients had partial trapping using coils to reduce the rebleeding risk immediately after diagnostic angiography, which was followed by surgical trapping after the OA-PICA bypass.

We applied the stent-assisted technique, according to our extensive experience, to PICA-involved VADAn. Two stent-assisted coiling procedures and 1 stent-assisted trapping procedure were performed. The clinical outcomes were favorable for these patients, and postoperative angiography indicated complete occlusion. Stent-assisted coiling has several advantages: 1) maintaining the patency of the parent artery, and therefore preventing ischemic complications; 2) forming an aneurysmal neck, which allows coil placement; 3) altering hemodynamics and inducing thrombosis into the aneurysmal sac; and 4) attaching the intimal flap to the vessel wall and reducing the size of pseudoaneurysms.

ECOPICAs, excluding the intradural origin of PICAs, have specific anatomical characteristics. Notably, the perforating arteries supplying the lateral surface of the brainstem originate from the VA not the PICA. Consequently, there are risks of lateral medullary infarction as a result of internal trapping of the VA, even when the ECOPICA is preserved. In the present study, of the 6 VADAn with ECOPICAs, 5 were supra-PICA cases and 1 was a PICA-involved case. All lesions were treated with internal trapping. We had concerns regarding potential brainstem infarction, but these events did not occur. Although ECOPICAs were observed relatively often and had anatomical features that

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**Fig. 2.** Radiologic findings of stent-assisted trapping of the ruptured right vertebral artery dissecting aneurysm (VADAn). A: The right vertebral angiogram (VAG) displays a dilatation and narrowing of the right vertebral artery (VA) that is considered a dissection. B: The three-dimensional rotational angiogram shows the proximal part of the VADAn, including the origin of the posterior inferior cerebellar artery (PICA, arrow), and the central VADAn is regarded as the ruptured point (arrowhead). C: Performing a successful internal trapping on the VADAn just distal to the origin of the PICA with stent placement from the VA to the PICA (arrowheads indicate both ends of the stent). D: Postoperative VAG reveals a completely occluded VADAn and well-preserved PICA flow through the stent. E: Follow-up angiogram after 7 months demonstrates recanalization of the previously trapped VADAn and blood flow of the basilar artery through the VADAn. F: Treating the recanalized VADAn with additional coiling via the contralateral VA; the VADAn was successfully occluded.
should be considered when treating VADAn, we did not find evidence that these features affected treatment or prognosis. VA dominance is another important angiographic factor in treating VADAn. When the affected segment is on the dominant

Fig. 3. Radiologic findings of endovascular treatment of bilateral vertebral artery dissecting aneurysms (VADAn). A : Three-dimensional brain computed tomography angiography demonstrates bilateral VADAn (asterisks). B : The vertebral angiogram (VAG) shows the dissecting aneurysms in the intracranial portion of the bilateral VAs. C : The three-dimensional rotational angiogram demonstrates that the left VADAn has a bleb-like lesion, which is considered to be the source of the SAH (arrow). D and E : A left VAG obtained immediately after the endovascular trapping using detachable coils (asterisk) shows the complete obliteration of the ruptured VADAn distal to the PICA. F : The right VAG after the staged intervention shows 2 overlapping stents in the dissected vessel. G : After deploying 2 overlapping stents, the definite stagnation of contrast inside the aneurysm is achieved (arrow). H : The three-dimensional rotational angiogram of the right VA demonstrates remodeling of the left VADAn by 2 overlapping stents.

Fig. 4. Flow chart for treating a ruptured vertebral artery dissecting aneurysm. VA : vertebral artery, VADAn : vertebral artery dissecting aneurysm, f/b : followed by, PICA : posterior inferior cerebellar artery, AICA : anterior inferior cerebellar artery.
VA trapping and proximal occlusion can cause fatal ischemia. Therefore, the treatment strategy should be planned to preserve VA and basilar artery patency during and after treatment. Theoretically, the balloon occlusion test (BOT) provides valuable information regarding collateral flows, but BOT is not always recommended during the acute bleeding stage. We treated 3 cases with stent-assisted coiling for a total of 4 lesions of the dominant VA without BOT. All 3 VADs were successfully occluded, and the dominant VA flows were preserved.

VADs sometimes occur bilaterally. The known pathogenesis for bilateral presentation is spontaneous dissection, which involves pre-existing vessel wall defects that typically present with symmetric distribution. These characteristics predispose the arteries to an increased risk of contralateral VADAn rupture via hemodynamic changes resulting from the occlusion of ipsilateral ruptured VA segments. We performed subsequent staged EVT on contralateral unruptured aneurysms as a strategy to avoid future rupture.

Although there was no angiographic result of VADs that involved the anterior spinal artery (ASA) in this series, ASA is one of considerable anatomical factors in treating VADs. The ASA arises from near the termination of VA bilaterally in 45.5%, and the bilateral ASAs joins together at a distance to the VBJ from 1.6 mm to 7.1 mm (mean 4.8 mm). It has a number of small perforating branches that supply the anterior surface of the medulla and anterior two thirds of the upper cervical cord, and occlusion of the ASA results in infarction of medial or lateral part of medulla oblongata and spinal cord ischemia. Because of presence of anastomoses among the perforators of VA, PICA, ASA, and BA, occlusion does not always lead to ischemia of brain stem and spinal cord. However we cannot sure that the frequency and the number of their anastomoses are sufficient enough to avoid ischemia, the result of occlusion is uncertain. Therefore, in cases of VADs associated with ASA involvement, proximal occlusion or multiple stenting are preferred to consider for preventing ischemia of brain stem and spinal cord.

Several potential technique related complications of EVT have been reported, including aneurysm rupture, VA branch occlusion, hemodynamic compromise of the vertebrobasilar system resulting from vertebral artery occlusion, and recanalization of occluded vessels. In the present study, rebleeding occurred in 2 patients during EVT. MacKay et al. proposed that stent-assisted coiling of the dissection might cause a dissection rupture or lead to recanalization if the coil migrates through the dissected vessel wall. Rebleeding during the endovascular procedure was successfully managed with additional compact coil insertion or rescue stent placement combined with a reversal of the anticoagulant. There were 5 complications recorded in this study: 2 patients developed rebleeding at the end of the coiling procedure, 1 patient developed symptomatic medullary infarction, and 2 patients experienced recanalization of the VADAn after the first EVT. Taha et al. reported 8% recanalization during the perioperative period after complete internal trapping. Therefore, we propose that follow-up angiography is necessary during the perioperative period even when EVT is considered successful.

The prediction of patient outcomes following a ruptured VADAn is important because these events are associated with high morbidity and mortality. Previous studies have suggested the initial stroke severity, including National Institute of Health Stroke Scale score, and patient age as prognostic factors. In the present study, of the 10 patients with poor initial clinical grade (HHG IV or V), clinical outcomes were favorable in 3 patients (e.g., good recovery, moderate disability) and unfavorable in 7 patients (e.g., severe disability, persistent vegetative state, and death). Conversely, among the 16 patients with an initial FG IV, 8 patients (50%) experienced favorable clinical outcomes and 8 patients (50%) had unfavorable outcomes. Our findings therefore demonstrate that the initial clinical state is a good predictor of clinical outcome, and initial HHG scores are better predictors than FG scores.

This study does have some limitations. First, the size of the study population is relatively small. However, given that most of treatment options were used in this study and considering low incidence of the ruptured VADAn, this study could strengthen the use of EVT for VADAn. Second, this study was a retrospective study in which the data were acquired through a retrospective chart review. Thus, it is thought that a prospective study using a larger number of patients will be necessary to determine the safety and effectiveness of EVTs for VADAn with the concept of prompt application of treatment.

CONCLUSION

Ruptured VADs should be treated as soon as possible because of the high risk of rebleeding and mortality. EVT has been demonstrated as safe and effective for ruptured VADs because of its easy accessibility, minimal invasiveness, and rapid treatment potential after diagnostic angiography. Recent advancements in stent-assisted techniques, including stent-assisted coiling, enable both destructive (internal trapping) and reconstructive (preservation of VA and PICA patency) treatments. The careful selection of an appropriate EVT technique following the meticulous inspection of the angioarchitecture, including the location of the PICA origin, VA dominance, and bilateral lesions, is mandatory for successful treatment outcomes with low complication risks.

References

1. Aoki N, Sakai T : Rebleeding from intracranial dissecting aneurysm in the vertebral artery. Stroke 23 : 1628-1631, 1990
2. Arnold M, Bousser MG, Fahrni G, Fischer U, Georgiadis D, Gandjour J, et al. : Vertebral artery dissection : presenting findings and predictors of outcome. Stroke 37 : 2499-2503, 2006
3. Chen YA, Qu RB, Bian YS, Zhu W, Zhang KP, Pang Q : Stent placement to treat ruptured vertebral dissecting aneurysms. Interv Neuroradiol 19 : 479-482, 2013
4. Chung J, Kim BS, Lee D, Kim TH, Shin YS : Vertebral artery occlusion
with vertebral artery-to-posterior inferior cerebellar artery stenting for preservation of the PICA in treated ruptured vertebral artery dissection. Acta Neurochir (Wien) 152: 1489-1492, 2010
5. Chung SY, Yoon BH, Park MS, Kim SM: A case of endovascular treatment for followed by side to side bypass after internal coil trapping of a ruptured vertebral artery dissection. J Neurosurg 118: 131-139, 2013
6. de Bray JM, Penisson-Besnier I, Dubas F, Emile J: Extradural and intracranial vertebralbasilar dissections: diagnosis and prognosis. J Neurol Neurosurg Psychiatry 63: 46-51, 1997
7. Endo H, Matsumoto Y, Kondo R, Sato K, Fujisawa M, Inoue T, et al.: Medullary infarction as a poor prognostic factor after internal coil trapping of a ruptured vertebral artery dissection. J Neurosurg 118: 131-139, 2013
8. Hamada I, Iai Y, Morioka M, Yano S, Todaka T, Ushio Y: Multimodal treatment of ruptured dissecting aneurysms of the vertebral artery during the acute stage. J Neurosurg 99: 960-966, 2003
9. Harahisa K, Katarzyna W, Murao K, Fujisawa M, Yonezawa U.: Treatment of ruptured vertebral artery dissecting aneurysms. A short report. Interv Neuroradiol 20: 304-311, 2014
10. Hsu CY, Cheng CY, Lee JD, Lee M, Huang YC, Wu CY, et al.: Clinical features and outcomes of spinal cord infarction following vertebral artery dissection: a systematic review of the literature. Neur Res 35: 676-683, 2013
11. Iihara K, Sakai N, Murao K, Sakai H, Higashi T, Kogure S, et al.: Dissecting aneurysms of the vertebral artery: a management strategy. J Neurosurg 97: 259-267, 2002
12. Kim MJ, Chung J, Kim SL, Roh HG, Kwon BJ, Kim BS, et al.: Stenting from the vertebral artery to the posterior inferior cerebellar artery. AJNR Am J Neuroradiol 33: 348-352, 2012
13. Kitakaze K, Morimoto T, Sasaki T, Takakura K: Rebleeding from vertebral artery dissection after proximal clipping. Case report. J Neurosurg 77: 466-468, 1992
14. Koh JS, Ryu CW, Lee SH, Bang JS, Kim GK.: Bilateral vertebral-artery dissecting aneurysm causing subarachnoid hemorrhage cured by staged endovascular reconstruction after occlusion. Cerebrovasc Dis 27: 202-204, 2009
15. Luo CB, Chang CY, Teng MM, Chang FC: Endovascular treatment of ruptured vertebral artery dissecting aneurysms with electrodetachable coils. J Chin Med Assoc 68: 578-584, 2005
16. Lylyk P, Perrat R, Herzwitz D, Basso A: Treatment of a vertebral dissection with stents and coils: technical case report. Neurosurgery 43: 385-388, 1998
17. MacKay CI, Han PP, Albuquerque FC, McDougall CG: Recurrence of a vertebral artery dissecting pseudoaneurysm after successful stent-supported coil embolization: case report. Neurosurgery 53: 754-759; discussion 760-761, 2003
18. Mahmood A, Dujovny M, Torche M, Dragovic I, Ausman II: Microvascular anatomy of foramen caecum medullae oblongatae. J Neurosurg 75: 299-304, 1991
19. Marinkovic S, Milosevlici M, Gibo H, Malikovic A, Djulejic V: Microsurgical anatomy of the perforating branches of the vertebral artery. Surg Neurol 61: 190-197; discussion 197, 2004
20. Mercier PH, Brassier G, Fourrier HD, Picquet J, Papon X, Lasjaunias P: Vascular microanatomy of the pontomedullary junction, posterior inferior cerebellar arteries, and the lateral spinal arteries. Interv Neuroradiol 14: 49-58, 2008
21. Mizutani T, Aruga T, Kiritto T, Miya Y, Saito I, Tsuchida T: Recurrent subarachnoid hemorrhage from untreated ruptured vertebrobasilar dissecting aneurysms. Neurosurgery 36: 905-911; discussion 912-913, 1995
22. Ramgren B, Cronqvist M, Romner B, Brandt L, Hults S, Larsson EM: Vertebralbasilar dissection with subarachnoid hemorrhage: a retrospective study of 29 patients. Neuroradiology 47: 97-104, 2005
23. Santos-Franco JA, Zenteno M, Lee A: Dissecting aneurysms of the vertebral system. A comprehensive review on natural history and treatment options. Neurosurg Rev 31: 131-140; discussion 140, 2008
24. Schievink WI: Spontaneous dissection of the carotid and vertebral arteries. N Engl J Med 344: 898-906, 2001
25. Shin YS, Kim BM, Kim SH, Soh SH, Ryu CW, Koh JS, et al.: Endovascular treatment of bilateral intracranial vertebral artery dissecting aneurysms presenting with subarachnoid hemorrhage. Neurosurgery 70 (1 Suppl Operative): 75-81; discussion 81, 2012
26. Su W, Gou S, Ni S, Li G, Liu Y, Zhu S, et al.: Management of ruptured and unreptured intracranial vertebral artery dissecting aneurysms. J Clin Neurosci 18: 1639-1644, 2011
27. Taha MM, Sakaida H, Asakura F, Maeda M, Toma N, Yamamoto A, et al.: Endovascular management of vertebral artery dissecting aneurysms: review of 25 patients. Turk Neurosurg 20: 126-135, 2010
28. Tsukahara T, Woda H, Saitoe K, Yaota H, Takahashi A: Proximal balloon occlusion for dissecting vertebral aneurysms accompanied by subarachnoid hemorrhage. Neurosurgery 36: 914-919; discussion 919-920, 1995
29. Yamaura A, Watanabe Y, Sakai N: Dissecting aneurysms of the intracranial vertebral artery. J Neurosurg 72: 183-188, 1990
30. Yamaura I, Tani E, Yokota M, Nakano A, Fukami M, Kaba K, et al.: Endovascular treatment of ruptured dissecting aneurysms aimed at occlusion of the dissected site by using Guglielmi detachable coils. J Neurosurg 90: 853-856, 1999
31. Yoon WK, Kim YW, Kim SR, Park IS, Kim SD, Jo KW, et al.: Angiographic and clinical outcomes of stent-alone treatment for spontaneous vertebrobasilar dissecting aneurysm. Acta Neurochir (Wien) 152: 1477-1486; discussion 1486, 2010
32. Zhang Z, Wang H, Zhou Y, Wang J: Computed tomographic angiography of anterior spinal artery in acute cervical spinal cord injury. Spinal Cord 51: 442-447, 2013
33. Zhao WY, Krings T, Alvarez H, Ozanne A, Holmin S, Lasjaunias P: Management of spontaneous haemorrhagic intracranial vertebral artery dissection: review of 21 consecutive cases. Acta Neurochir (Wien) 149: 585-596; discussion 596, 2007