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Research article

Endovascular treatment of intracranial vertebral artery dissecting aneurysm, a case series study with two years follow up on complications

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ABSTRACT

Background: This study is aimed to analyze the clinical outcomes of endovascular treatments for patients with intracranial vertebral artery dissecting aneurysms.

Methods: Clinical data of 32 patients with vertebral artery dissecting aneurysms who underwent endovascular procedures in the Department of Neurosurgery of our University from January 2016 to December 2019 were retrospectively analyzed. Nine cases were treated with endovascular occlusion; 23 cases received reconstructive treatment, including 20 cases of stent combined with coil embolization, and 3 cases of stent implantation. The angiography taken at 3–22 months after surgery was reviewed.

Results: The endovascular treatments for all 32 cases were successful. Thirty-one cases had no postoperative complications during index hospital. Mid-term follow-up showed that: 27 cases (84%) had embolism; 5 cases (16%) had recurrence, of which 4 cases were treated again with endovascular procedures followed with no further complications and no recurrence, and 1 case received closely monitor but no reoperation. During an average follow-up of 10.5 months, except for one case that was self-discharged due to end-stage brainstem compression and respiratory failure, the rest of the patients were in stable conditions without bleeding or infarction.

Conclusion: Endovascular treatment of intracranial vertebral artery dissecting aneurysms is safe and effective. Recurrent vertebral artery dissecting aneurysms can be treated with endovascular reoperations with satisfactory outcomes.

1. Introduction

Intracranial dissecting aneurysm (IDA) refers to the pathological dissection between the intima and media or between the media and adventitia of an intracranial artery, which leads to bulging of the arterial wall and aneurysm-like expansion [1]. IDA can occur in all age groups while having high incidence in young and middle-aged groups. IDA is one of the important reasons for stroke. Most of the IDAs occur in the vertebral artery (IVADA), some can also take place in the basilar artery and the internal carotid artery [2].

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1.1. Clinical symptoms

The clinical manifestations of this disease can vary, such as headache, and vomiting due to subarachnoid hemorrhage (SAH). These clinical symptoms can be due to the pathological damage of the diseased vessel wall, the configuration of the lumen cerebral infarction, and nerve compression. Intracranial vertebral artery dissecting aneurysm often leads to hemorrhagic stroke endangering the patient's life and can also lead to ischemic stroke resulting in neurological dysfunction and poor life quality [3,4].

1.2. Diagnosis of IDA

With the development of imaging diagnosis technology, the diagnosis rate of IDA is increasing. The annual incidence of IDA in the vertebral-basal artery is 1/100,000 to 1.5/100,000, of which intracranial vertebral artery dissecting aneurysm (IVADA) accounts for 75%–80% [5]. The diagnosis of IVADA mainly relies on clinical imaging, namely magnetic resonance Imaging (MRI) and angiography.

1.3. Disease progress of IVADA

Patients with intracranial vertebral artery dissecting aneurysm (IVADA) often see a doctor due to subarachnoid hemorrhage initially [6]. The course of the disease is fast and dangerous. The case fatality rate is 19%–50%, and the risk of rebleeding within a week is very high. Therefore, IVADA patients with rupture and bleeding should receive immediate interventions such as whole brain DSA, endovascular treatment or craniotomy [7].

Unruptured IVADA has relatively slower disease progression, which allows more time for MRI, high-resolution MRI (HR-MRI), high-resolution vessel wall imaging (HR-VWI), computed tomography angiography (CTA), digital subtraction angiography (DSA), and other medical examinations and evaluations. The symptoms of unruptured IVADA include dizziness, headache, and ischemic manifestations. Some may have symptoms of cranial nerve and brainstem compression [8]. Patients could be diagnosed from imaging in physical examinations or trauma without relevant clinical symptoms. Conservative treatment and closely follow up are recommended for patients with unruptured IVADA [9,10].

IVADA patients with subarachnoid hemorrhage (SAH) have high risk of bleeding, disability, and mortality, and thus should be actively treated [11]. Patients with symptoms of cerebral ischemia can be treated with antiplatelet or anticoagulant drugs. However, antiplatelet, or anticoagulant drugs may prevent thrombosis, thus affecting the healing of IVADA and increasing the risk of rupture and bleeding [12,13].

1.4. IVADA treatment methods

While the most popular treatment for IVADA is occlusion/ligation of vessels, IVADA treatment methods can be categorized into craniotomy treatment and endovascular treatment [14]. In most cases, aneurysm isolation combined with bypass is required during surgery. When the lesion is adjacent to complex structures such as the brain stem and the posterior cranial nerve, the difficulty of the operation increases. With the advancement of clinical technology, endovascular treatment has gradually become the main treatment strategy for intracranial vertebral artery dissecting aneurysms [15].

This case series study summarizes the characteristics of intracranial dissecting aneurysms and investigates the clinical outcomes of endovascular treatments.

2. Methods

2.1. Patients data

The Department of Neurosurgery of our hospital diagnosed and treated 32 cases of vertebral artery dissecting aneurysms from January 2016 to December 2019. The endovascular treatments are summarized in the followings.

2.2. Auxiliary examination

All patients underwent digital subtraction angiography (DSA) examination, including bilateral carotid artery and bilateral vertebral angiography. Thirteen patients with unruptured aneurysms underwent MRI (3.0T) examination, including T1 image, T2 image, Flair image, DWI. Ten patients with unruptured aneurysms underwent high-resolution magnetic resonance imaging (HR-MRI), and high-resolution vessel wall imaging (HR-VWI) to further understand the characteristic of the intimal flaps and the intravascular hematomas formed by intimal arterial damage. The severity of subarachnoid hemorrhage was assessed with the Hunt Hess classification. The higher the Hunt Hess grade indicates more severe neurological damage.

2.3. Treatment methods

2.3.1. Intravascular reconstruction treatment

Twenty-three cases received intravascular reconstruction treatment, including 20 cases of stent combined with coil embolization and 3 cases of stent placement only. The stents were Enterprise stents (Johnson & Johnson), LIVS Stents (microvention), or Neuroform

EZ stents (Stretcher), commonly with a diameter of 3.5 mm. The length of stents were tailed to the aneurysm. The coils were microvention-filled coils, cosmos coils, Johnson & Johnson-MICRUSPHERE series coils, Johnson & Johnson-Orbit series coils, Medtronic-Axium series detachable coils, or Stryker-Target coils. During the operation, the stent catheter was first delivered to the position under the guidance of the micro-guide wire (the tip was generally up to the basilar artery segment), and then the tip of the micro-catheter was delivered to the aneurysm lumen under the guidance of the micro-guide wire, next the aneurysm lumen was filled with micro coils. The stent was delivered through the stent catheter and released to cover the lumen of the aneurysm. After the stent was opened well, continue to tamp the coil through the microcatheter to embolize the aneurysm. The status of the operation was verified by angiography. The operation would be complete when the aneurysm-bearing artery was unobstructed, and the aneurysm disappeared under angiography.

2.3.2. Endovascular occlusive treatment

Nine cases received occlusion of aneurysm and aneurysm-bearing artery, that is, using coils to fill the aneurysm lumen while occluding the blood vessel containing the aneurysm. Occlusion materials can be various types of coils. The operation was complete when the local aneurysm was no longer visible under angiography.

2.4. Perioperative management

Anticoagulants and antiplatelets were applied perioperatively with a routine clinical protocol. Patients with ruptured aneurysms are not routinely given antiplatelet drugs before surgery, and patients with unruptured aneurysms are routinely given antiplatelet drugs for at least 3 days before surgery. During surgery, intravenous antiplatelet drugs were used appropriately. Patients with stents were given antiplatelet drugs postoperatively. During the operation, diluted heparin solution was given to the patients systematically. Heparin was not routinely used after the operation.

2.5. Evaluation of treatment effect and follow-up

Patients' outcomes were evaluated during the intraoperative and postoperative periods. During the intraoperative period, the patients were assessed with immediate angiography to see if the aneurysmwas present. During the postoperative period, the patients were followed up via telephone, or outpatient visits. CT or MRI examination would be performed if needed. Postoperative complications were assessed before discharge and within 1 month after surgery. Long-term complications were assessed 1 month after the surgery. The patients were followed up for any complications including bleeding or ischemic, neurological dysfunction, aneurysm recurrence, and occlusion recanalization.

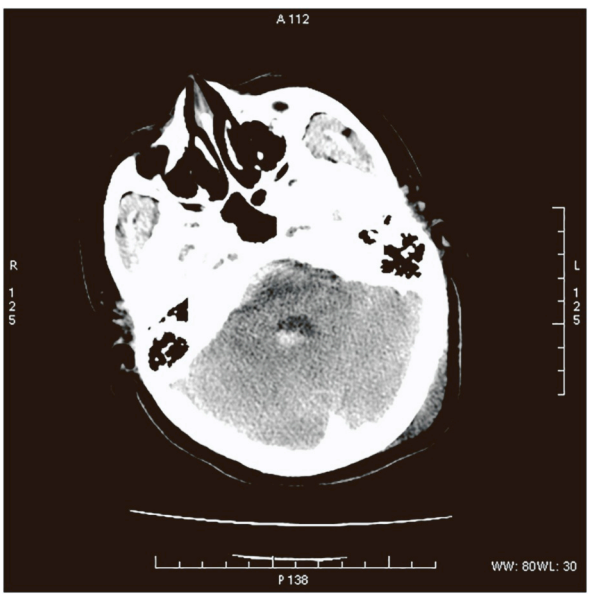

Fig. 1. CT findings of patients with IVADA hemorrhage: hemorrhage is mainly at the subtentorial cerebellum, the cistern in front of the brainstem and the third and fourth ventricles.

3. Results

3.1. General characteristics

A total of 32 patients with vertebral artery dissecting aneurysms were studied, aged from 36 to 71 years with an average age of 51.2 years, including 21 males and 11 females. Seventeen cases were right vertebral artery dissecting aneurysms, 15 cases were left-sided. Two cases involved posterior inferior cerebellar artery (PICA) and basilar artery. Nineteen cases (59.4%) showed new onset of subarachnoid hemorrhage, of which 18 cases can be categorized as Hunt Hess grade 1–2 with headache and vomiting, and 1 case can be categorized as Hunt Hess grade 3 with acute consciousness dysfunction. Thirteen cases were unruptured aneurysms (4 cases were unintentionally found during physical examinations; 5 cases were cerebral infarction and cerebral ischemia; 4 cases had dizziness, headache, and neck pain). All patients had no history of neck trauma.

3.2. Imaging features

Thirteen patients underwent MRI examinations, 5 cases found arterial intimal valve and false arterial lumen, and 8 cases found vertebral artery wall hematoma. Among 32 cases of DSA examination, 19 patients presented bleeding; 27 cases showed "beading sign", that is, irregular fusiform or aneurysm-like expansion with or without proximal and (or) distal stenosis; 3 cases showed obvious authenticity and falsehood. In the arterial lumen, there was obvious contrast agent retention in the DSA venous phase. Fig. 1 shows the CT findings of an IVADA with bleeding. Fig. 2 shows dual lumen under DSA. Fig. 3 A-D shows the HR-MRI manifestations of the endometrial valve and thrombotic aneurysm.

3.3. Endovascular treatments outcomes

Except for one case who was self-discharged due to the end stage of life, the remaining 31 cases had no intraoperative and postoperative complications (e.g., no aneurysm rupture and bleeding), and no new onset neurological dysfunction after the operation.

3.4. Endovascular occlusive treatment outcomes

Nine cases received endovascular occlusive procedures without postoperative complications. Re-examination within 6 months showed no visible aneurysm. Fig. 4 A-D shows the endovascular occlusive treatment.

3.5. Intravascular reconstruction treatment outcomes

Total 23 cases received intravascular reconstruction procedures.

Three cases underwent stent implantation only, whose aneurysms were no longer visible under angiography after surgery. No postoperative complications were observed. Among these three cases, one case revealed recurrence one month after surgery. The stent combined with coil embolization was performed again for this patient. The aneurysm had no further progression during the 1 month follow-up after the reoperation. For the other two cases, the aneurysms were significantly reduced or disappeared during the 3 months follow-up after the initial surgery. Fig. 5A–D shows a stent implantation only procedure.

In the 20 cases of stent combined with coil embolization, the aneurysm was completely occluded. Fig. 6A–C shows the stent

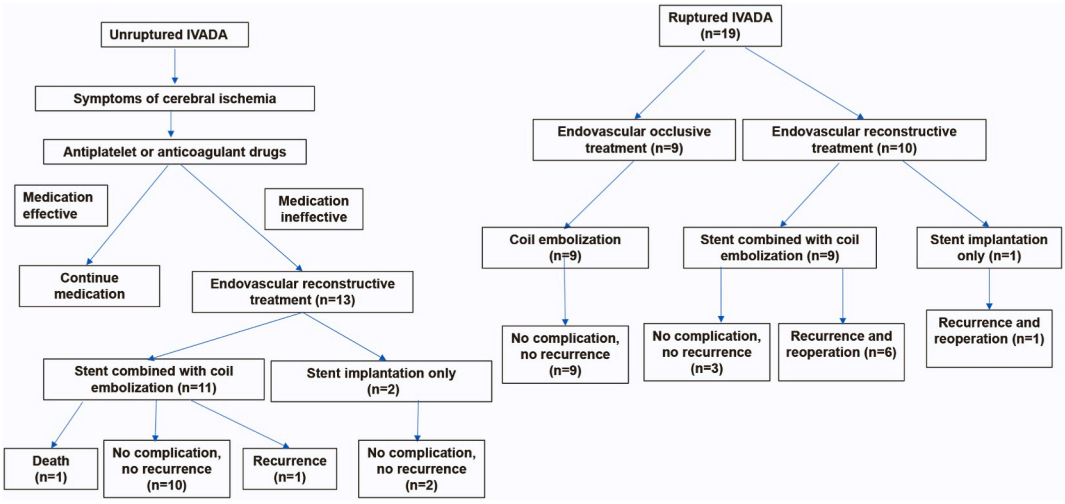

Fig. 2. IVADA imagined in DSA: dual lumen (3D imaging).

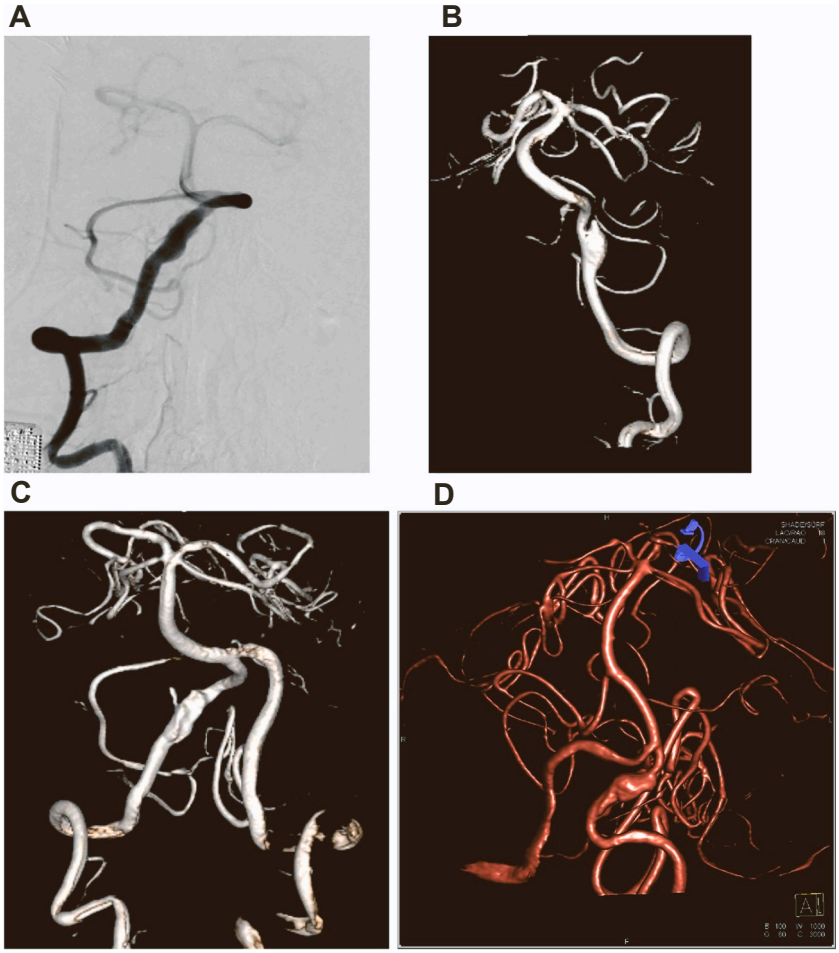

Fig. 3. (A) DSA appearance of VADA: double-lumen sign, (B\C\D) 3D imaging of vertebral artery dissecting aneurysm.

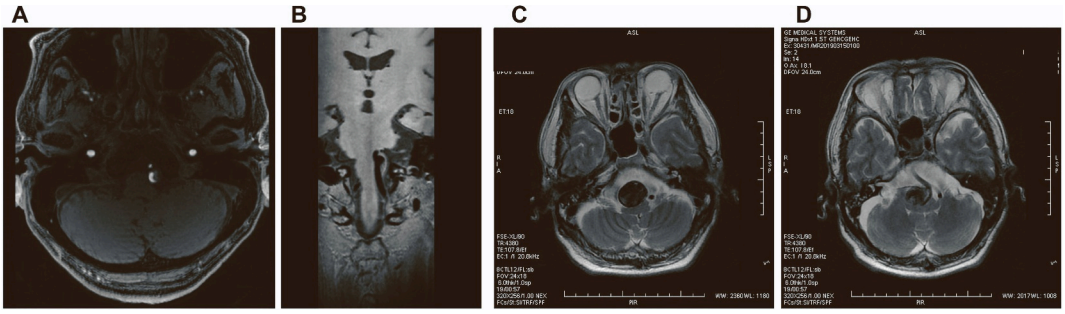

Fig. 4. (A\B) HR-MRI performance of VADA intimal valve and thrombotic aneurysm, (C\D) HR-MRI performance of VADA: thrombosis in the lumen of the dissecting aneurysm compressing the brain stem.

combined with coil embolization procedure. One patient was self-discharged with brainstem compression and respiratory failure. Fifteen cases had no postoperative complications, and no aneurysm developed during the 18 months follow-up. Four cases had recurrence. Among these four cases, reoperations including aneurysm and artery occlusion or coil embolization were performed for three of the cases. No visible aneurysm under angiography was observed after the reoperations. One patient showed recurrence at 4 months after the surgery but refused reoperation. This patient had no remarkable clinical symptoms and had maintained normal physical activity with good quality of life.

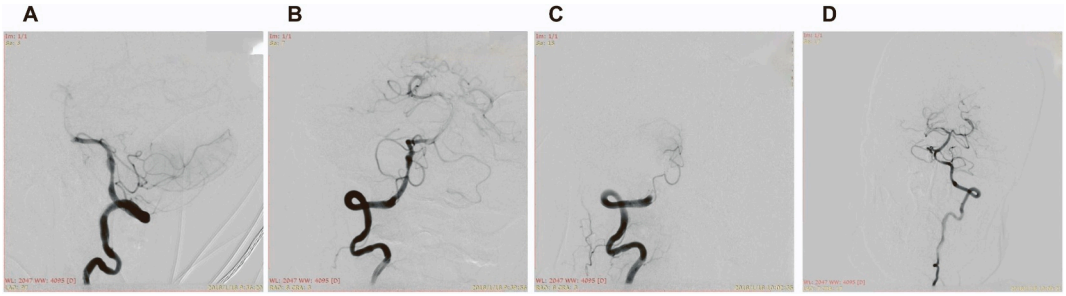

Fig. 5. (A, B) Anteroposterior and lateral angiography before occlusion of the dissecting aneurysm, (C\D) angiography after endovascular occlusive treatment of dissecting aneurysms.

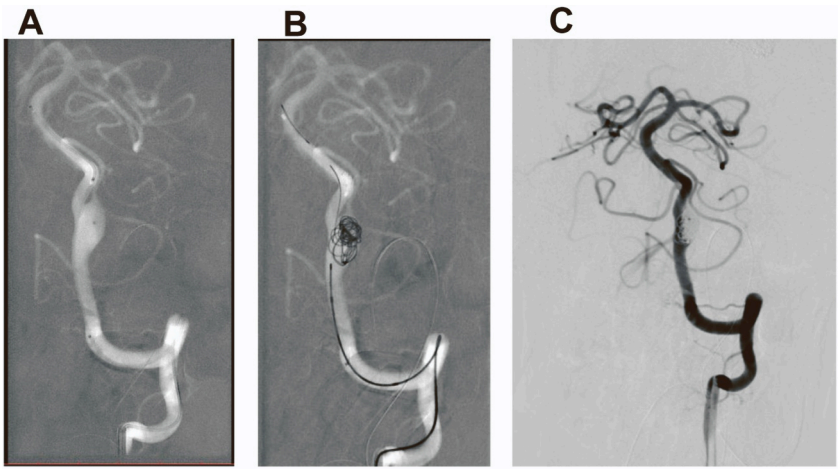

Fig. 6. Stent combined with coil embolization: (A) Coil microcatheter and stent microcatheter in place, (B) the stent was released and the coil was filled. (C) The dissection aneurysm disappeared and the parent artery was unobstructed after stent combined with coil embolization.

3.6. Vertebral artery dissecting aneurysm with a lesion of the posterior inferior cerebellar artery

In this case series, a patient with vertebral artery dissecting aneurysm involving a lesion of the posterior inferior cerebellar artery (PICA, Posterior inferior cerebellar artery) was treated with endovascular occlusion at the initial surgery. The aneurysm and the parent artery were occluded completely, and the PICA was well protected at this initial surgery (Fig. 7A–C). Four months later, the aneurysm recurred. During the reoperation, the recurrent aneurysm was embolized with a Y-stent assisted coil. The aneurysm was completely embolized, and the blood flow of the PICA and the vertebral artery was unobstructed (Fig. 8A–D). At the reexamination after one and a half years, the aneurysm completely disappeared, and the blood flow of the PICA and the vertebral artery was unobstructed

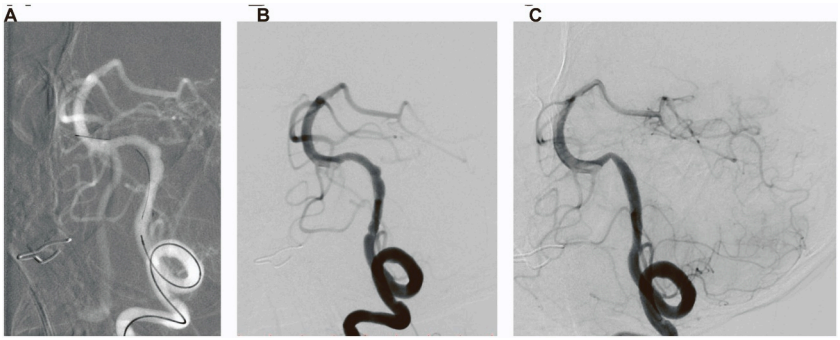

Fig. 7. (A) Stenting alone after stent release during surgery, (B) immediate angiography after the release of the stent showed that the parent artery was patent and the dissecting aneurysm became lighter, (C) reexamination 3 months after operation showed that the dissecting aneurysm disappeared.

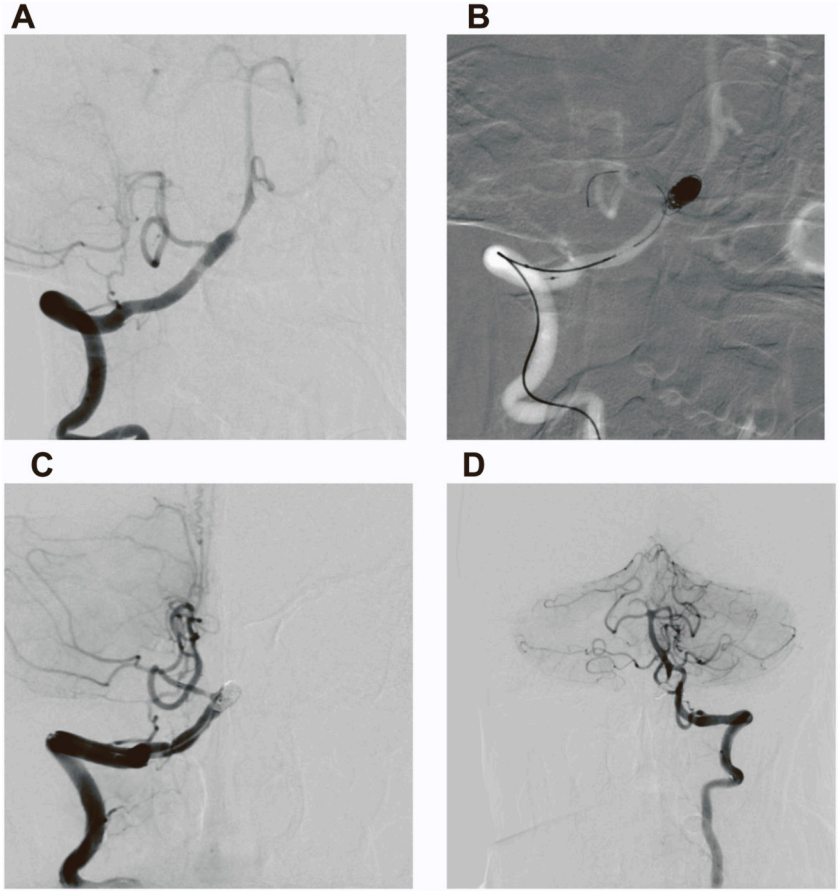

Fig. 8. (A) Angiography showed hemorrhagic vertebral artery dissecting aneurysm involving the opening of PICA and vertebral artery true lumen stenosis, (B) the ipsilateral PICA was protected by stent, and the dissection aneurysm was occluded by coil. (C) Immediate postoperative angiography showed complete embolization of the dissection aneurysm and good protection of the PICA, (D) the contralateral vertebral artery angiography showed unobstructed blood flow in the vertebrobasilar artery and bilateral posterior cerebral artery.

(Fig. 9A–E).

4. Discussion

In this case series, we presented the diagnosis and treatment outcomes of 32 cases of patients with IVADA. We summarized our treatment strategies in Fig. 10 A-B.

Typical imaging indications for arterial dissection include (4, 5, 6, 8): (1) eccentric arterial stenosis with dilated outer diameter; (2) beaded or segmental stenosis; (3) intramural hematoma; (4) double-lumen; (5) intimal valve; (6) dissecting aneurysm formation [5, 16]. Among these, double-lumen and damaged intimal valve are direct signs of arterial dissection diagnosis. For dissecting aneurysms with typical manifestations such as beading, dual lumen, and endometrial valve, imaging examination such as CTA, MRA, or DSA can be used to make diagnosis independently, while atypical lesions need to be diagnosed in combination with multiple examinations. Our study showed an example of dual lumen under DSA.

Several studies [17,18] have shown that, HR-MRI can clearly show the walls of intracranial arteries and is an effective non-invasive imaging method to diagnose IDA lesions. Except for patients with acute bleeding, all patients in our study received HR-MRI to examine their arterial walls and aneurysm lumen.

The purpose of endovascular treatment is to reduce or block the blood flow to the dissecting aneurysm, repair the damaged intima, prevent SAH or cerebral hemorrhage caused by continued progression or rupture, reduce the occurrence of ischemic events, and relieve the damage to the surrounding brain tissue or brain symptoms of nerve compression [1].

Treatment methods include occlusive treatment and reconstructive treatment [14]. Occlusive treatment uses embolic materials to occlude the aneurysm-bearing artery and aneurysm. Reconstructive treatment uses endovascular stents to keep the aneurysm-bearing artery unobstructed. The embolic materials and the stent can also direct blood flow to promote thrombosis in the aneurysm lumen.

Endovascular occlusive treatment mainly refers to occlusion of dissecting aneurysms and the blood vessels containing the aneurysm. Although endovascular occlusive treatment is considered as the most reliable technique for treating hemorrhagic VADA, it is

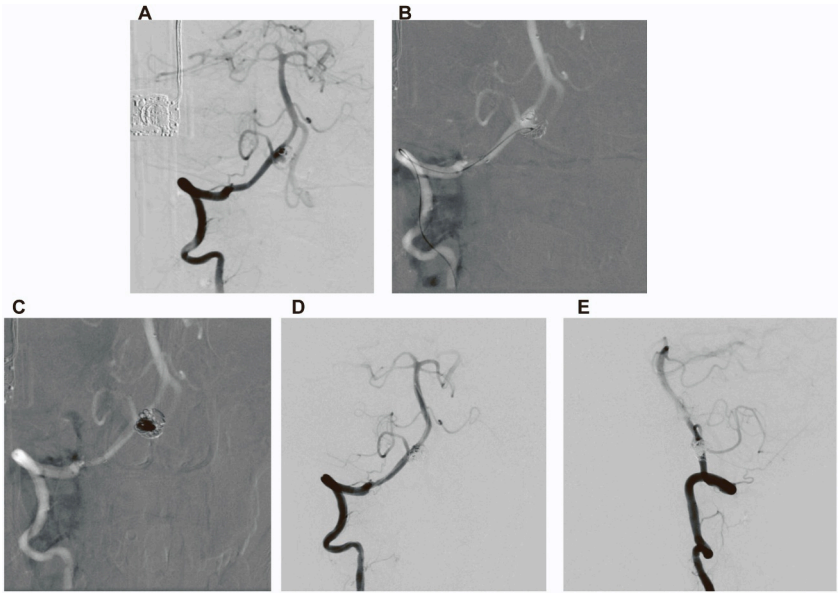

Fig. 9. (A) The patient was reexamined 4 months after the operation, and the parent artery was recanalized, (B\C) the patient was embolized again: the tip of the B-coil microcatheter was placed into the lumen of the recurrent aneurysm, (C) the stent-assisted microcatheter passed through the mesh of the PICA stent and reached the distal end of the right vertebral artery to form a Y-shaped stent-assisted coil for embolization of recurrent aneurysms, (D\E) immediate postoperative angiography showed that the recurrent dissecting aneurysm was completely embolized, PICA and parent vertebral artery blood flow was unblocked.

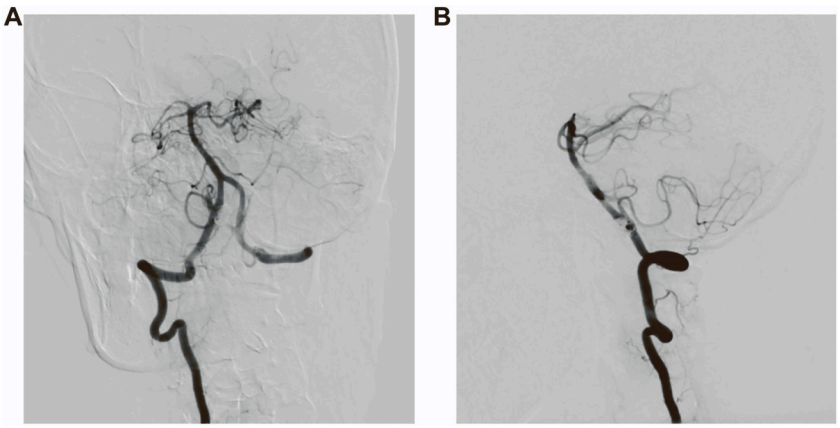

Fig. 10. (A\B) After the second intervention, the patient was reexamined one and a half years after the second intervention, the aneurysm was completely cured, the blood flow of PICA and parent vertebral artery was unobstructed, and the anteroposterior and lateral radiographs were obtained.

associated with postoperative complications such as bleeding and ischemia [19]. The prerequisite for using this surgical technique is that the compensatory blood supply after occlusion should be sufficient. If necessary, a balloon occlusion test is required to evaluate the collateral circulation. If the compensation is insufficient, occlusive treatment is not recommended, and stent reconstruction treatment can be used. The critical operation steps for the endovascular occlusion are the followings [20]: first place the tip of the microcatheter into the dissection artery, then use a coil to fill the aneurysm lumen and the diseased artery starting from the distal end to the proximal end. If the artery with the aneurysm does not involve important branches, at least 2–5 mm of the proximal artery should be embolized to avoid aneurysm recurrence. In this case study of hemorrhage patients, aneurysm and artery occlusion is the first treatment choice for patients with dissecting aneurysms. The immediate and long-term follow up outcomes were satisfactory [21].

Intravascular reconstruction treatment includes stent combined with coil embolization and stent implantation alone.

Stent combined with coil embolization is an important way of endovascular treatment for VADA. This procedure has high risks of postoperative bleeding and recurrence. Its efficacy still needs long-term clinical follow up. The placement of a stent slows down or even changes the blood flow, and promotes thrombosis in the aneurysm lumen. In addition, the radial support force of the stent presses the

intimal valve to adhere to the blood vessel wall and occludes the dissection. The stent can also be used as a framework for the attachment of neovascular endothelial cells to promote endothelial repair and achieve anatomical healing. In recent years, new types of blood flow guiding devices (Pipeline stent, Tubrge stent) have achieved good therapeutic effects in treating dissection. However, its use is limited due to potential postoperative perforating events and high cost of materials [21,22].

Stent implantation alone is mainly used for patients with unruptured VADA and those with difficulties of using coil embolization. Some research has reported that using multiple stents placement, increasing the metal coverage of the stent, or using a new type of blood flow guiding device can increase the blood flow guidance effect and improve the treatment effect [23,24]. The number of cases in this group who underwent stent implantation alone was small. The long-term follow up for these patients showed that the aneurysm had shrunk or disappeared, suggesting that the blood flow guidance effect of stent alone implantation was effective. However, some patients with postoperative aneurysm enlargement required reoperation of stent combined with coil embolization. The postoperative outcome was satisfactory, indicating the significance of coil embolization in addition to the stent placement. The details of the stent implantation procedures were provided in the appendix.

For IDA with atypical expansion, it is possible that there is not enough space to release the coils. When it is not possible to fill the coils, stent placement technique is used. IDA is often associated with stenosis at the proximal or distal end of the aneurysm. If the stenosis of the aneurysm-carrying artery severely affects the intravascular operation, for example, the opening of the stent, a balloon can be used as appropriate to expand the aneurysm-bearing artery and then proceed the stent implantation.

Patients with recurrent vertebral artery dissecting aneurysms may require two treatment modalities: endovascular occlusive treatment and reconstruction treatment. Our study also showed a case with vertebral artery dissecting aneurysm with a lesion of the posterior inferior cerebellar artery. This case suggested, for hemorrhagic dissecting aneurysms involving the PICA, occlusive treatment can be used to prevent rebleeding of the aneurysm, and reconstructive procedure can be performed for recurrence. For unruptured vertebral artery dissecting aneurysms involving PICA, reconstructive treatment and Y-stent technology are procedure options to protects both PICA and vertebral artery.

The main complications of endovascular treatment of IDA include intraoperative or postoperative bleeding, intraoperative or postoperative ischemic complications, postoperative mass effect aggravation, and recurrence. Even if the preoperative evaluation shows sufficient compensatory blood flow, ischemic complications may still occur after the occlusion of the aneurysm-bearing artery. Patients undergoing stent reconstruction treatment may have intraoperative or postoperative bleeding, cerebral ischemia, and cranial nerve palsy [12,25].

Our study has limitations regarding the small sample size. Large-scale clinical studies are still needed to confirm the long-term efficacy of endovascular treatment. While vertebral artery dissecting aneurysms are relatively rare and their treatments are often challenging, our study provides valuable clinical experience in treating this disease. Secondly, this is a single-center observational study, and thus has an endogenous limitation of observations study such as recall bias, selection bias.

5. Conclusion

In conclusion, endovascular treatment is a valid choice for vertebral artery dissecting aneurysms. Recurrence after endovascular treatment is a problem worthy of attention. The recurrence rate of IDA treated with stent reconstruction is 5%–26% [26]. Risk factors that impact the recurrence of IDA after endovascular treatment include: (1) the size of IDA; (2) the degree of embolization of the coil in the aneurysm; (3) whether the aneurysm involves important branches; (4) the number of stents; (5) the metal coverage of the stent in the diseased area; and (6) the potential interaction among the above factors [20,27]. In addition, the treatment of IVADA emphasizes individualized treatment plans, including conservative treatment, endovascular treatment, and craniotomy treatment.

Ethic statement

This study was approved by the ethics committee of the First Affiliated Hospital of Anhui Medical University (No.PJ2021-08-41). All patients gave their written informed consent.

Author contribution statement

Jing Luo: Conceived and designed the experiments; Performed the experiments; Contributed reagents, materials, analysis tools or data; Wrote the paper.

Fei Liu: Conceived and designed the experiments; Performed the experiments; Contributed reagents, materials, analysis tools or data.

Liang Zhao, Baochun Cheng: Performed the experiments; Analyzed and interpreted the data.

Yangchun Hu, Xiaojian Wang: Analyzed and interpreted the data.

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Data availability statement

Data will be made available on request.

Declaration of interest's statement

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

List of abbreviation

Intracranial dissecting aneurysm DA
subarachnoid hemorrhage SAH
Intracranial vertebral artery dissecting aneurysm IVADA
digital subtraction angiography DSA
high-resolution magnetic resonance imaging HR-MRI
high-resolution vessel wall imaging HR-VWI

Appendix

Stent implantation procedures

To select the stent for stent implantation procedures, the length of the artery in the dissected lesion must be accurately measured. The appropriate type of stent must be selected to ensure that the stent can cover the entire section of the dissected lesion after release. The surgeons should ensure the stent can extend at least 5 mm from the distal and proximal ends of the lesion to avoid recurrence. If conditions permit, preferentially use high metal coverage stents, or use multiple stents overlapping release technology. Due to the diverse morphological manifestations of IDA in digital subtraction angiography (DSA), it can be manifested as fusiform expansion (dissection lesions involve the blood vessels of the diseased segment in a circle) and lateral protrusion (dissection lesions only involve part of the tube wall on the cross section) or atypical dilation (DSA only sees atypical dilation; contrast agent retention in the dissected vessel can be seen). When IDA expands in a fusiform shape, it is often difficult to identify the ruptured bleeding spot. To achieve the goal of uniform and compact coils embolization in the aneurysm lumen, it is recommended to first embolize the coil in the aneurysm lumen, and then use the reserved stent catheter to release the stent (post-stent release technology), which can further compress the coil released at the early stage [28]. When IDA is protruding from the side, the bleeding point is often the most prominent part on the side. Therefore, the top of the aneurysm is filled first, and then the remaining parts of the aneurysm. To reduce the risk of recurrence, the stent is released in the aneurysm-bearing artery through the stent catheter in place in advance. It is also possible to release the stent first, and then embolize it through the mesh of the stent (stent penetration technique) [29].

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