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HOW I DO IT

Trans-radial artery microcatheter angiography-assisted juvenile ruptured brainstem arteriovenous malformation resection

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Abstract

Background Due to their crucial functional location, surgical treatment of brainstem arteriovenous malformations (AVMs) has always been challenging. For unruptured AVMs, we can determine whether radiological therapy, interventional treatment, or surgical resection is feasible based on the AVM structure. However, for ruptured AVMs, microsurgical resection and interventional embolization are effective methods to prevent further rupture. In the microsurgical resection of AVMs, we usually use a hybrid operation to confirm the AVM structure and determine if the AVM is completely resected during the surgery.

Method We report a case of juvenile ruptured brainstem AVM resection. The right lateral position and left suboccipital retrosigmoid approach were used. We established an interventional approach via left radial artery and set a microcatheter in the feeding artery. Methylene blue injection via a microcatheter showed the AVM structure, and we totally resected the brainstem AVM under electrophysiological monitoring and navigation. Intraoperative angiography was performed to ensure complete resection without residual nidus.

Conclusion This case demonstrates that the trans-radial approach is convenient and safe for special positions in hybrid operations. Methylene blue injection via a microcatheter in the feeding artery provides clearer visualization of the AVM structure under the microscope.

Keywords Brain stem AVM · Hybrid operation · Intraoperative DSA · Trans-radial artery approach · Methylene blue localization

Relevant surgical anatomy

Brain stem arteriovenous malformation (AVM) resection is challenging [4]. Because they are packed densely with cranial nerves and tracts, all brainstem AVMs are located in functional areas [2] and drain deeply with high Spetzler–Martin grades. In contrast to cerebral and cerebellar AVMs, most brainstem AVMs are located in the pial or epipial region [1]. More than half of brainstem AVMs are in the pons. An individualized surgical plan is needed [3].

Description of the technique

The patient gave approval for this publication. This patient is an 18-year-old girl with a chief complaint of sudden headache 2 months prior. She was admitted to a local hospital, and computed tomography (CT) scanning showed obvious hemorrhage in the fourth and third ventricles (Fig. 1A). Haematoma evacuation and Ommaya implantation were

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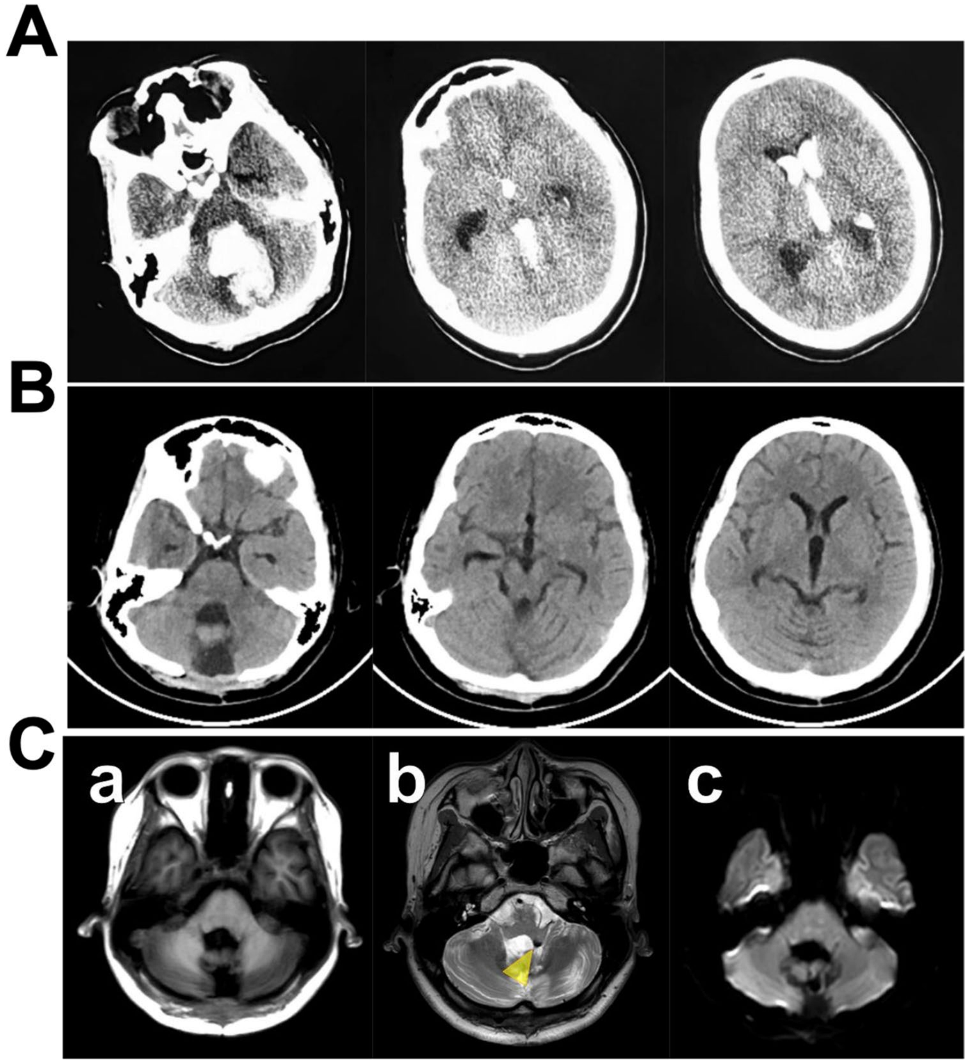

Fig. 1 **A** Head CT 2 months prior. **B** Recent CT. **C** Recent MRI T1 (a), T2 (b), and DWI (c) images. Arrow head: vascular malformation

performed. After 2 months of rehabilitation therapy, she was transferred to our hospital for further treatment. This patient did not have a history of hypertension, diabetes, or other chronic diseases. She had no history of smoking or alcohol abuse. The patient's preoperative muscle strength, vision, language, memory, and cognitive function tests were normal. The Allen test showed that the bilateral ulnar artery was well compensated.

Recent CT scanning showed no neo hemorrhage or ischemic lesion (Fig. 1B). Magnetic resonance imaging (MRI) demonstrated that the vascular sign was located in the left cerebellopontine angle (CPA) (Fig. 1C). We performed digital subtraction angiography (DSA), showing a CPA arteriovenous malformation (AVM). The feeding artery was the left anterior inferior cerebellum artery (AICA) and drained to the cerebellar cortical veins (Fig. 2). The Spetzler−Martin grade was 3, and the Lawton–Young grade was 4.

Because the feeding AICA branch was slender, it was difficult to set a microcatheter near the nidus. In addition, the drainage vein was close to the feeding artery. Interventional AVM embolization was not optimal. According to previous hemorrhagic history and images, we decided to perform brainstem AVM resection in a hybrid operating room. The left suboccipital retrosigmoid approach and right lateral position were selected. A 5F-25 cm artery sheath (Terumo Corporation, Tokyo, Japan) was set in the left radial artery using Seldinger to establish a trans-radial artery (TRA) approach. We used a 5F Simmons 2 catheter (Cook Medical, Bloomington, Indiana) to establish the approach to the left subclavian artery (Fig. 3A (a, b)). Saline was maintained in the TRA sheath. We exposed the left CPA and branches of the left AICA. There were some communicating vessels between the feeding artery and drainage vein. We coagulated and dissected them and found that the vein was still bright red with high tension.

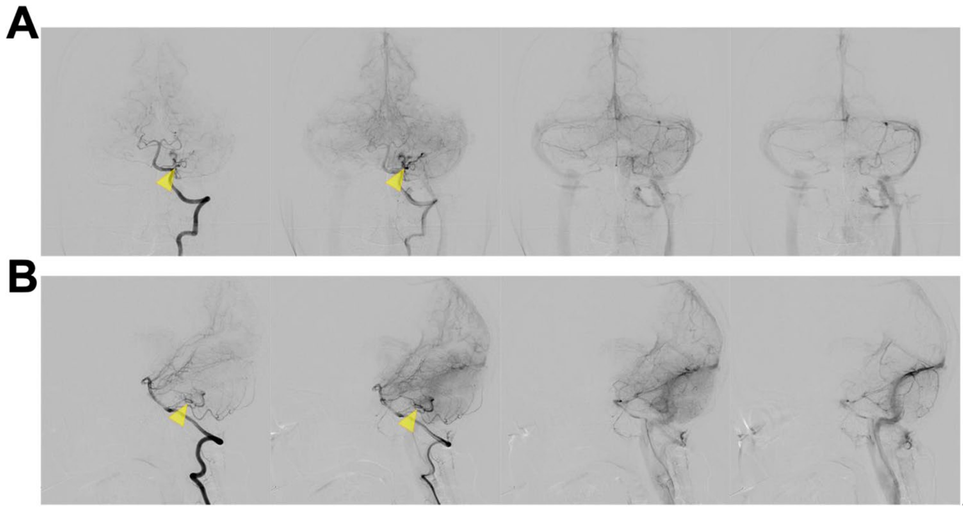

Fig. 2 Preoperative DSA of the left vertebral artery in the anteroposterior position (**A**) and lateral position (**B**). Arrow head: vascular malformation

An Echelon-10 microcatheter (EV3, Irvine, CA) was set in the left main trunk of the AICA under Synchro-2 microwire (Stryker Neurovascular, Fremont, CA) guidance. DSA via microcatheter showed AVM structure (Fig. 3A (c)). Dilated methylene blue was injected using an Echelon-10 microcatheter, and the operator could clearly judge the AVM position and vascular structure (Fig. 3B). Under motor evoked potential (MEP), somatosensory evoked potential (SSEP), and cranial nerve monitoring, the feeding arteries were dissected, and finally, the AVM was resected (Fig. 3C). There was no obvious MEP or SSEP decrease during the operation. Posterior cranial nerves were all protected well. Intraoperative DSA showed that the AVM was totally resected (Fig. 3D).

The nasal tracheal cannula was kept in place until 8 days after the operation. The immediate postoperative images showed no intracranial hematoma on CT, no obvious edema in the operation region on T2 fluid-attenuated inversion recovery (FLAIR) imaging, and no neoinfarction on diffusion-weighted imaging (DWI) (Fig. 4).

The patient was discharged with a modified Rankin scale (mRS) score of 2 and limb muscle strength grade of V. The Romberg sign was positive.

Indications

The diagnosis of this patient was juvenile ruptured brainstem AVM with a deep position and a high rebleeding rate [5, 6]. Radiological therapy is an optional but not optimal choice. Although there were credible evidences that radiotherapy provides excellent occlusion rate with reduced mortality in such brainstem microAVM, radiotherapy has a slow onset and a high rebleeding rate. AVM occlusion requires a waiting period of 2–3 years. AVM resection in early stage could reduce the rebleeding rate for young patients.

In this case, the feeding artery and drainage vein were too close. It is easy to result in perforating branches and drainage vein embolization. The patient is a young girl with adequate bilateral ulnar artery compensation. The TRA is a good choice when we perform intraoperative DSA in the lateral position. We could not modulate the artery sheath when we chose the transfemoral artery (TFA) approach.

Limitations

Precise localization was crucial for brain stem AVM. MRI navigation with merged DSA may not be accurate in the hybrid operation room. Before craniotomy, the patent of TRA access should be confirmed. Because of the lateral position, left upper arm abduction is insufficient. The disadvantages of insufficient support for the TRA approach may be more obvious.

How to avoid complications and specific perioperative considerations

1. Nasal intubation and delayed removal are beneficial to avoid respiratory complications after brainstem AVM resection. The white card test is needed before intubation removal.
2. Electromagnetic navigation using MRI structural imaging combined with DSA can provide intraoperative navigation. However, it cannot completely localize the lesion accurately if the lesion is small.

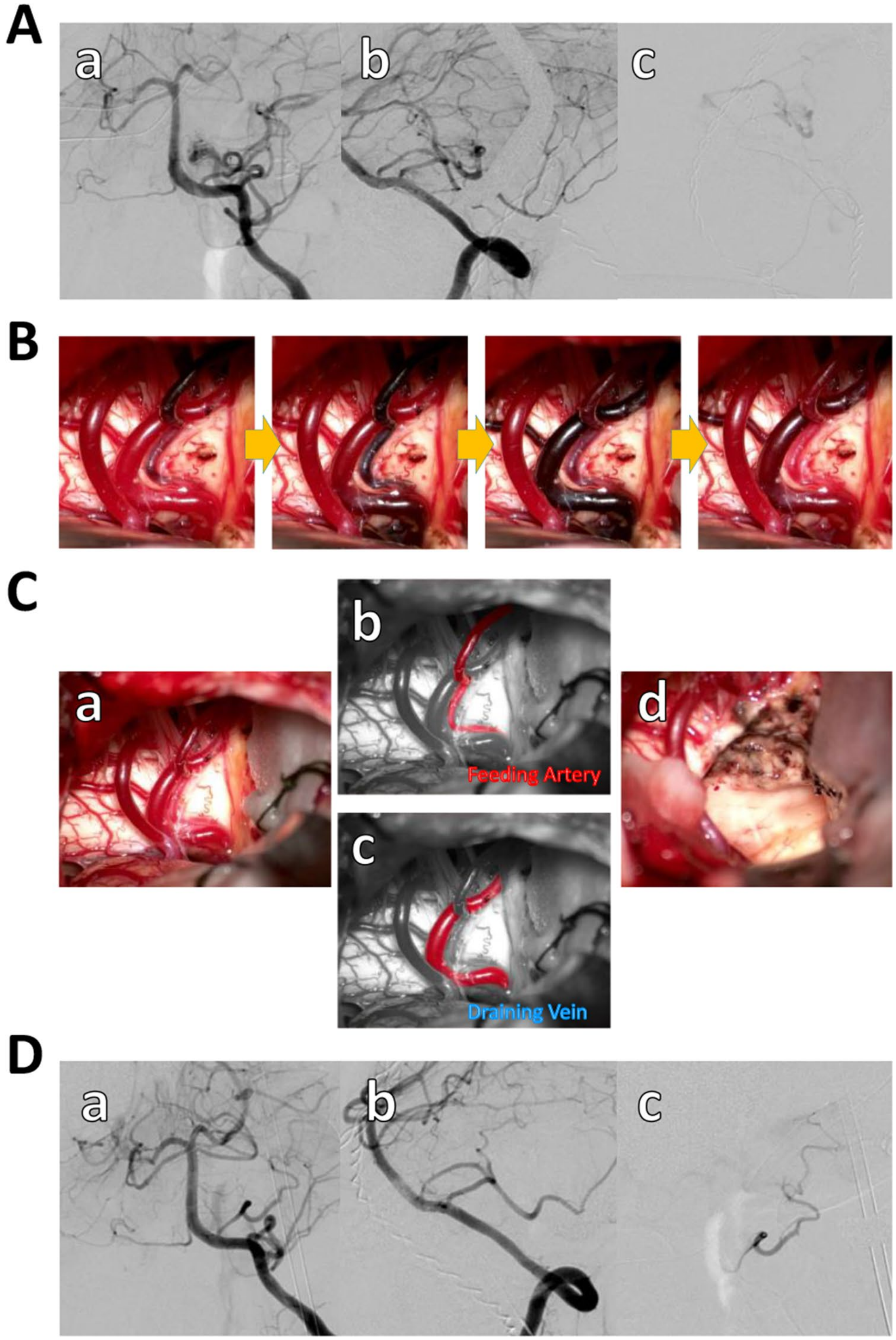

Fig. 3 **A** Intraoperative DSA before AVM resection. Left vertebral artery angiography in the anteroposterior position (a), lateral position (b), and left AICA angiography via a microcatheter (c). **B** Methylene blue injection via microcatheter. **C** Pictures during operation. Pictures of AVM (a), feeding artery (b), draining vein (c), and AVM resection (d). **D** Intraoperative DSA after AVM resection. Left vertebral artery angiography in the AP position (a), lateral position (b), and left AICA angiography via microcatheter (c)

3. Intraoperative neurophysiological monitoring, including SSEP, MEP, and cranial nerve monitoring, is necessary in all brainstem surgeries.
4. Intraoperative DSA can ensure complete resection of the lesion.
5. For the prone and lateral positions, the TFA sheath could not be adjusted during the operation. The TRA is convenient and safe.
6. Adequate radial artery evaluation and Allen tests are essential.

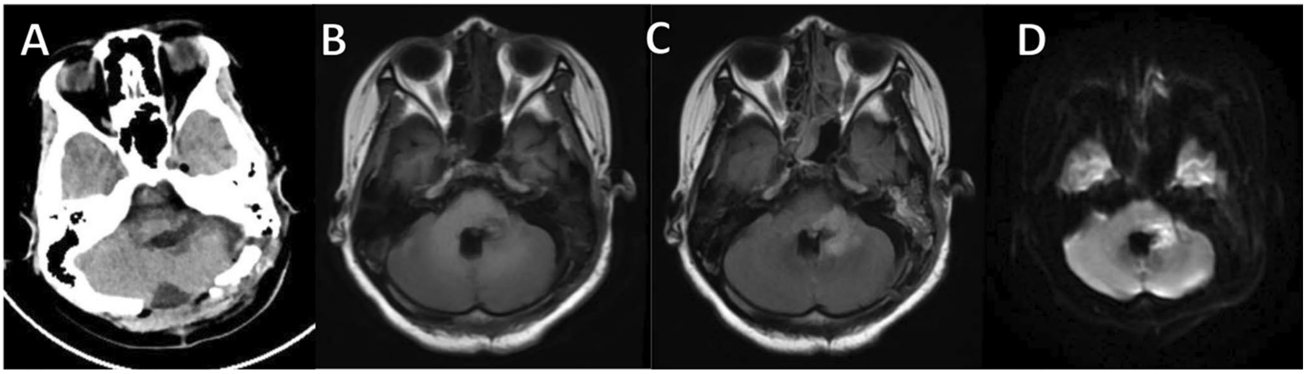

Fig. 4 Postoperative CT (**A**), MRI-T1 (**B**), MRI-T2 FLAIR (**C**), and DWI (**D**)

7. Continuous saline infusion in the TRA sheath is very important to avoid thrombosis-related complications.
8. Methylene blue injection via a microcatheter helps operators distinguish the feeding artery and normal artery under microscope.

Specific information for the patient

The patient should be fully informed about the risks and benefits and plan alterations during surgery. Intraoperative DSA must be performed to confirm AVM total resection without residual tissue. The left radial artery might be occluded after the artery sheath remains.

Supplementary Information The online version contains supplementary material available at https://doi.org/10.1007/s00701-024-05915-4.

Author contributions Peixi Liu: participation in surgery, conception, and design of study, provision of study material, collection and/or assembly of data, manuscript writing, and final approval of manuscript.

Hongfei Zhang: literature collection and collation.

Tianming Qiu: participation in surgery, conception, and design of study.

Wei Zhu: conception and design of the study and revision and final approval of the manuscript.

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Data availability Not applicable.

Code availability Not applicable.

Declarations

Ethics approval All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional research committee and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards. The study was approved by the Huashan Hospital Institutional Review Board (HIRB), Fudan University, Shanghai, China.

Consent to participate The patient gave approval for this publication.

Conflict of interest The authors declare no competing interests.

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Key points

1. Juvenile ruptured brain stem AVMs should be treated as early as possible to prevent rebleeding.
2. Radiological therapy is an optional choice but has a slow onset. The benefit/risk balance for the treatment strategy should be taken into consideration.

3. Intraoperative DSA ensures AVM total resection.
4. The TRA approach in the hybrid operation is convenient in the prone, lateral decubitus, and lateral oblique positions. The Allen test before the operation is crucial for ulnar artery compensation.
5. TRA sheath saline infusion must be maintained to avoid thrombosis complications.
6. Methylene blue injection clearly demonstrated the AVM structure. It provided more accuracy and short time repeatability than routinely used ICG injection.
7. SSEP, MEP, and cranial nerve monitoring are quick measures to determine functional protection.
8. Postoperative nasal intubation and delayed removal are needed. The white card test is needed before intubation removal.
9. If needed, jejunal tube placement in the early stage could avoid posterior cranial nerve-induced dysphagia complications.
10. Early-stage habitation therapy is needed.