Acta Neurochirurgica (2023) 165:983–987
https://doi.org/10.1007/s00701-022-05472-8

HOW I DO IT - VASCULAR NEUROSURGERY - ARTERIOVENOUS MALFORMATION

Clipping and exclusion of a thoracic pial arteriovenous fistula with multiple shunting points: how I do it

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Received: 26 November 2022 / Accepted: 21 December 2022 / Published online: 16 January 2023

Abstract

Background Thoracic pial arteriovenous fistulas (pAVFs) are rare vascular malformations that usually consist of a single dilated pial artery connecting directly to an enlarged draining vein. Multiple shunting point thoracic pAVFs are even rarer entities causing progressive myelopathy.

Method We present our surgical technique to identify and exclude multiple shunting point thoracic pAVF with appropriate pre-operative planning. This surgical technique is illustrated by an intraoperative video.

Conclusion Double injection pre-operative angiography represents a helpful tool to plan the surgery. Intraoperative exposure with pedicle removal and the use of micro-Doppler improve the identification and the exclusion of a multiple shunting thoracic pAVF.

Keywords pAVF · Arteriovenous fistula · Arteriovenous malformations · Thoracic myelopathy

Abbreviations

pAVF	Pial arteriovenous fistula
DSA	Digital subtraction angiography
MEPs	Motor evoked potentials
SSEPs	Somato-sensory evoked potentials
Th	Thoracic

Relevant surgical anatomy

Pial arteriovenous fistulas (pAVFs) are rare vascular malformations that consist of a dilated pial radiculomedullary artery connecting directly to an enlarged draining vein.

They are usually a single feeder malformation nourished by the radicular artery, branch of the segmental artery after its entrance in the intervertebral foramen.

The segmental arteries progressively feed the anterior spinal artery (ASA) and posterior spinal arteries (PSA).

Specifically, in the thoracic spine, the segmental arteries arise mainly from the posterior intercostal arteries, direct branches of the aorta.

The drainage of the pAVFs consists in an enlarged spinal vein, which can be the anterior spinal vein or one of the three posterior spinal veins [4, 7].

According to the classification of Addison of 1992, the pial AVFs correspond to fistula type IV, which are more frequent in adult and are located in the intradural space but extramedullary [1, 2].

In 2002 and 2006, Spetzler reviewed the classification and identified the pial AVF as an intradural ventral arteriovenous fistula, a high-flow malformation located ventrally at the midline of the spinal cord.

In the Spetzler classification, dural fistulas are distinguished in type A, with a single feeder, and type B, with multiple feeders and higher risk of bleeding [8].

The presence of multiple feeders represents also a risk factor for the recurrence of pAVFs, because the multiple shunting points are not always identifiable in the preoperative digital subtraction angiography (DSA).

This article is part of the Topical Collection on *Vascular Neurosurgery - Arteriovenous malformation*

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Description of the technique

The surgery is planned with an appropriate preoperative radiological assessment to study the precise anatomy of the vessels.

First-line imaging is represented by the MRI. The T2-weighted sagittal MRI shows the presence of the perimedullary dilated vessels and the hyperintensity signal, which represents an indirect sign of a pAVF (Fig. 1).

We then performed a double-injection DSA, which consists in an almost simultaneous injection of contrast in two different radicular arteries, previously cannulated. It allows to identify every vascular feeder of the AVF, in order to better understand its anatomy and to confirm its exclusion.

In our patient, the preoperative DSA showed a complex fistula with double feeders arising from the right radicular artery of Th8 and the right medullary artery of Th10 (Fig. 2).

The patient is positioned prone, with the head fixed in the Mayfield head clamp. Intraoperative monitoring for detection of motor and somato-sensitive evoked potentials (MEPs and SSEPs) is placed and baseline tracing recorded. The Th8-Th9 level is identified with a C-Arm fluoroscopy. The skin is cut with a midline linear incision, and the right hemilamina of Th8, Th9, and Th10 is exposed with a monopolar. Curved autostatic retractors are positioned. Under a microscope, a Th8-Th9 right hemilaminectomy is performed. The removal of the pedicle and dissection of extradural dentate ligament represent the crucial steps to allow the maximal visualization of the ventral surface.

Fig. 1 T2-weighted sagittal MRI shows the presence of perimedullary dilated vessels. It consists in an indirect sign of the spinal AVF

The dura is opened and suspended with 6–0 Prolene stitches. After the incision of the arachnoid, the abnormal vessels are exposed and meticulously isolated. After complete mobilization of the vessels, two different shunting points, one dorsal and one ventral, are identified and confirmed with a micro-Doppler. A first clip is placed in the dorsal shunting point. The ventral shunting point is exposed and identified after appropriate suspension of the dentate ligament. A temporary clip is placed in the ventral shunting point and the exclusion of the fistula confirmed with a micro-Doppler. The ventral temporary clip is replaced by the definitive clip. A final control with the micro-Doppler (Fig. 3) and the indocyanine fluorescence confirms the exclusion of the fistula. MEPs and SSEPs remained unaltered during the whole procedure. After accurate hemostasis, the dura is closed watertight. Paravertebral muscles are re-approached together and subcutaneous stiches with staples are used for the skin closure. The postoperative angiogram showes complete exclusion of the fistula. (Fig. 4).

Indications

Case selection includes a pial arteriovenous fistula (pAVF) of the thoracic spine radiologically confirmed with preoperative MRI and DSA in a patient with progressive myelopathy with ataxia and low-grade right lower limb weakness. According with the data in literature, endovascular treatment has a 64% of success rate in the exclusion of a pAVF, compared with more than 90% for surgical treatment [6, 9]. Considering the presence of a multiple shunting point pAVF, the surgical treatment is strongly recommended.

The described approach can be used, in general, with all the spinal AVFs.

Limitations

Clipping of a multiple-feeder pial AVF requires preoperative accurate planning. However, a double injection DSA is still not a standard preoperative procedure in the daily practice.

Without preoperative double-injection DSA, it is not always possible to identify a double shunting point pAVF, leading to a higher rate of recurrence [3].

In order to expose the ventral shunting point, it is necessary to remove the vertebral pedicle and to suspend the

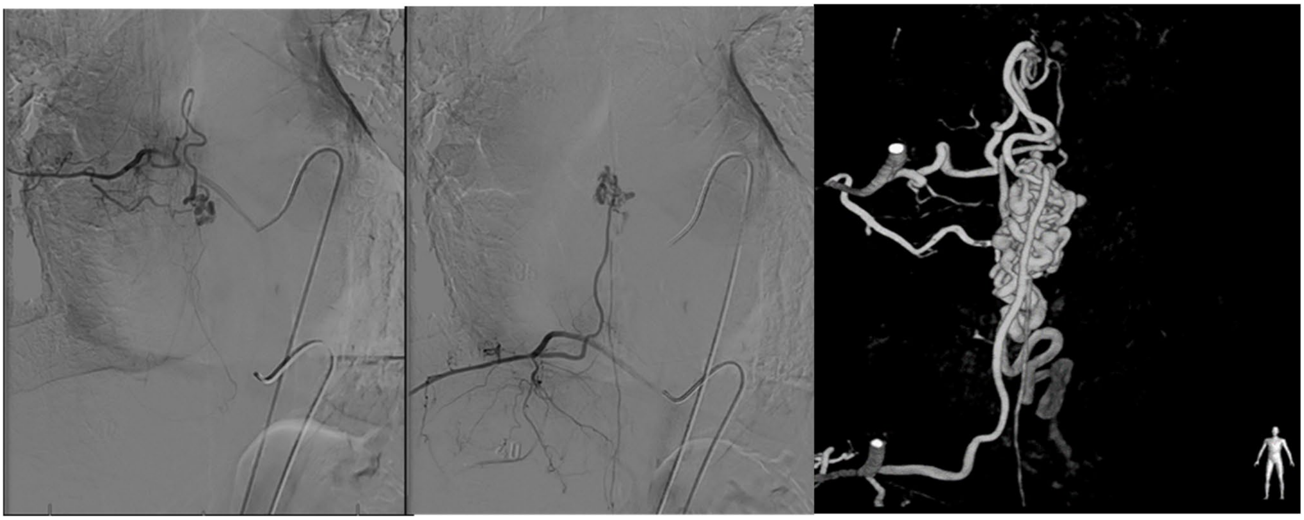


Fig. 2 Preoperative double injection microcatheter angiography, showing a multi-feeders fistula with vessels deriving both from the right radicular artery of Th8 and the right medullary artery of Th10. The 3D DSA reconstruction of the sAVF helps to understand the anatomy

dentate ligament; the risk of potential instability of the spinal segment remains negligible.

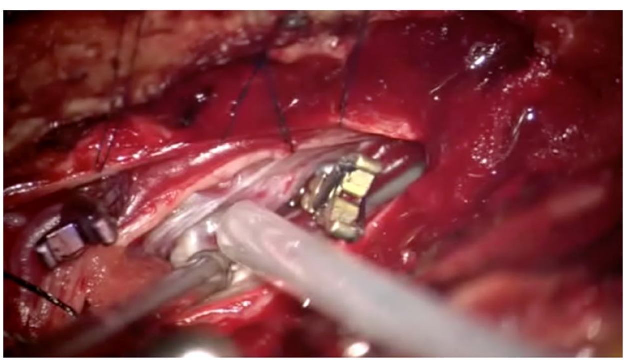


Fig. 3 The use of microdoppler allows to confirm the exclusion of the fistula and the patency of the neighboring vessels

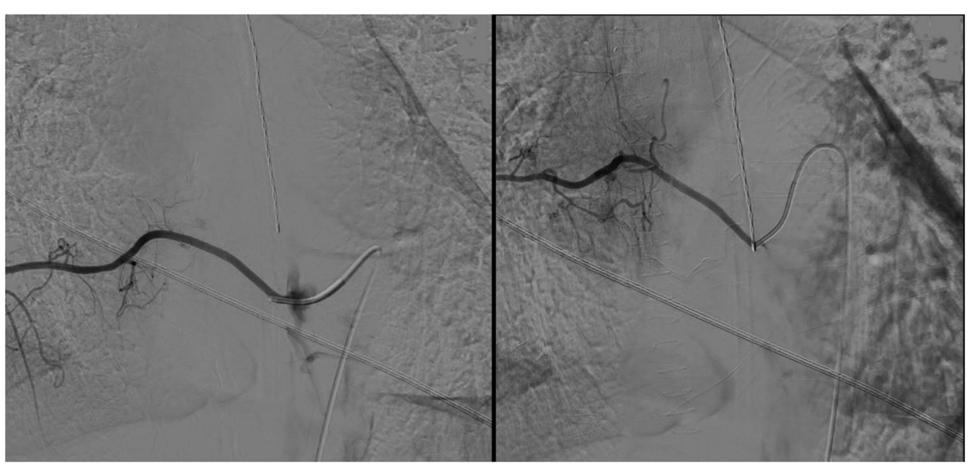
How to avoid complications

The first step consists in a good preoperative evaluation of the MRI and the DSA, in collaboration with neuroradiologists, to deeply understand the anatomy of the fistula and the feeders [5].

Especially in double shunting point fistula, a wide exposure of the vessels both dorsally and ventrally is mandatory to identify the anatomy and avoid complications due to suboptimal visualization. Nevertheless, the maximal exposure can be obtained with a hemilaminectomy, thus allowing the wide opening of the dura and the arachnoid layers. [10] An appropriate anterior exposure can request vertebral pedicle removal or thoracic vertebral root resection. Hemilaminectomy instead of spinosectomy plus bilateral laminectomy should be preferred in order to minimize the risk of instability.

The set of clips must be available, complete, and checked in advance and the surgeon must be familiar with.

Fig. 4 Immediate postoperative double injection angiography showing complete exclusion of the fistula



Hemostatic material and clips need to be ready in case of bleeding from accidental rupture of the pAVFs. Control of the blood pressure during the procedure is mandatory and the collaboration between surgical and anesthesiologic team is critical.

In order to decrease the risk of unnecessary vessel closure, it is suggested to use a temporary clip and check the correct exclusion with the use of a micro-Doppler and the indocyanine fluorescence.

Intraoperative neuromonitoring with SSEPs and MEPs is mandatory during the whole procedure [10].

Specific perioperative considerations (pre- and post-op workup, instructions for the postop care, etc.)

An immediate post-operative DSA should be performed, with the patient still intubated, to evaluate the correct exclusion of the fistula.

The patient should be carefully observed in the intensive care unit for the first 24 h and, once extubated, immediately examined neurologically to exclude new post-operative motor deficits. An MRI at 3 months and 12 months (Fig. 5) with a DSA at 6 months was performed for the patient.

Fig. 5 12 months follow-up MRI showing reduction of the dilated vessels and the T2 hyperintensity at the MRI, resulting in an improvement of the indirect signs of myelopathy

Specific information to give to the patient about surgery and potential risks

The accidental rupture of the pAVFs can determine an important bleeding difficult to stop.

The wide exposure can lead to sensitive deficit due to thoracic root section and potential instability due to pedicle removal and hemilaminectomy.

If the anatomy is not clear or the intraoperative check is not well performed, the clipping of the fistula can lead to normal blood flow interruption, causing ischemia and consequent severe neurological deficits. Additional risks to be mentioned are wound dehiscence and persistence of the shunt, despite the intraoperative evidence of exclusion.

Supplementary Information The online version contains supplementary material available at https://doi.org/10.1007/s00701-022-05472-8.

Declarations

Ethics approval This work has been conducted in compliance with the protocol, the current version of the Declaration of Helsinki, the ICH-GCP or ISO EN 14155 (as far as applicable) as well as all national legal and regulatory requirements. Diagnostic and surgical procedure have been conducted according with the standard operating procedures of the hospital policy, approved by the ethical commission. Informed consent form has been correctly signed by the patient who gave his approval for the use of the data for the present publication.

Informed consent The patient consented to the procedure.

Consent for publication The patient gave his informed consent for the redaction and publication of the paper and the intraoperative video.

Conflict of interest The authors declare no conflict of interest.

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Key points 1. Preoperative micro-catheterization and double-injection DSA to understand the fistula's anatomy.

2. Identification and double check of the correct spinal level with fluoroscopy.

3. Wide surgical exposure with hemilaminectomy (should be sufficient), dura and arachnoid opening.

4. If necessary, removal of the vertebral pedicle and/or section of the thoracic spinal root section.

5. Use of a temporary clip and check the correct exclusion with a micro-Doppler and/or indocyanine green fluorescence.

6. Use of the intraoperative neuromonitoring.

7. Perform an early postoperative angiography to confirm exclusion.