Spinal arteriovenous lesions: anatomical and radiological approach

Poster No.: C-2783
Congress: ECR 2019
Type: Educational Exhibit
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Keywords: Neuroradiology spine, Vascular, Anatomy, CT-Angiography, MR-Angiography, Catheter arteriography, Diagnostic procedure, Arteriovenous malformations, Fistula
DOI: 10.26044/ecr2019/C-2783

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Learning objectives

• To know the vascular anatomy of the spine.
• To propose a simplified algorithm for radiological diagnosis, based on Kim and Spetzler’s classification of spinal arteriovenous lesions.
• Exemplify the different spinal arteriovenous lesions with radiological cases.
Background

Spinal arteriovenous (AV) lesions are a group of diverse and infrequent entities (5-10 cases / million), characterized by an abnormal communication between arteries and veins in the spine.

The understanding of their physiopathology has evolved gradually along years, resulting in different classifications and nomenclatures. One scheme divides spinal AV lesions according to their feeding artery in meningeal and pial lesions. This classification may be useful, however, we believe that it is difficult to apply in daily practice of neuroradiological diagnosis. Other nomenclature, based in physiopathology and anatomy aspects, divide spinal AV lesions in fistulas and malformations. We believe that this classification is easier to apply in neuroradiological practice.

These abnormal shunts leads to congestion and venous hypertension, hemorrhages, mechanical compression and vascular steal.

Spinal AV lesions, usually underdiagnosed, can manifest with a wide variety of neurological symptoms, so a high suspicion index is required.

The imaging findings depends on the technique to be used. MRI is the best non-invasive diagnostic method. It demonstrates flow voids along spinal cord in a peri/intramedullary situation, usually associated with central T2 hyperintensity, swelling and sometimes some degree of Gadolinium enhancement of the spinal cord. The spinal cord atrophies over time. Conventional spinal angiography remains the gold standard to confirm the diagnosis, define precisely the vascular architecture of the lesion and planify the treatment.
Findings and procedure details

VASCULAR ANATOMY

Arteries:

Each segment of the spine (metamere) is supplied by paired segmental arteries (left and right) that feed all its components, including the vertebral body, paraspinal muscles, dura, nerves roots and spinal cord. Those segmental arteries have multiple longitudinal and transverse connections at different levels, configuring two network anastomoses: a extraspinal and intraspinal-extradural system (Fig. 1 on page 8, Fig. 2 on page 8).

The segmental artery gives a dorsal branch, the dorsal spinal artery. This artery irrigates the posterior elements, giving a dorsal branch and a ventral branch. The dorsal branch of the dorsal spinal artery gives muscles branches that feed the post-transverse anastomotic network that communicates with the adjacent upper and lower levels. The ventral branch of the dorsal spinal artery travels through the neural foramen, sends branches that irrigate the epidural and dural elements, as well as a radicular artery to supply the nerve root (Fig. 2 on page 8).

In some levels, the radicular artery has greater caliber and reaches the spinal cord, where it contributes to the formation of the anterior spinal artery. This type of radicular artery is known as radiculomedullary artery (Fig. 1 on page 8).

The number of radiculomedullary arteries that feed the anterior spinal artery is not constant (6 to 10) and its origin is unpredictable. Classically, there are two dominant radiculomedullary arteries, one at the cervical level and the other at the dorso-lumbar level (Adamkiewicz). The Adamkiewicz artery originates in 80% of cases between T9 and L3 on the left side, 15% on the right side and 5% on other levels.

On the anterior surface of the spinal cord, the radiculomedullary arteries form a longitudinal connection called the anterior spinal artery, that travels along the anterior sulcus and predominantly supply the gray matter of the spinal cord. Radiculomedullary arteries, specially the prominent Adamkiewicz artery, present an identifying "hairpin turn" at their anastomosis with the anterior spinal artery.

On the posterolateral surface of the spinal cord, the radiculopial arteries form two longitudinals connections called posterior spinal arteries. They are in fact a discontinuous
longitudinal system which predominantly supply the surface of the spinal cord, i.e., the white matter.

In the medullary cone, an "arterial basket" is formed between the anterior spinal artery and the posterior spinal arteries, which anastomose via the "rami cruciantes" (Fig. 3 on page 9).

**Veins:**

The blood of the spinal cord parenchyma is drained by intrinsic veins in a radial and horizontal pattern until the radial veins reach the surface of the cord. At the level of the spinal pia-mater, blood is accumulated in essentially two longitudinal collectors (extrinsic): the anterior and posterior median spinal veins (Fig. 4 on page 10).

The superficial venous blood collectors drain into the epidural venous plexus through radicular veins. The transition of the midline vessel to the radicular vein forms a hairpin course, similar to the arterial configuration.

**CLASSIFICATION OF SPINAL ARTERIOVENOUS LESIONS**

Kim and Spetzler proposed a classification of spinal arteriovenous (AV) lesions based on anatomical and pathophysiological factors, as well as intraoperative observations and imaging characteristics, dividing them into:

**Arteriovenous fistulas (AVF):**

Correspond to AV lesions where there is a direct communication between an artery and a vein, without an interposed capillary network or vascular nidus. They are the most frequent type of spinal AV lesions (70%), and tend to affect older and middle-aged men (> 40 years old). They are presumably acquired and their symptoms are predominantly due to venous hypertension.

According to their location AVF are classified in:

a. Extradural AVF.

b. Intradural dorsal AVF.

c. Intradural ventral AVF.

**Arteriovenous malformations (AVM):**
Correspond to AV lesions where there is a communication between an artery and a vein with an interposed vascular nidus. They are less frequent (30%), without predilection for gender and tend to affect younger people. They are presumably congenital and their symptoms are predominantly due to hemorrhage, compression, vascular steal and venous congestion.

According to their location they are classified in:

a. Extradural-intradural AVM.
b. Intramedullary AVM.
c. Conus medullary AVM.

**Types of AVF:**

**EXTRADURAL AVF #**

Corresponds to a communication between a branch of an extradural artery and a vein of the epidural plexus. There is significant dilatation of the venous plexus, with mass effect and compression of adjacent roots and spinal cord, with subsequent venous hypertension, vascular steal and myelopathy (Fig. 5 on page 11, Fig. 6 on page 12).

**INTRADURAL DORSAL AVF #**

Corresponds to a communication between the radicular artery and the medullary venous system, at the dural sleeve of the nerve root. It produces obstruction of the venous outflow with arterialization of the venous plexus, venous hypertension and myelopathy (Fig. 7 on page 13).

**INTRADURAL VENTRAL AVF #**

Corresponds to a ventral lesion of the midline in the subarachnoid space, with a fistula between anterior spinal artery and a dilated venous network. It produces similar physiopathological alterations than its dorsal counterpart (Fig. 8 on page 14, Fig. 9 on page 15). There are 3 subtypes (A, B, C), depending on the size of the lesion.

**Types of AVM:**

**EXTRADURAL - INTRADURAL AVM #**

Also known as juvenile or metameric AVM.
Corresponds to an extensive lesion with a nidus that compromise a metameric level (bone, muscle, skin, spinal canal, spinal cord and nerve roots) (Fig. 10 on page 16, Fig. 11 on page 17).

INTRAMEDULLARY AVM #

Analogous to an intracranial AVM. Corresponds to an AV lesion with communication between an artery and a vein with an interposed vascular nidus, located completely in the medullary parenchyma. They present one or multiple feeders of the anterior/posterior spinal arteries (figure 9). They are subdivided into compact or diffuse types, depending on the angioarchitecture of the nidus (Fig. 12 on page 18, Fig. 13 on page 19).

CONUS MEDULLARY AVM #

Corresponds to a different category AVM, located in the conus medullaris, with a complex angio-architecture characterized by multiple feeders of the anterior and posterior spinal arteries, with direct AV communications, a nidus and markedly dilated veins (Fig. 14 on page 20, Fig. 15 on page 21).

DIAGNOSTIC ALGORITHM

To facilitate the imaging diagnosis, we propose the use of a simplified diagnostic algorithm based on Kim and Spetzler's classification (Fig. 16 on page 22):

STEP 1: Define the presence / absence of a vascular nidus.

1. With nidus# AVM.
2. Without nidus# AVF.

STEP 2: Evaluate the anatomical location of the lesion to obtain the diagnosis.
Fig. 1: Schematic representation of the spine arterial anatomy, anterior oblique view.

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Fig. 2: Schematic representation of the spine arterial anatomy, transverse view (similar to a CT or MRI axial slice).

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**Fig. 3:** Schematic representation of the arterial anatomy of the conus medullaris, anterior oblique view.

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**Fig. 4:** Schematic representation of the spinal cord venous anatomy, anterior oblique view.

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**Fig. 5:** Schematic representation of an extradural AV fistula.

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**Fig. 6:** Extradural AV fistula. 72 y/o woman. Dilated abnormal vascular structures in the vertebral body and in the anterior epidural space (arrows in A, B and C). MR angiogram shows abnormal communication between a branch of an extradural artery and vein of the epidural plexus (arrow in D).

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Fig. 7: Schematic representation of an intradural dorsal AV fistula.

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Fig. 8: Schematic representation of an intradural ventral AV fistula.

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Fig. 9: Intradural AV fistula. 23 y/o woman. Dorsolumbar intradural vascular dilations (white arrows in A and B). Spinal cord edema (blue arrows in A and B). Enhancement with Gadolinium (arrow in C). The angiography shows the Adamkiewicz artery in left T11 (white arrow in D), tortuosity of the anterior spinal artery (blue arrow in D) and intradural fistula in T12 (arrow E); there is absence of a vascular nidus.

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Fig. 10: Schematic representation of an extradural-intradural ventral AV malformation.

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**Fig. 11:** Extradural-intradural AV malformation (metameric). 5 y/o girl. Large cervical vascular nidus with medullary and subarachnoid involvement (white arrows in A, B and C), as well as dural and extradural involvement (blue arrows in B and C). Angiography shows AVM’s nidus (white arrows in D and E) with feeders from the thyrocervical trunk and the vertebral artery (blue arrows in and, E).

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**Fig. 12:** Schematic representation of an intramedullary AV malformation.

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Fig. 13: Intramedullary AV malformation. 22 y/o man. MR evidences cervicodorsal hematomyelia (white arrows in A) and dilated vascular structures (blue arrows in A). Gadolinium study shows an intramedullary lesion with a vascular nidus aspect at T4 level (blue arrows in B, C). Angiography confirmed the presence of an intramedullary vascular nidus (blue arrow in D).

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**Fig. 14:** Schematic representation of a conus medullaris AV malformation.

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**Fig. 15:** Conus medullaris AV malformation. 33 y/o woman. An intramedullary vascular nidus is identified at the level of the conus (blue arrows in C and D), associated with multiple intradural extramedullary anomalous vascular structures (white arrows in A, B and C).

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Fig. 16: Simplified diagnostic algorithm of spinal AV lesions. The first step is to define the presence/absence of the vascular nidus. As a second step, the anatomical location of the lesion is evaluated to obtain a diagnosis.

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Conclusion

To better understand the spinal AV lesions is necessary to know the normal vascular anatomy, as well as their physiopathological mechanisms.

The use of a simplified algorithm based on the presence or absence of vascular nidus, in addition to its anatomic location, maybe useful in the radiological diagnosis of the spinal AV lesions.
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