· 专题讲座 ·

Spinal arteriography: a primer

David A KUMPE *

(*University of Colorado Health Sciences Center, Denver, Colorado* 80262, *USA*)

ABSTRACT Spinal arteriography is an esoteric procedure that is seldom performed by peripheral interventionalists. This presentation is intended to outline some of the essential points that the interventionalist performing the procedure should be aware of, especially about spinal dural arteriovenous fistulae (SDAVF).

KEY WORDS Spinal arteriography; Spinal dural arteriovenous fistulae; Treatment, interventional

0 Introduction

The reason for performing spinal arteriography is either to detect and depict a spinal vascular malformation or to evaluate and potentially treat a vascular tumor involving the spinal column, particularly renal cell carcinoma.

1 Classification of spinal vascular malformations

1.1 The classical division of spinal malformations is[1]:

- Arteriovenous malformation
  - Perimedullary fistula Types Ⅰ, Ⅱ, Ⅲ
  - Glomerular
  - Juvenile
- Cavernoma
- Dural AVF

1.2 Spetzler proposed a modified classification in 2002[2]:

- Neoplasm
  - Hemangioblastomas
  - Cavernous malformations
- Aneurysm
  - Spinal aneurysms (rare)
- Arteriovenous lesions
  - Arteriovenous fistulas
    - Extradural
    - Intradural
      - Dorsal
      - Ventral
  - Arteriovenous malformations
    - Extradural-intradural
    - Intradural
      - Intramedullary
      - Intramedullary-extramedullary
      - Conus medullaris

Certainly most interventionalists have seen images of complex vascular malformations of the spine. Most give up trying to understand the various types of malformations. However, there is one spinal vascular malformation which should be differentiated from all other types and recognized by non-neurointerventionalists: spinal dural arteriovenous fistulae (SDAVF). These lesions are far more common than any other type of malformation, comprising 70%—90% of all spinal vascular malformations, and as such are more likely to be encountered in daily practice. In brief, SDAVF almost always have a single arterial feeder (very occasionally two) and require localized embolization and/or operation, whereas other types of vascular malformations generally have multiple arterial feeders and require complex embolizations and one or multiple large operation (s). In the Spetzler classification these are Arteriovenous fistulas which are Intradural, Dorsal.

2 Basic spinal cord arteriography and anatomy

The spinal cord is 45 cm long. There are multi-

Correspondence to: David A Kumpe, MD, Fellow of the American College of Radiology, Professor of Radiology, Surgery, and Neurosurgery at the University of Colorado Health Sciences Center and Director of Interventional Neuroradiology at the University of Colorado Hospital, USA. Address: Room 2244, Department of Radiology, University of Colorado Health Sciences Center, 4200 East Ninth Avenue, Denver, Colorado 80262, USA. E-mail: david.kumpe@uchsc.edu

Tel: 303-372-6141 Fax: 303-372-6360

Received: 2005-04-20 **Accepted:** 2005-05-23

ple sources of arterial supply. Anterior and posterior branches originate separately from vertebral, costocervical, intercostal, lumbar, sacral segmental branches. There are 41 potential arterial sources for spinal cord arterial supply (**Fig. 1, Table 1—3**). A complete spinal arteriogram involves selective arteriography of each of these arteries.

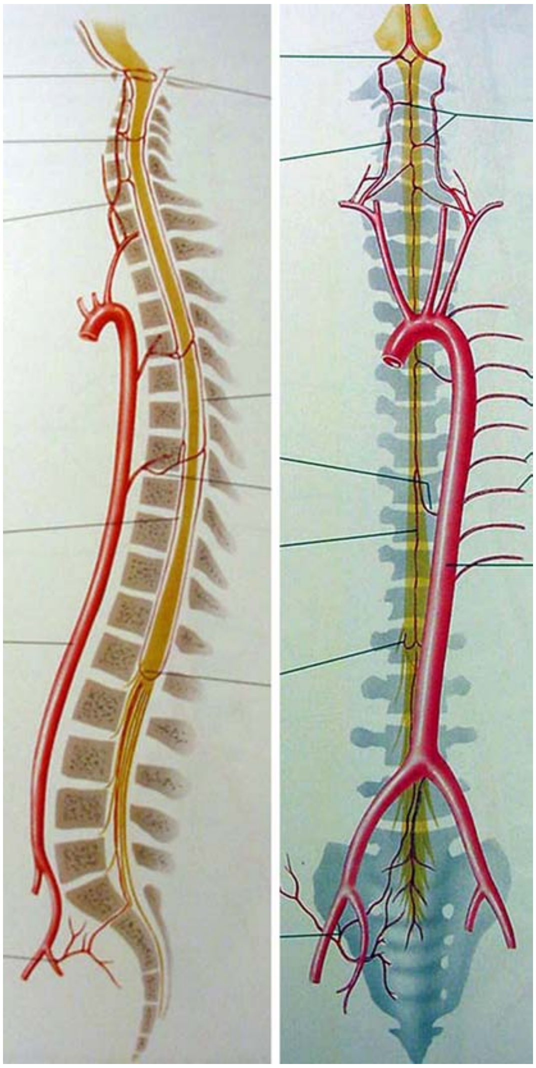

Fig. 1 Multiple sources of arterial supply

Table 1 Potential arterial sources for spinal cord arterial supply: cervical

Artery	Left	Right
Vertebral		
Costocervical (deep cervical)		
Thyrocervical (ascending cervical)		

Table 2 Potential arterial sources for spinal cord arterial supply: thoracic

Artery	Left	Right
Supreme intercostal		
T—4		
T—5		
T—6		
Bronchial(s) (1—3)		
T—7		
T—8		
T—9		
T—10		
T—11		
T—12		

Table 3 Potential arterial sources for spinal cord arterial supply: lumbar

Artery	Left	Right
L—1		
L—2		
L—3		
L—4		
Iliolumbar		
Lateral sacral		
Sacral		

In order to keep these branches straight, a chart is prepared with three columns, labeled Artery, Right, and Left. Check marks are made in each box as the artery is studied. Some useful technical points for performance of spinal angiography are as follows:

(1) Place a marking tape on chest to help number the level;

(2) Take preliminary images—large field;

(3) Try to catheterize arteries in order on one side;

(4) Image in single plane initially;

(5) Catheter: Mikaelsson, Cobra 4F, 5F;

(6) Hand inject 2—4 milliliters Visipaque;

(7) Frame rate 2 frames per second for 4 seconds, then 1 frame per second;

(8) Localize feeders—Indicate the feeders to the AVM on the chart with asterixes (*), and indicate the size of the feeder with one to three asterixes (* =small feeder; * * =larger feeder; * * * =very large feeder). Also, indicate on the chart whether

the feeder is anterior (a) or posterior (p);

(9) Localize artery of Adamkiewicz—Mark as A on recording sheet;

(10) After all feeders are localized with single plane imaging, do biplane imaging of the feeding arteries at 3—5 frames per second for 5 seconds, then 1 frame per second;

(11) Decide whether embolization is appropriate;

(12) If embolization is appropriate, review the contrast load: decide whether to perform immediate embolization or 2nd procedure?

(13) If no embolization, mark the skin over the involved foramen to help mark the correct level for the neurosurgeon.

There are 4 arterial groups to sort out at each level (**Fig. 2**): Intercostal (lumbar); posterior musculature; vertebral body; and spinal. Oblique views are usually necessary to sort out the region supplied by many of the arterial branches seen.

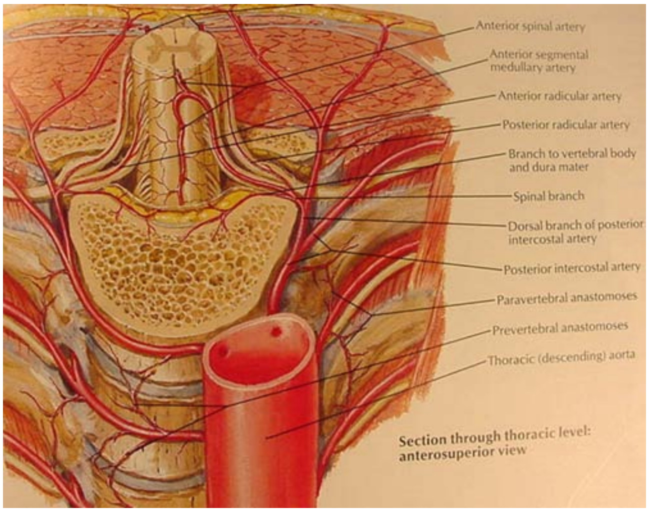

Fig. 2　Four arterial groups to sort out at each level

It is vital in all studies to identify the artery of Adamkiewicz (anterior radioculomedullary artery, ARMA, **Fig. 3**). It is usually found between T9 and T12 but it may occur either cranial or caudal to these levels.

3　Spinal dural arteriovenous fistulae (SDAVFs)

One should have some knowledge of SDAVFs, as these are the most frequently occurring spinal vascular malformation. These lesions are frequently missed for a year or more after symptoms begin. They are the most curable of all the spinal vascular malformations.

Fig. 3　The artery of Adamkiewicz (anterior radioculomedullary artery, ARMA)

SDAVFs have a male predominance (80%). Most patients present at age of 40—60 years old. The median time from onset of symptoms to diagnosis is 15 months. The most common location for these lesions is mid-thoracic (**Fig. 4—6**). They are very uncommon in the cervical region. Another rare lesion, the perimedullary fistula Type I, however, has a similar angiographic appearance and does occur in the cervical region.

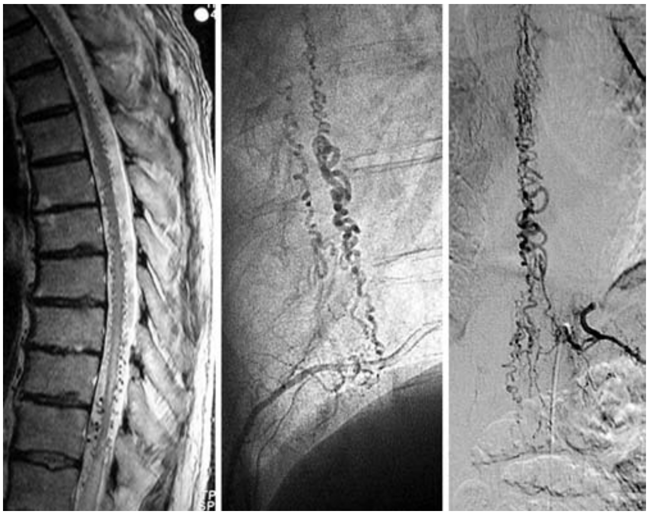

Fig. 4　MRI and angiogram showing SDAVF typically arising in the mid-lower thoracic region

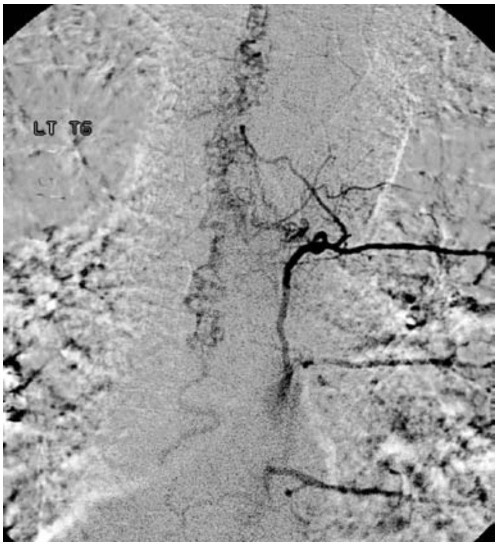

Fig. 5　Upper thoracic origin of SCDAVF

Fig. 6　Sacral origin of SDAVF

Anatomically, there is shunting in the dura at one foramen. The pathophysiology of these lesions is well recognized. Increased spinal venous pressure produces a decreased A-V pressure gradient, leading to decreased drainage of normal spinal veins, which produces venous congestion and intramedullary edema. This pathophysiology explains the characteristic MRI finding: on T2 MR image there is hyperintensity in the spinal cord due to venous congestion and edema (**Fig. 7**). There is typically a peripheral hypointensity around the region of hyperintensity. Serpiginous filling defects are present outside the cord and represent the dilated veins. The veins are characteristically concentrated posterior to the cord, but are seen anteriorly as well.

Fig. 7　Sagittal T2 weighted MRI images in 3 different cases of symptomatic SDAVF. Hyperintensity in the cord surrounded by a peripheral hypointensity due to venous congestion, and probably edema of the cord (arrows). Serpiginous filling defects due to surrounding distended veins (arrowheads)

Treatment options include both surgical obliteration of the shunt point and draining vein at the affected foramen, or embolization, generally with NBCA glue as the primary agent, with particles or coils used to help direct the glue to the proper location (**Fig. 8**). If glue embolization is to be performed, it is vital that the glue enter the draining vein at the foramen to successfully and permanently obliterate the fistula. If there is a simple fistulous connection between artery and vein involving only one or two artery-to-vein connections, glue will likely penetrate to the draining vein. When the anatomy is more complex, with multiple artery-to-vein connections, glue will often not penetrate sufficiently. Such complex lesions are better operated. Reported success rates for embolization range from 25%－70%. Embolization is likely to be successful when the arteriovenous connection is a simple one with only one or two arteries participating in the fistula. When multiple small arteries are feeding the fistula, the likelihood of success with embolization is much less. Surgical success in obliterating

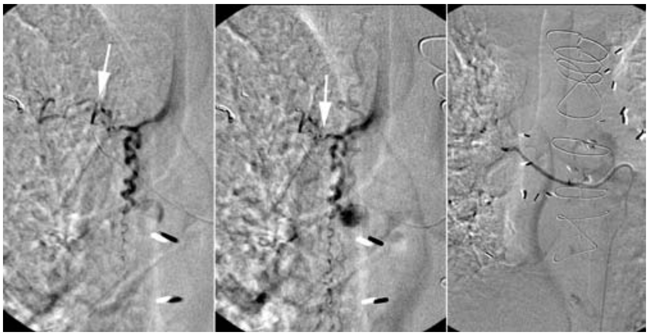

Fig. 8 Selective catheterization of artery to SDAVF　left: feeding artery (arrow); middle: fistula (arrow); right: SDAVF disappeared after embolization

the lesion is usually >90%.

4 Clinical results of treating SDAVFs

Success rate of embolization of treating SDAVF was 25%-70% in past reports, but should be better currently because of better patient selection. The largest single institution series (110 patients) found in the literature was from China[3]. Less positive (but still excellent) results were reported in another large series by a Dutch group in several papers[4,5]. This large series gives insight into the clinical presentations of the patients as well as the results of treatment with either/both surgery and embolization. 83% of their patients were male, with a median age of first symptom of 57.6 years (range 21-78 years). Median interval to diagnosis was 15.0 months (range 7 days-16.4 years). The initial presenting symptoms were gait disturbance in 34%, numbness in 24%, and paresthesias in 21%. At the time of presentation, 80% had urinary problems, 78% had leg weakness, and 19% had progressed to being wheelchair bound. The pattern of motor deficit progression was gradual in 63%, acute episodes on gradual progression in 26%, stepwise progression in 7%, and acute in 5%. Forty-four patients were available for later follow up following treatment. Thirty-four had embolization as the first procedure, and 10 were operated as the first procedure. Nine patients underwent multiple embolizations, and 5 had surgery after unsuccessful embolization. Median time of followup was 5.7 years (range 8 months-15 years). Clinical improvement was mixed. Overall 70% of patients said that their overall daily life activities were better, while 7% were worse and 11% were much worse. When asked about specific functions, patients rated walking and muscle power as better; on the other hand, numbness, paresthesias, micturition, anal sphincter function, and erectile function were unchanged; leg pain and muscle spasm were worse. The lack of improvement in some functions probably represents permanent nerve damage which occurred before the lesion was corrected.

In conclusion, spinal arteriography is technically somewhat demanding, tedious because of the large number of selective catheterizations, exacting because of the necessity to image every arterial branch, and also time consuming. The interventional neuroradiologist has an obligation to produce a diagnostic study. The procedure should include image processing, image analysis (subtraction, pixel shifting by radiologist), and identification of normal spinal arteries, such as Artery of Adamkiewicz, that are all critical for treatment planning. The interventional neuroradiologist also has a role in treating appropriately selected spinal vascular malformations.

References

[1] Krings T, Mull M, Gilsbach JM, et al. Spinal vascular malformations. Eur Radiol, 2005,15(2):267-278.

[2] Spetzler RF, Detwiler PW, Riina HA, et al. Modified classification of spinal cord vascular lesions. J Neurosurg, 2002,96(2 Suppl):145-156.

[3] Li M, Zhang HQ, Zhi XL, et al. Diagnosis and treatment of spinal dural arteriovenous fistulas: 110 cases report. Zhonghua Wai Ke Za Zhi, 2003,41(2):99-102.

[4] Jellema K, Canta LR, Tijssen CC, et al. Spinal dural arteriovenous fistulas: clinical features in 80 patients. J Neurol Neurosurg Psychiatry, 2003,74(10):1438-1440.

[5] Jellema K, Tijssen CC, van Rooij WJ, et al. Spinal dural arteriovenous fistulas: long-term follow-up of 44 treated patients. Neurology, 2004,62(10):1839-1841.