VASCULAR IMAGING OF THE SPINE

Ashutosh P. Jadhav, MD, PhD
University of Pittsburgh
Pittsburgh, PA

1. Overview:

a. Major vascular pathologies of the spine include spinal cord infarct and vascular anomalies.
b. Neuroimaging is critical in diagnosis, pre-surgical planning and treatment of spinal cord disease.
c. MRI is valuable in distinguishing spinal cord infarct from other pathologies as well as identifying hemorrhagic pathologies such as acute hemorrhage (spinal SAH, EDH, SDH) and cavernomas and supportive evidence of vascular anomalies (prominent arterial feeders, engorged veins, cord edema, chronic blood products).
d. CT angiography and MR angiography are increasingly sensitive modalities which can play a role in identifying critical normal vasculature (e.g. artery of Adamkiewicz), revealing spinal aneurysms as well as localizing feeding arteries, nidus and draining veins in the case of spinal AVM or dAVF.
e. Catheter based spinal angiography is an invasive technique reserved in cases of diagnostic uncertainty. This modality remains the gold standard for the elucidation of vascular anatomy.
f. Endovascular approaches are increasingly utilized for the treatment of spinal aneurysm, AVM and dAVF as well as for pre-operative embolization of spinal tumors.

2. Indications for imaging

a. Diagnostic evaluation of suspected spinal vascular pathology
b. Pre-operative evaluation of spinal anatomy
    i. Identify artery of Adamkewiecz prior to aortic surgery (risk of spinal cord ischemia 3-5%)
    ii. Identify arterial feeders and venous drainage in the case of AVM/dAVF
    iii. Shorten procedural time and contrast usage
    iv. Post-operative followup after surgical treatment of vascular anomaly
c. Surveillance imaging after surgical intervention or with conservative management

3. Vascular Anatomy

a. 31 pairs of segmental arteries
b. Fetal stage: all supply cord but in adults only 6-10
c. Cervical segment (best supplied): Vertebral artery (V4 segment and branches from V2/3), deep cervical artery, ascending cervical artery, Inferior thyroid artery, supreme intercostal artery , 2-4 radicular arteries
d. Thoracic segment (T3-T7): watershed region with only 2-3 radicular arteries supplying cord
e. Lower thoracic segment and lumbar segment: 0-4 radicular arteries as well as the major supply (Artery of Adamkiewicz), lumbar arteries, Iliolumbar and median/lateral sacral arteries, conus artery (Desprogres-Gotteron)

4. Two major pathologies:

a. Ischemia

i. Accounts for 1-2% of all neurovascular pathology and 6% of all acute myelopathies
ii. Causes
    1. Pediatrics: cardiac malformations and trauma
    2. Adults: atheroma, abdominal aneurysm, aortic surgery, embolic, dissection, hypotension, spinal AVM, diving, coagulopathies, sickle cell disease, cocaine
iii. Time course: peak at 12-72 hours
iv. Symptoms: weakness, back pain (70%)
v. Treatment: supportive, permissive hypertension, lumbar drain

vi. Syndromes
    1. Anterior spinal artery: bilateral motor and pain/temperature loss (sparing of proprioception and vibration); flaccidity and hyporeflexia followed by hyperreflexia and spasticity; autonomic dysfunction (bowel, bladder, sexual dysfunction; hypotension); respiratory compromise if high cervical
    2. Anterior horn syndrome: pure motor (painful brachial diplegia if cervical) followed by progressive distal amyotrophy over time
    3. Sulcal artery infarct: partial Brown-Sequard syndrome (ipsilateral hemiparesis with contralateral spinothalamic sensory loss)
    4. Central spinal infarct: bilateral spinothalamic sensory deficit
    5. Transverse medullary infarct: bilateral motor; complete sensory; loss of bowel/bladder
    6. Posterior spinal artery infarct: anesthesia at site of occlusion and loss of vibration/proprioception below the site of occlusion

b. Hemorrhagic

i. Manifestations: SAH, Epidural Hematoma, Subdural Hematoma, Superficial Siderosis, Contusion
ii. Causes: Vascular Malformations, Cavernous Malformation, Spinal Artery Aneurysm, Trauma

5. Imaging modalities:

a. Cord: MRI spine

i. Can be helpful in detecting presence of frank fistulas, a nidus of serpentine signal voids in AVMs, or posteriorly draining enlarged veins in dural arteriovenous fistulas (AVFs), venous congestion, blood products associated with cavernoma or partially thrombosed AVM
ii. MR may show cord edema but location of edema does not predict level of shunt
iii. Increasingly utilized to detect spine ischemia
iv. Sagittal plane: larger coverage with shortage acquisition time
v. Axial plane: better visualization of both sides of median line
vi. Contrast: absent enhancement in acute stage but can help differentiate mimics
vii. Usually >1 vertebral level
viii. Acute findings after infarct: DWI: restricts; T2/STIR: hyperintense; involves grey matter; central ‘owl’s eye’ pattern; T1: isointense, slight cord enlargement

b. Vascular anatomy: DSA, MRA, CTA

i. Limitations of DSA: Invasive, Contrast can be nephrotoxic and used in large quantities (300 mL), Radiation exposure, Time intensive, Small risk of major complication (<1%), to localize the possible feeders, selective catheterization of all arteries potentially supplying the spinal cord and its meninges may be required including vertebral, costocervical, and thyrocervical trunks and all of the intercostal lumbar and iliolumbar arteries, Multiple sessions may be required
ii. Advantages of CTA: Large field of view, Higher spatial resolution, co-visualization of bone and vasculature, 3-4 times shorter exam time
iii. Limitations of CTA: Poor background suppression (unless pre-contrast scan performed), contrast exposure, radiation exposure
iv. Limitations of MRA: Traditionally (before year 2000), MRA was not able to detect normal spinal arteries and veins. Furthermore, delineation of vein versus artery was poor, Newer techniques aim to improve spatial coverage, spatial resolution and temporal resolution, optimizing one parameter can sacrifice another parameter

v. Challenges of MRA:
    1. Coverage: need large field of view (AKA can arise anywhere along thoracolumbar spine)
    2. Resolution: spinal arteries and veins have small caliber and can run close together spatially
        a. Anterior spinal artery: 0.2-0.8 mm
        b. Adamkewiecz: 0.5-1 mm
        c. Vein: 0.4-1.5 mm
    3. Temporal: great anterior radiculo-medullary vein is larger than the Artery of Adamkiewicz and could be mistaken for artery and so transit time has to be well resolved
        a. AV circulation time: 9-12 second

REFERENCES:

1. Thron A. Vascular Anatomy of the Spine. Oxford: Oxford University Press; 2002
2. Lasjaunias P, Berenstein A, TerBrugge KG, eds. Spinal and Spinal Cord Arteries and Veins. Berlin: Springer-Verlag; 2001
3. Oda S, Utsunomiya D, Hirai T, et al. Comparison of dynamic contrast-enhanced 3T MR and 64-row multidetector CT angiography for the localization of spinal dural arteriovenous fistulae. AJNR Am J Neuroradiol 2014;35:40712.
4. Backes WH, Nijenhuis RJ.. Advances in spinal cord MR angiography. AJNR Am J Neuroradiol 2008;29:619–31
5. Novy J, Carruzzo A, Maeder P, Bogousslavsky J. Spinal cord ischemia: clinical and imaging patterns, pathogenesis, and outcomes in 27 patients. Arch Neurol. 2006 Aug;63(8):1113-20.