Spinal Vascular Anatomy and Pathology

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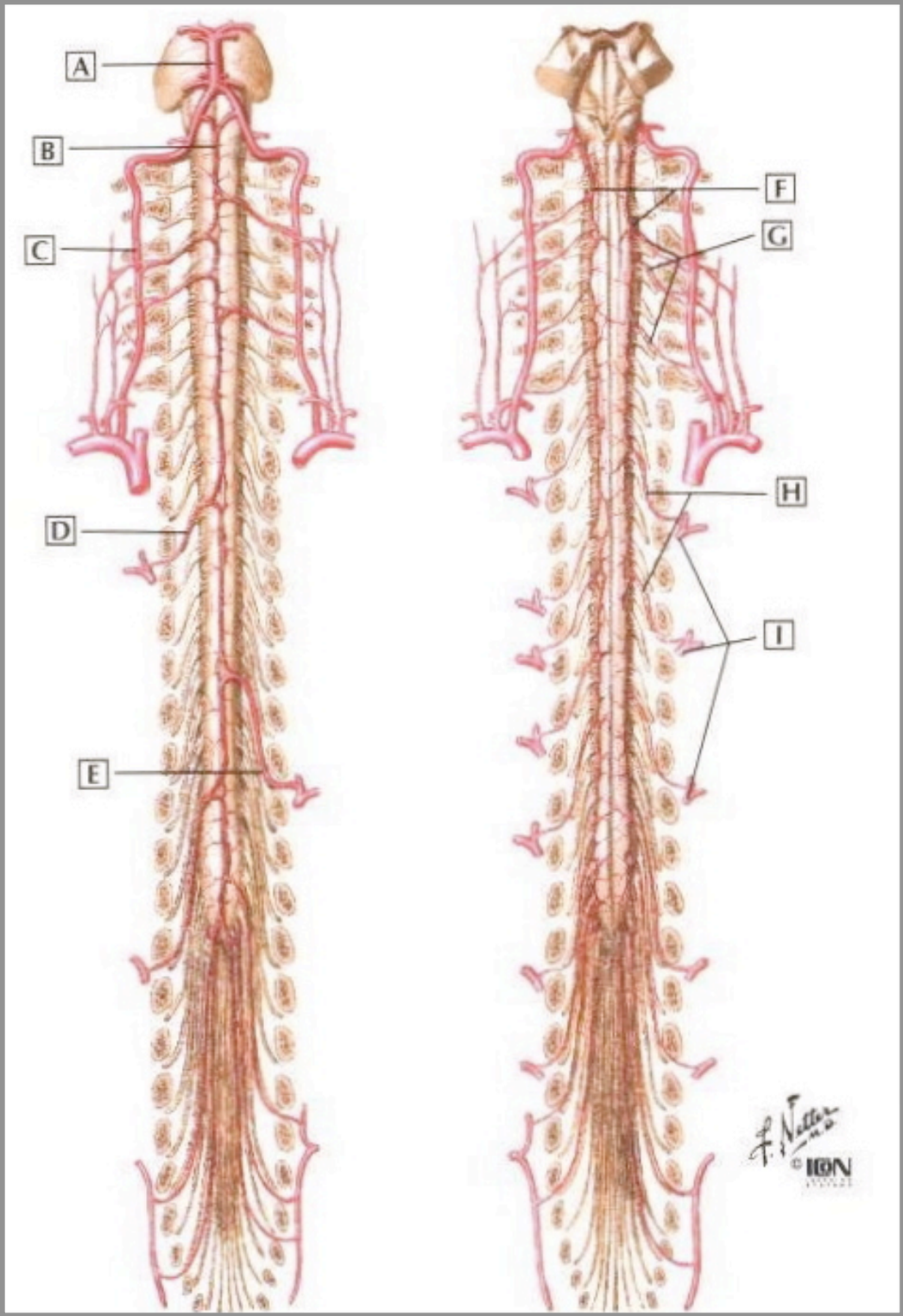
Objectives

- Arterial supply
- Venous Drainage
- Vascular Pathology
- Case Presentation

Blood Supply to the Spine and Spinal Cord

Arterial Supply to the Spinal Cord



Upper Spinal Cord

C1-4 : Ant and Post spinal arteries
C5-6 : Ascending vertebral artery and branches from thyrocervical trunk
C7-T3: Costocervical trunk

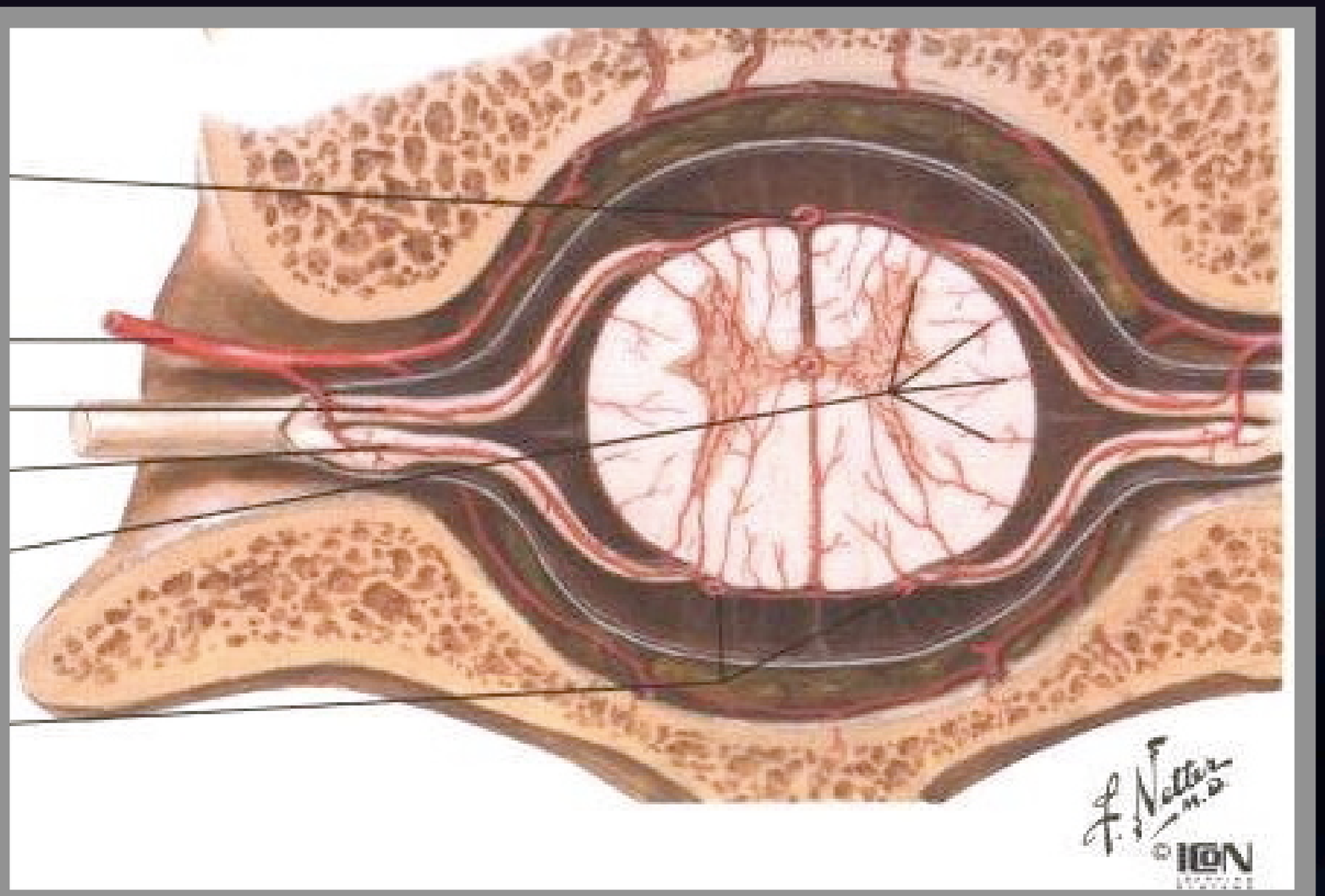
Middle Spinal Cord

T4-8 : Supplied mainly by a single thoracic radicular artery @ T7 from aorta

Lower Spinal Cord

T9-Sacrum: Supplied mainly by a single LEFT T11 great radicular artery --> Artery of Adamkiewiz
75% from T10-12
T-L spinal also receive supply from aortic and iliac branches
Lateral Sacral artery supplies sacral elements
ASA ends at conus gives rise to rami cruciantes to PSA's

Arterial Supply to the Spinal Cord



<u>Anterior</u>

- Anterior horns
- Spinothalamic
- Corticospinal

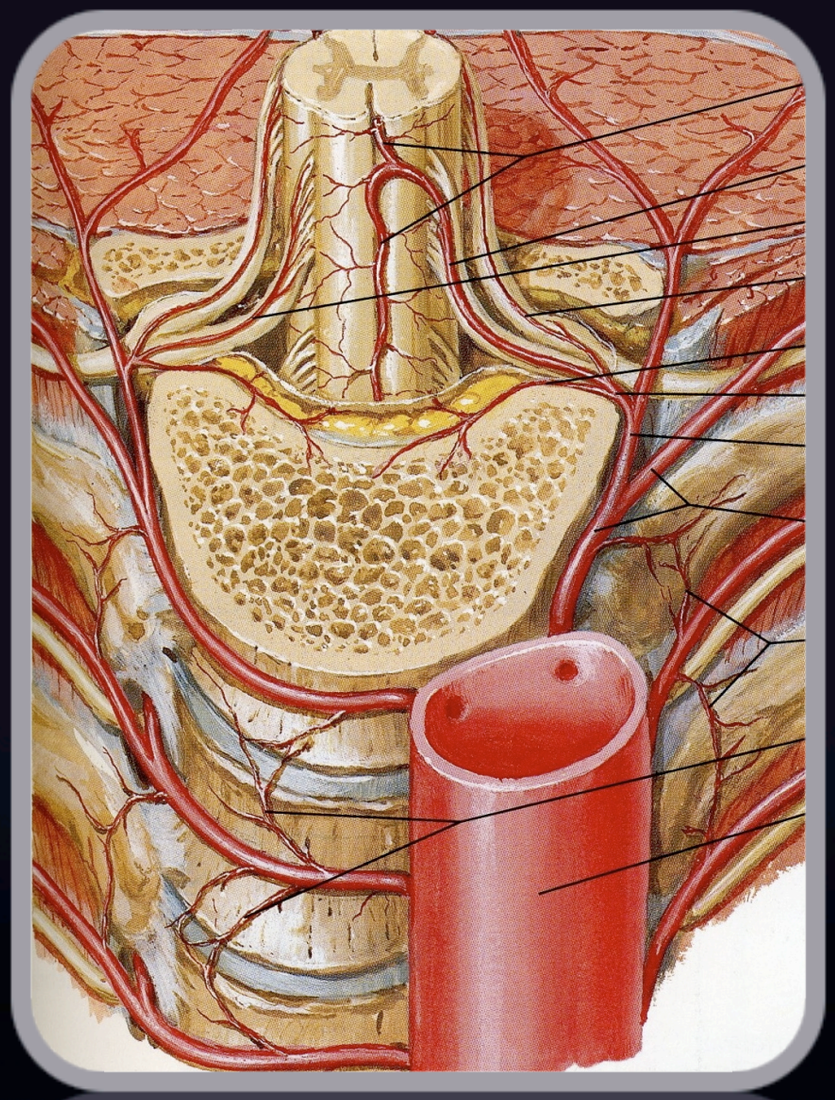
<u>Posterior</u>

- Posterior Columns
- Corticospinal (variable)

<u>Vascular Watershed Areas</u>

- Hypotension --> Central Grey matter
- ASA infarct --> Anterior 2/3
- T1-4 and L4 most vulnerable to cord infarct from intercostal artery occlusion or aortic dissection

Arterial Supply to the Spine



Vertebral bodies and spinal cord derive blood supply from intercostal arteries that branch off the aorta.

Posterior Intercostal Artery (aka Segmental artery)
- Dorsal Branch
  - Spinal Branch
    - Anterior Radicular
      - Ant Medullary (L side)
        - Ant Spinal
    - Posterior Radicular
    - Vertebral/Dural Branch

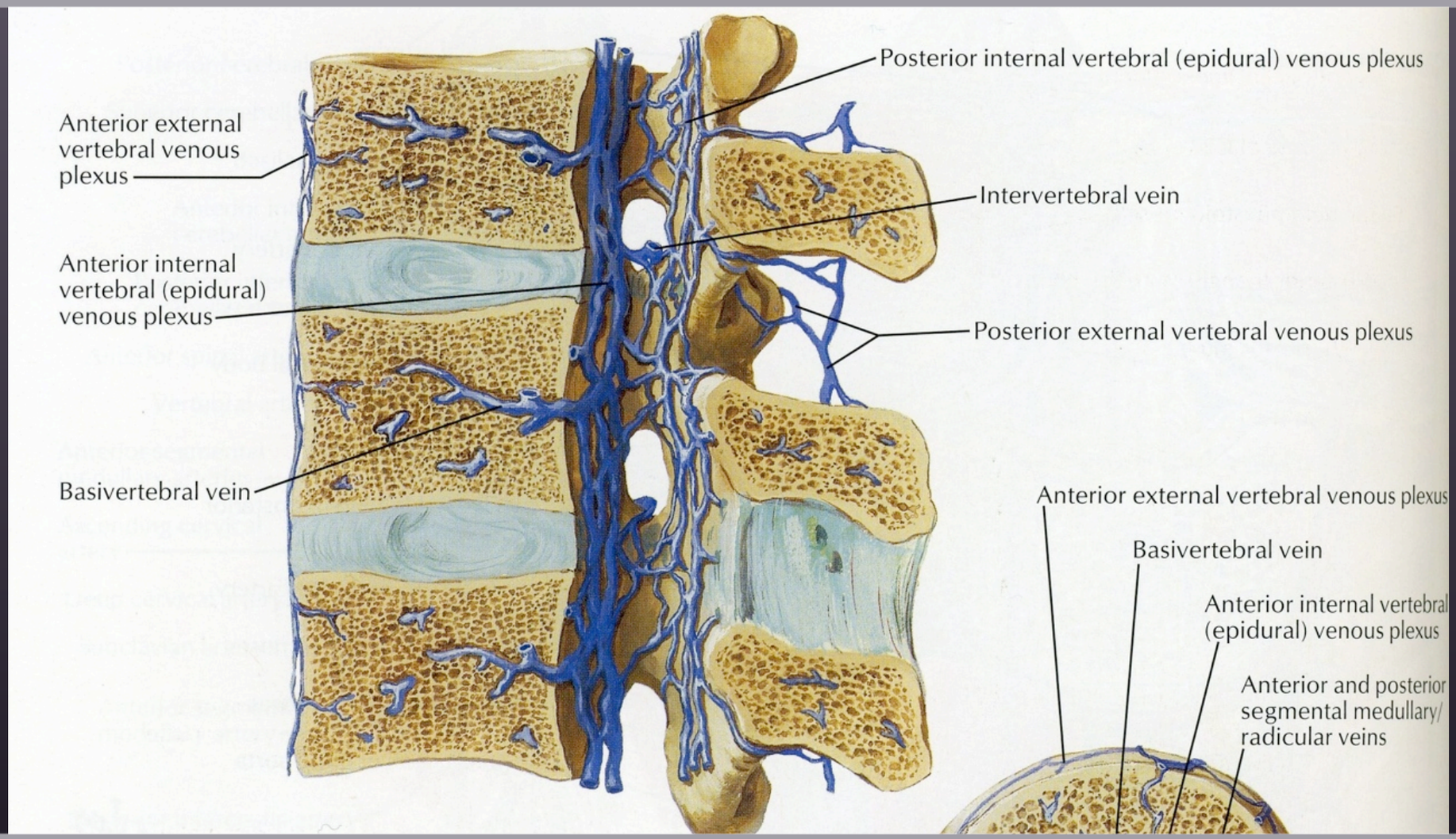
75% of blood supply to cord from Anterior spinal artery fed by 5-10 unpaired medullary arteries

In T-spine = Anterior medullary artery. Largest of these medullary arteries known as Artery of Adamkiewiez.

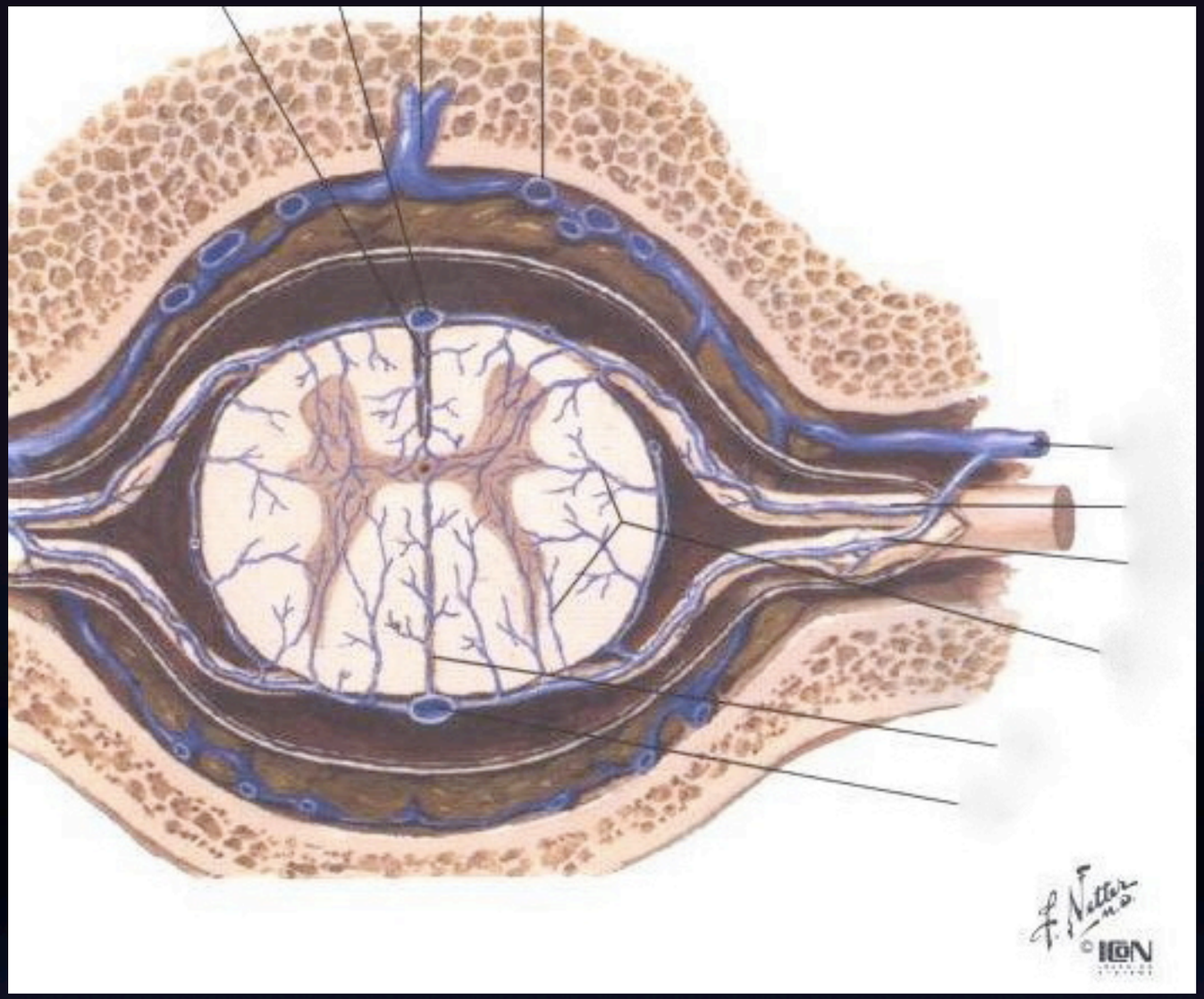
Arterial supply to Thoracic cord is lower than Cervical and Lumbar supply.

Venous Drainage from the Spine and Spinal Cord

Venous Drainage from the Spine



Venous Drainage from the Spine Cord



Verterbal

- Large valveless network
- Foramen magnum to sacrum
- 20x greater capacitance than arterial system

Internal Vertebral Venous Plexus

- epidural venous network around thecal sac
- thin walled, valveless sinuses
- Embedded in epidural fat
- Anterior>Posterior

Intradural Veins

- Parallel Spinal arteries
- Symmetric pattern of drainage vs. assymetric arterial supply
- Central Veins --> Epidural Batson's Plexus -->SVC/IVC, azygous/ hemiazygous system

Vascular Pathology

Overview

- Clinical Presentation
- Pathophysiology
- Classification Systems
- AVM
- Vascular Tumors
- Anuerysms

Myelopathic Symptoms

- Weakness of extremities
- Sensory Impairment
- Micturation/Defecation
- Sexual Dysfunction

Clinical Syndromes of Myelopathy

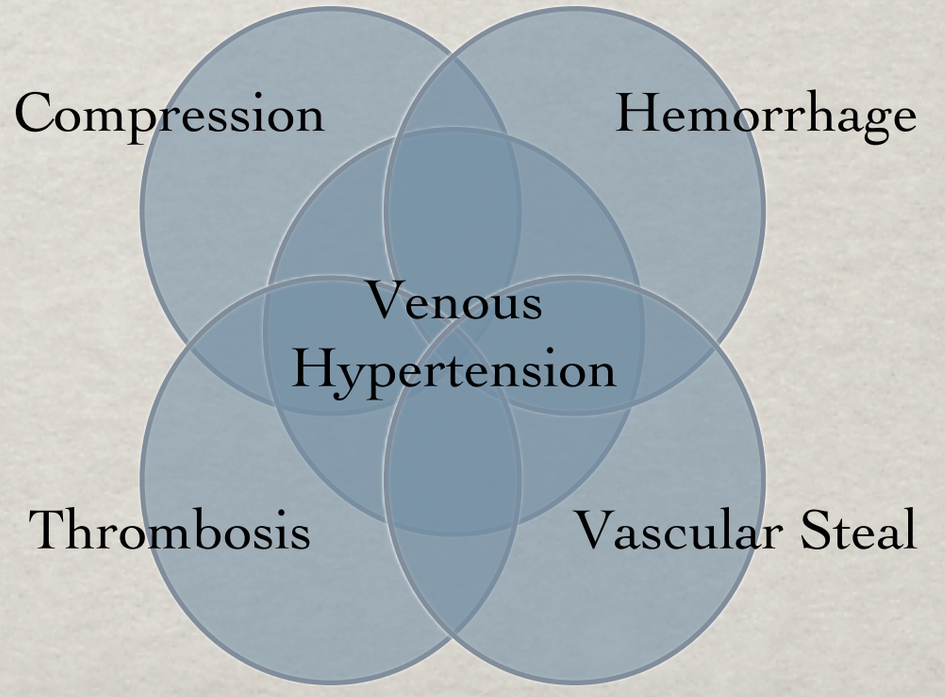
Syndrome	Motor	Sensory
Brown-Sequard	Ipsi paresis	Contra loss of pain and temp Ipsi loss of vibration and proprio Preserved tactile sensation
Anterior Spinal Cord	Bilateral paresis	Loss of pain and temp Preserved vibration and proprio
Posterior Spinal Cord	Preserved	Loss of 2pt, vibration and proprio Preserved pain, temp, and tactile
Central Cord	Variable segmental amyotrophy	Bilateral loss of pain and temp Preserved touch, vibration, and proprio

Wong JH and Awad IA. Ch9 in Vascular malformations of the central nervous system Lippincott 1999

Pathophysiology

Ischemic neuronal injury from:

- venous hypertension
- compression from mass effect
- hemodynamic diversion
- hemorrhage
- thrombosis



Wong JH and Awad IA. Ch9 in Vascular malformations of the central nervous system Lippincott 1999

Principles of Classification

- Pathology
- Localization in Spine
- Vascular Anatomy of Lesion
- Hemodynamics High Flow vs. Low Flow

Old nomenclature for spinal cord vascular lesion

angioma arteriovenosum
angioma cavernosum
angioma racemosum
angioma racemosum arteriovenosum
angioma racemosum venosum
angioreticuloma
classic AVM
dorsal extramedullary
epidural
extradural
Foix–Alajouanine
glomus
intradural extramedullary
intramedullary
intraspinal extramedullary
intraspinal extramedullary radiculomeningeal
juvenile
metameric
others
  perimedullary
  radiculomeningeal fistula
  retromedullary
  Types I, II, III, & IV
  varicosis spinalis
  ventral

Table1: Spetzler et al. JNS (Spine) 96:145-156, 2002.

Modified Classification of Spinal Cord Vascular Lesions

Proposed classification of spinal cord vascular malformations

- neoplastic vascular lesions
  - hemangioblastoma
  - cavernous malformation
- spinal aneurysms
- arteriovenous fistulas
  - extradural
  - intradural
    - ventral*
    - dorsal†
- AVMs
  - extradural–intradural
  - intradural
    - intramedullary
      - compact
      - diffuse
      - conus medullaris

* Includes the following subtypes: A, small shunt; B, medium shunt; and C, large shunt.

† Includes the following subtypes: A, single feeder; and B, multiple feeders.

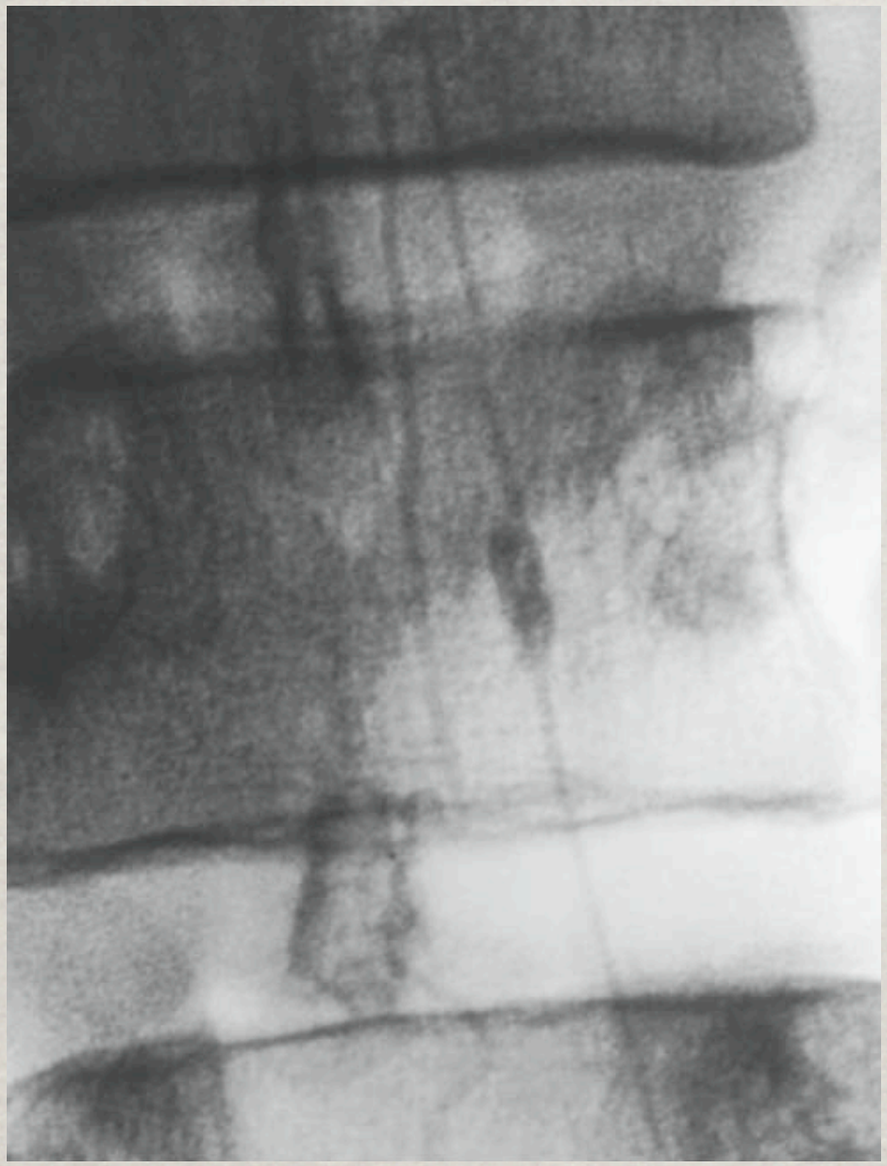
Table2: Spetzler et al. JNS (Spine) 96:145-156, 2002.

Neoplastic Vascular Lesions

- Hemangioblastoma — Spetzler et al. JNS 2002
- Cavernous Malformation

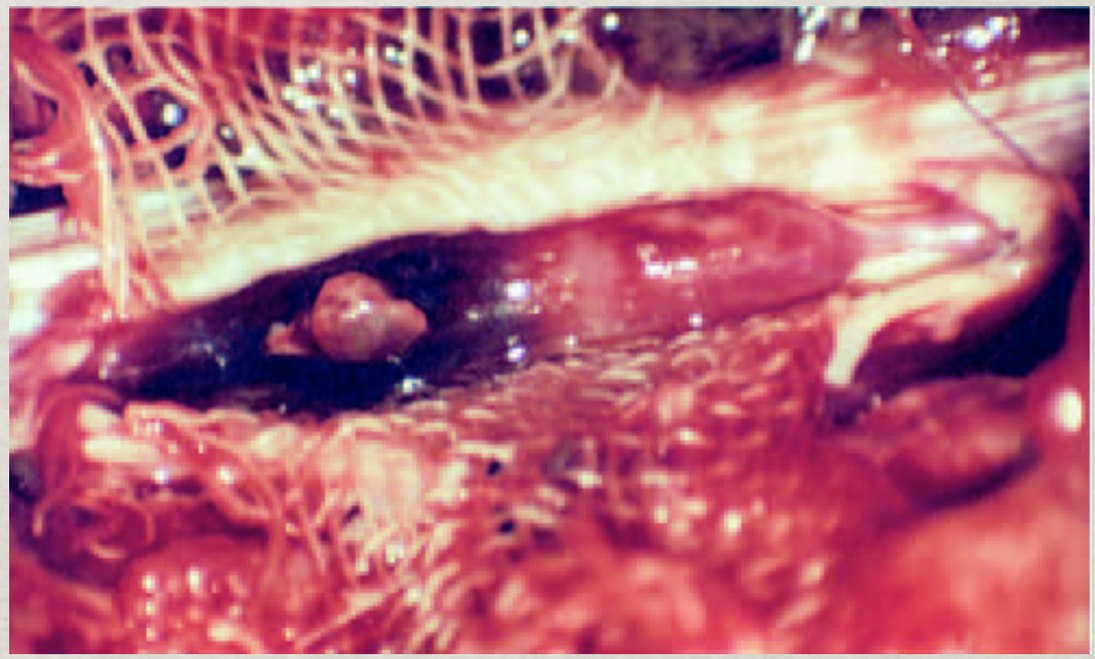
- Hemangiomas
- Angiosarcomas — Zozulya et al. JNS 2006
- Hemangiopericytoma
- Angiofibroma
- Angiolipoma
- Hemangioendothelioma

Spinal Aneurysms



A-P Angiogram demonstrating SAH
of artery of Adamkiewicz

- Rare vascular malformations
- Blood flow and Dissection
- Present w/ spinal SAH



Intraoperative: Muslin gauze wrapping of
dissecting aneurysm of artery of Adamkiewicz

Fig1: Spetzler et al. JNS 2002

Arteriovenous Fistulas and Malformations

Arteriovenous Fistulas

Extradural

Intradural

Dorsal

Ventral

Arteriovenous Malformations

Extradural-Intradural

Intradural

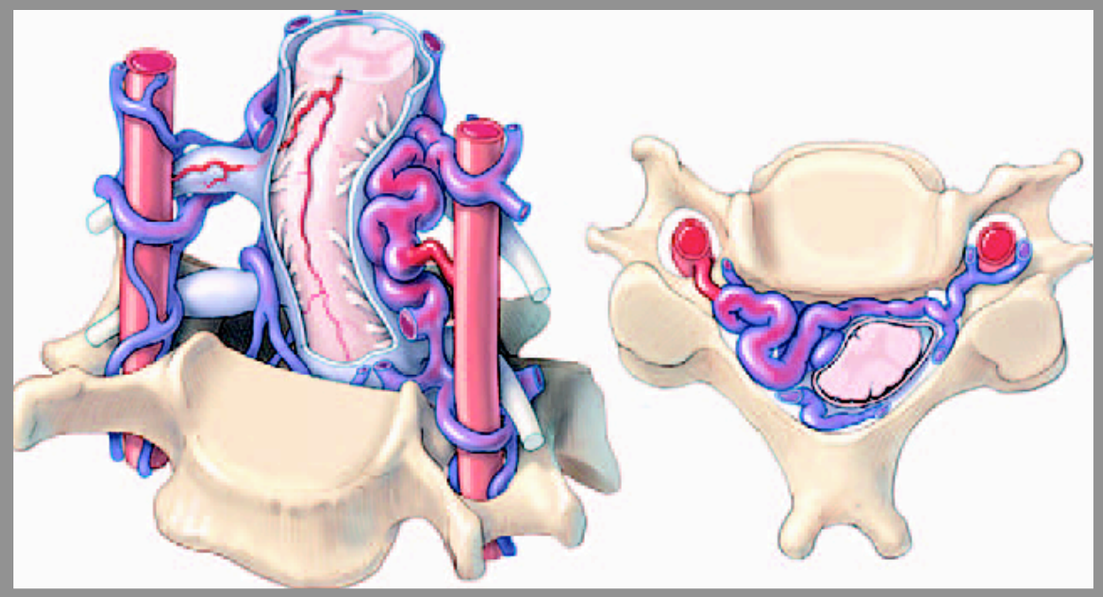
Intramedullary

Intramedullary-Extramedullary

Conus Medullaris

Spetzler et al. JNS 2002

Extradural AV Fistula
aka Epidural AV Fistula



<u>Pathophysiology</u>
- Spinal Cord compression
- Venous Congestion
- Vascular Steal

<u>Presentation</u>
- progressive myelopathy

<u>Hemodynamics</u>: High Flow Lesion
- Direct connection btwn extradural artery and vein
- Engorgement of epidural venous system

A-P Vertebral artery angiogram showing serpiginous fistula in epidural space compressing the spinal cord

Fig2: Spetzler et al. JNS (Spine) 96:145-156, 2002.

Arteriovenous Fistulas and Malformations

<u>Arteriovenous Fistulas</u>

Extradural

Intradural

Dorsal

Ventral

<u>Arteriovenous Malformations</u>

Extradural-Intradural

Intradural

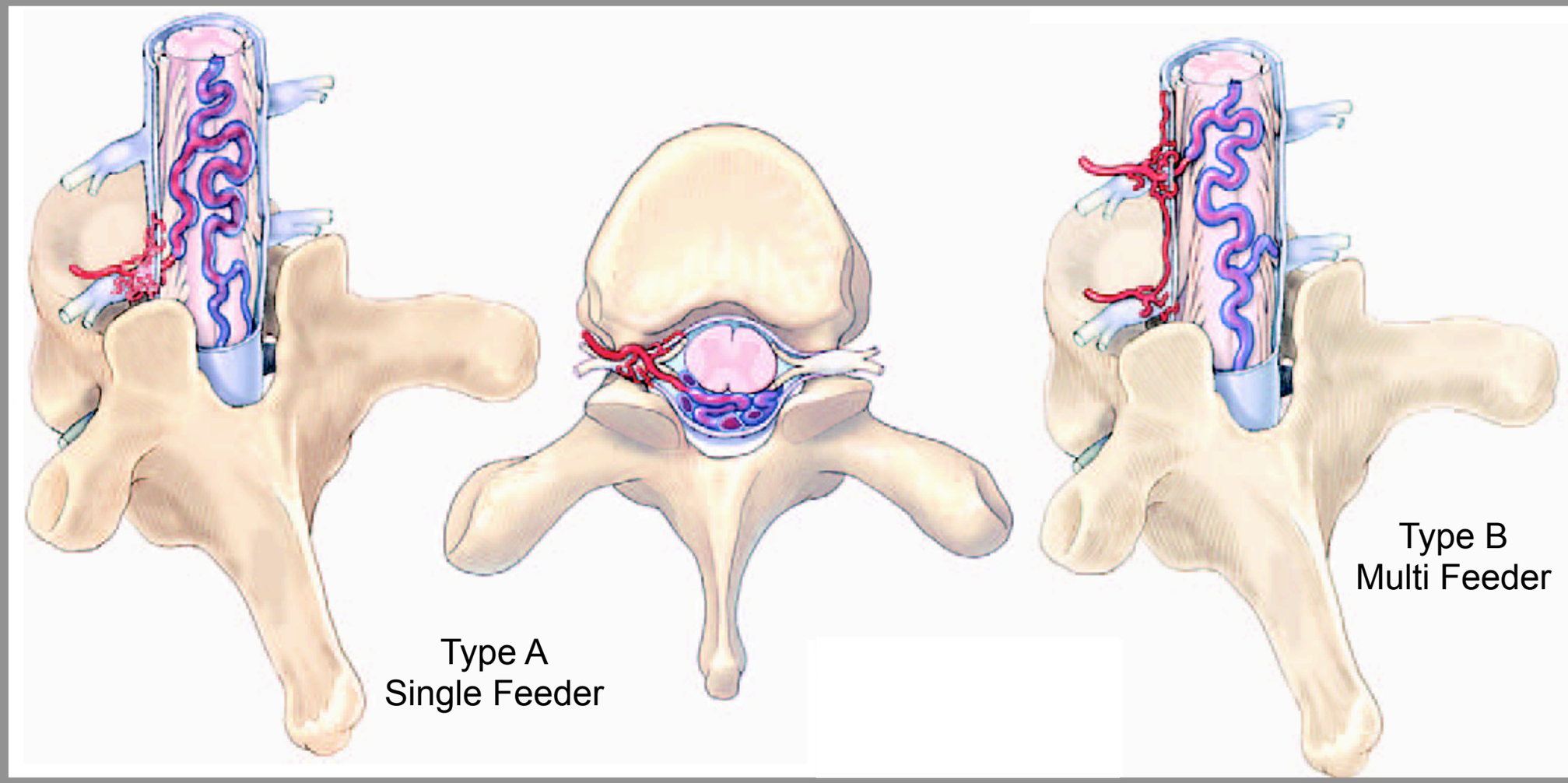
Intramedullary

Intramedullary-Extramedullary

Conus Medullaris

Spetzler et al. JNS 2002

Intradural Dorsal AV Fistula
aka Spinal Dural AVM or Type I



Pathophysiology
- venous congestion
- rarely hemorrhage
- most common type:
  - 80% of all spinal AVM

Presentation
- occurs in thoracic region
- progressive myelopathy
- poorly localized pain or
- focal radicular pain
- natural hx --> severe disability

Hemodynamics: Low Flow Lesion
- Feeding dorsal radiculomedullary artery enters @ dural root sleeve and forms a fistula arterializing the coronol venous plexus
  - Type A: Single feeding artery
  - Type B: Multi feeding artery

Fig3: Spetzler et al. JNS (Spine) 96:145-156, 2002.

Arteriovenous Fistulas and Malformations

<u>Arteriovenous Fistulas</u>

Extradural

Intradural

Dorsal

Ventral

<u>Arteriovenous Malformations</u>

Extradural-Intradural

Intradural

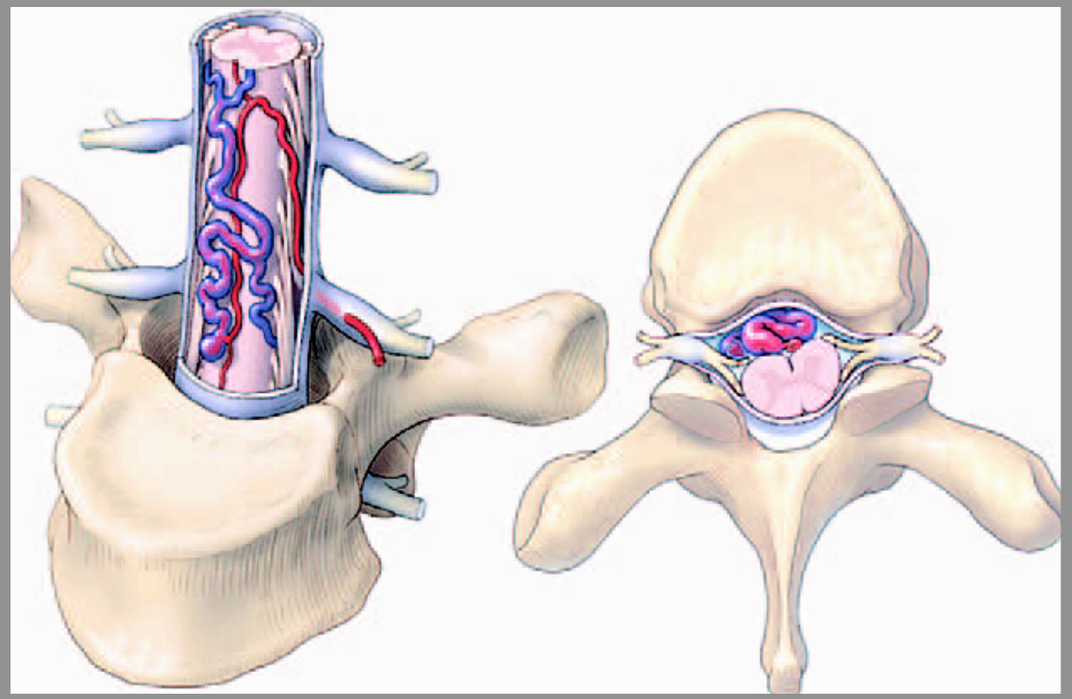
Intramedullary

Intramedullary-Extramedullary

Conus Medullaris

Spetzler et al. JNS 2002

Intradural Ventral AV Fistula
aka Perimedullary Spinal AVM, Type IV



Sagittal T2 MRI showing Serpigionus flow voids antero-lateral to spinal cord

Pathophysiology
- Compression (venous aneurysm)
- Hemorrhage (uncommon)
- Vascular Steal
- 10-20% of spinal AVMs

Presentation
- M=F
- T-L Jxn
- progressive myelopathy
- bladder and bowel symptoms

Hemodynamics: Low to High Flow Lesions
- Located in Subarachnoid space
- Direct fistula from ASA to anterior venous plexus
- Type A to C: Small to large shunts

Fig4: Spetzler et al. JNS (Spine) 96:145-156, 2002.

Arteriovenous Fistulas and Malformations

Arteriovenous Fistulas

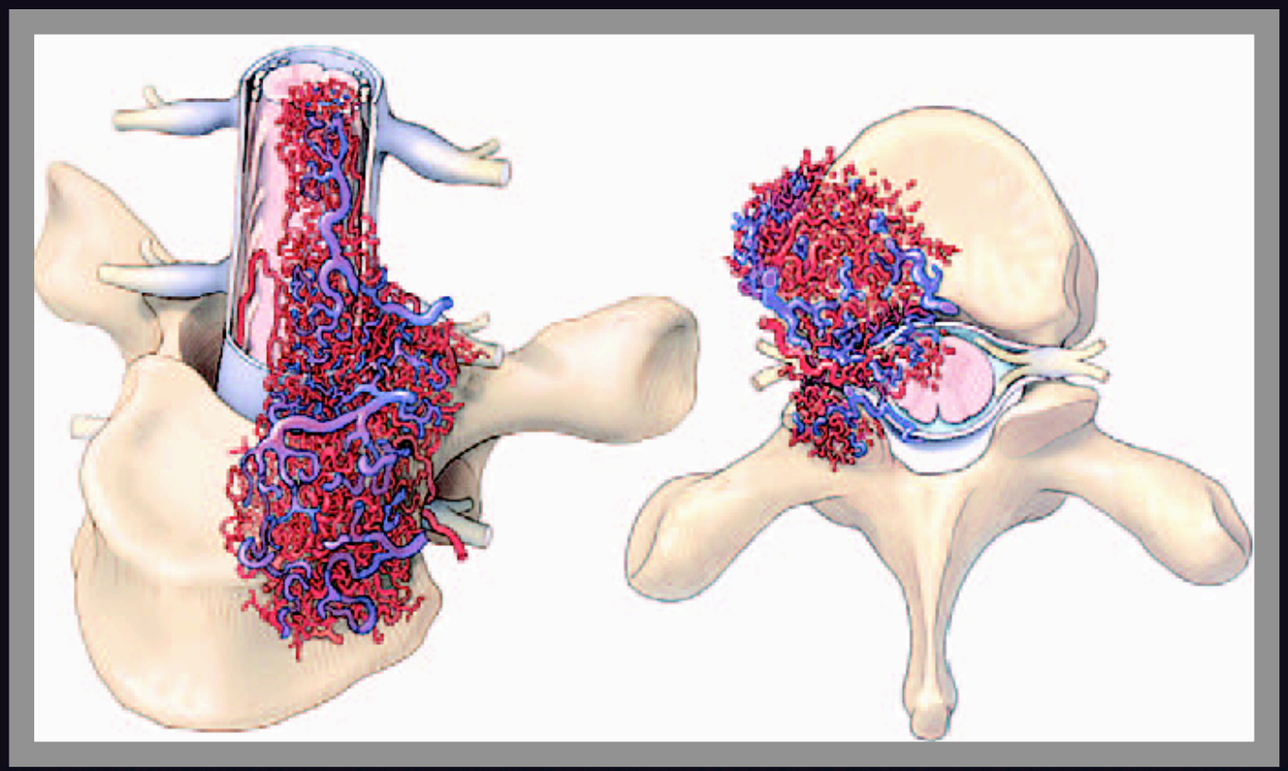
- Extradural
- Intradural
  - Dorsal
  - Ventral

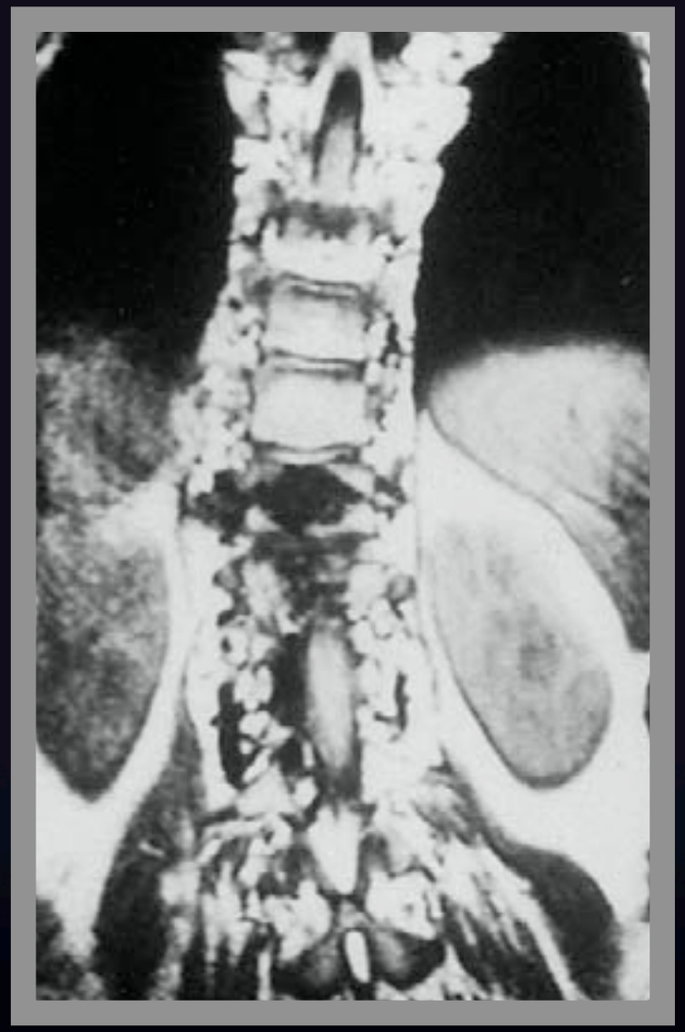
Arteriovenous Malformations

- **Extradural-Intradural**
- Intradural
  - Intramedullary
  - Intramedullary-Extramedullary
  - Conus Medullaris

Spetzler et al. JNS 2002

Extradural-Intradural AV Malformations
aka Juvenile Spinal AVM, Type III





Coronal T1 MR showing involvement of
spinal cord, vertebral column, extraspinal soft tissue

Pathophysiology
- Rare(~7% of spinal AVMs), No boundaries
- Compression
- Vascular steal
- Hemorrhage

Presentation
- M=F
- Present early
- progressive myelopathy

Hemodynamics: Low Flow Lesion?
- ASA and/or PSA feeders
- Persistance of primitive direct communications btwn arterial and venous channels

Fig6: Spetzler et al. JNS (Spine) 96:145-156, 2002.

Arteriovenous Fistulas and Malformations

<u>Arteriovenous Fistulas</u>

Extradural

Intradural

Dorsal

Ventral

<u>Arteriovenous Malformations</u>

Extradural-Intradural

Intradural

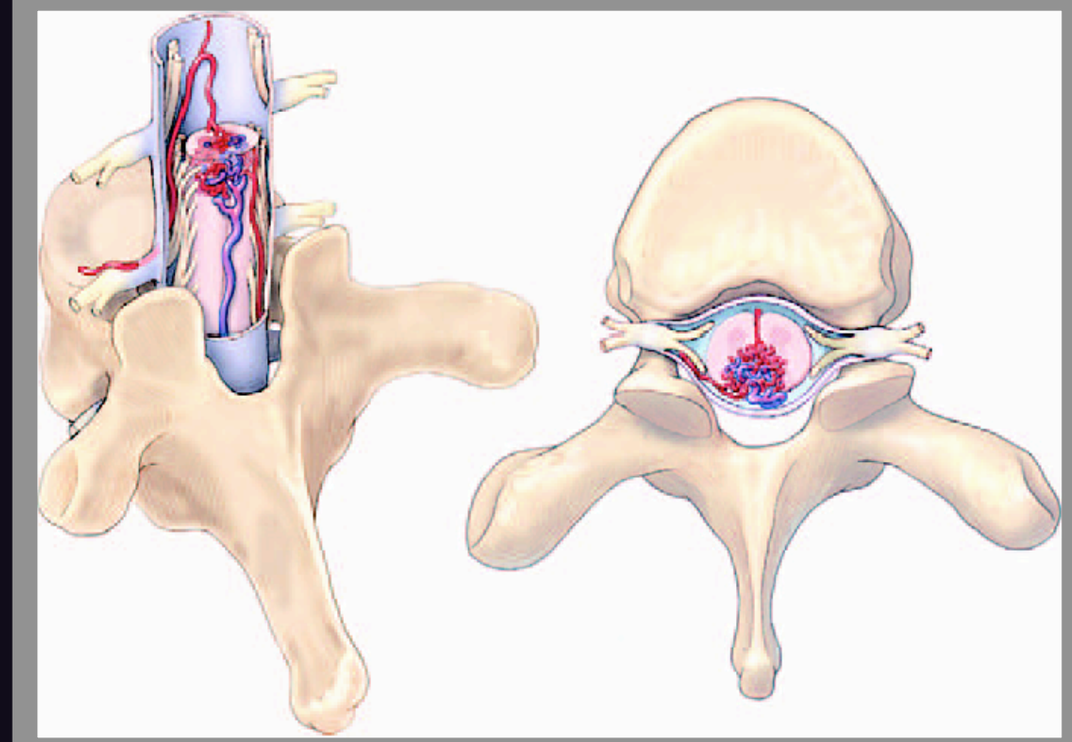
Intramedullary

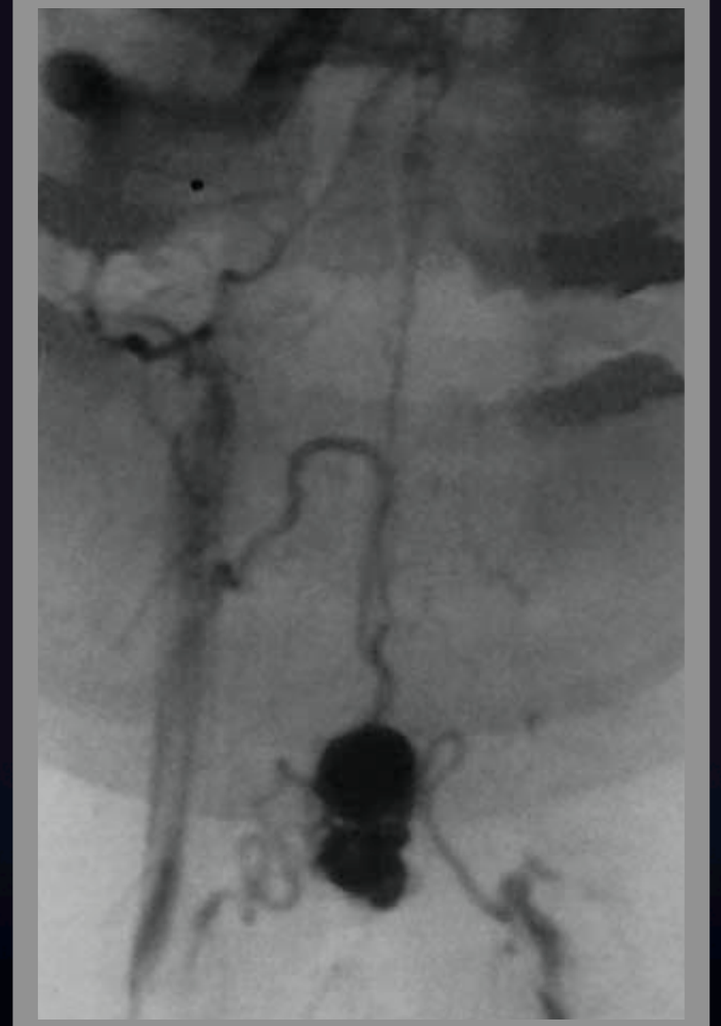
Intramedullary-Extramedullary

Conus Medullaris

Spetzler et al. JNS 2002

Intramedullary AV Malformations
aka Glomus Spinal AVM, Type II





AP R Vertebral artery angiogram showing multiple fistukas feeding an intramedullary malformation and aneurysm

Pathophysiology
- Second most common 20-44%
- Hemorrhage
- Compression
- Vascular Steal

Presentation
- Acute myelopathy
- Pain
- Progressive myelopathy

Hemodynamics: High Flow Lesions
- Multiple ASA or PSA feeders
- Aneurysms common
- Nidus may be compact or diffuse
- Volume Classification
  - Type I : normal
  - Type II : enlarged Volume
  - Type III: extra+intra-medullary

Fig7: Spetzler et al. JNS (Spine) 96:145-156, 2002.

Arteriovenous Fistulas and Malformations

<u>Arteriovenous Fistulas</u>

Extradural

Intradural

Dorsal

Ventral

<u>Arteriovenous Malformations</u>

Extradural-Intradural

Intradural

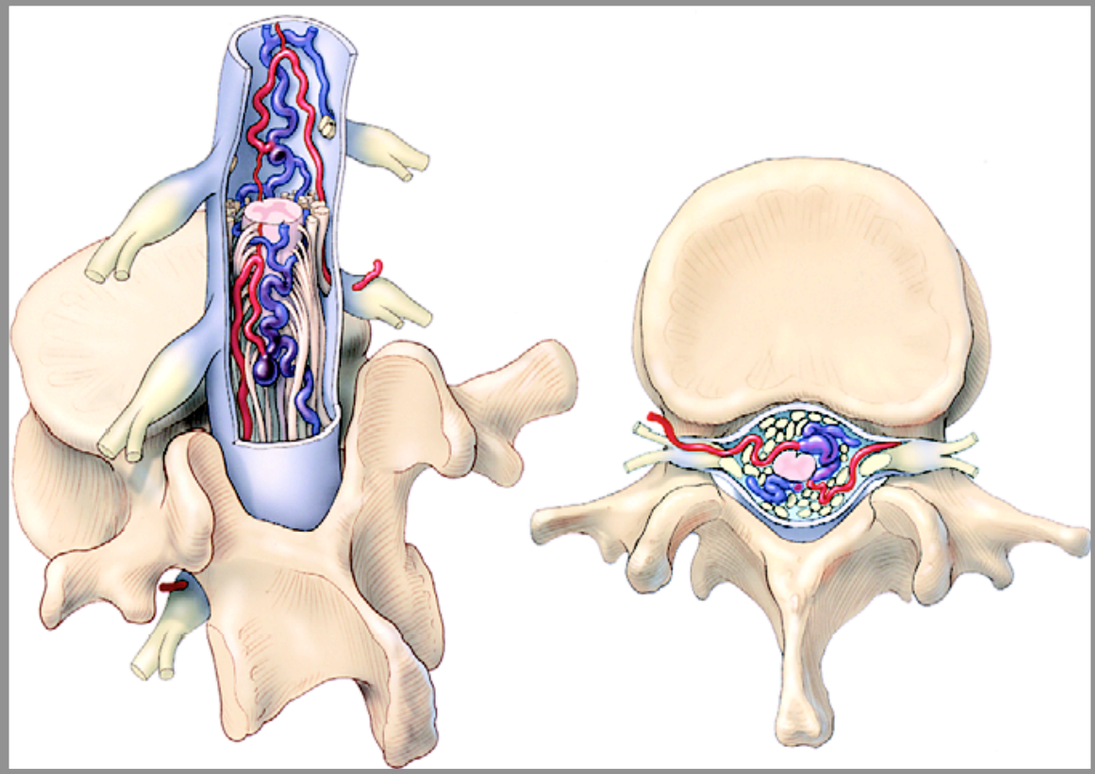
Intramedullary

Intramedullary-Extramedullary

Conus Medullaris

Spetzler et al. JNS 2002

Conus Medullaris AV Malformations
aka: New School



Intra-op photo showing multiple fistulas feeding malformation located on posterior cord

Pathophysiology
- Venous Hypertension
- Compression
- Hemorrhage

Presentation
- Progressive myelopathy
- Radiculopathy

Hemodynamics: Low Flow Lesion?
- Multiple feeders, multi-nidal, complex drainage
- ASA & PSA feeders
- Pial based but may also be intramedullary

Fig9: Spetzler et al. JNS (Spine) 96:145-156, 2002.

Surgical Outcomes of Spinal AVFs/AVMs

Spinal cord arteriovenous lesions treated surgically by the authors

		Postoperative Status (%)		
	No. of Lesions	Improved	Same	Worse
extradural AVF	2	100	0	0
dorsal intradural AVF	32	80	10	10*
ventral intradural AVF	7	75	25	0
extradural–intradural AVM	5	100	0	0
intramedullary AVM†	27	68	29	8
conus AVM	16	35	65	0

* Vein stripping occurred.
† Characterized by 8% residual tumor.

Spetzler et al. JNS 2002

Surgical Outcomes of Spinal AVFs/AVMs

Results of surgical treatment in 91 patients with AVMs

Axial Localization	Structural Features of Lesions	Treatment Results*				
		I	II	III	IV	Total
I. intramedullary	1. glomus or compact	7	10	3	1	21
	2. diffuse	4	5	0	0	9
II. intradural or perimedullary	1. glomus AVM	4	0	0	0	4
	2. AVF	3	6	4	2	15
III. dural	1. glomus AVM	0	5	0	0	5
	2. AVF	11	12	2	3	28
IV. epidural	1. glomus AVM	1	1	0	0	2
	2. AVF	0	1	0	0	1
V. intravertebral	1. glomus AVM limited by vertebra	0	1	0	0	1
	2. glomus AVM w/ paravertebral spreading	0	1	0	0	1
VI. combined	1. mainly intradural glomus AVM	1	1	1	0	3
	2. mainly extradural glomus AVM	1	0	0	0	1
total		32	43	10	6	91

* Roman numerals denote the following results: I, considerable or complete resolution of neurological symptoms; II, improvement of symptoms; III, no changes; IV, aggravation of symptoms.

Zozulya et al. Neurosurg Focus 2006