Spinal Vascular Anatomy and Pathology

Forrest Hsu MD/MSc
Foothills Medical Centre
22 March 2007
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 Adamkiewicz
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

**Anterior**
- Anterior horns
- Spinothalamic
- Corticospinal

**Posterior**
- Posterior Columns
- Corticospinal (variable)

**Vascular Watershed Areas**
- 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
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 Adamkiewicz.

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

- Anterior external vertebral venous plexus
- Anterior internal vertebral (epidural) venous plexus
- Basivertebral vein
- Posterior internal vertebral (epidural) venous plexus
- Intervertebral vein
- Posterior external vertebral venous plexus
- Anterior external vertebral venous plexus
- Anterior internal vertebral (epidural) venous plexus
- Anterior and posterior segmental medullary radicular veins
- Basivertebral vein
Venous Drainage from the Spine Cord

**Vertebral**
- 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. asymmetric arterial supply
- Central Veins --> Epidural Batson’s Plexus --> SVC/IVC, azygous/hemiazygous system
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

<table>
<thead>
<tr>
<th>Syndrome</th>
<th>Motor</th>
<th>Sensory</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brown-Sequard</td>
<td>Ipsi paresis</td>
<td>Contra loss of pain and temp</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Ipsi loss of vibration and proprio</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Preserved tactile sensation</td>
</tr>
<tr>
<td>Anterior Spinal Cord</td>
<td>Bilateral paresis</td>
<td>Loss of pain and temp</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Preserved vibration and proprio</td>
</tr>
<tr>
<td>Posterior Spinal Cord</td>
<td>Preserved</td>
<td>Loss of 2pt, vibration and proprio</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Preserved pain, temp, and tactile</td>
</tr>
<tr>
<td>Central Cord</td>
<td>Variable segmental amyotrophy</td>
<td>Bilateral loss of pain and temp</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Preserved touch, vibration, and proprio</td>
</tr>
</tbody>
</table>

*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. Ch 9 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

<table>
<thead>
<tr>
<th>Term</th>
</tr>
</thead>
<tbody>
<tr>
<td>angioma arteriovenosum</td>
</tr>
<tr>
<td>angioma cavernosum</td>
</tr>
<tr>
<td>angioma racemosum</td>
</tr>
<tr>
<td>angioma racemosum arteriovenosum</td>
</tr>
<tr>
<td>angioma racemosum venosum</td>
</tr>
<tr>
<td>angioreticuloma</td>
</tr>
<tr>
<td>classic AVM</td>
</tr>
<tr>
<td>dorsal extramedullary</td>
</tr>
<tr>
<td>epidural</td>
</tr>
<tr>
<td>extradural</td>
</tr>
<tr>
<td>Foix–Alajouanine</td>
</tr>
<tr>
<td>glomus</td>
</tr>
<tr>
<td>intradural extramedullary</td>
</tr>
<tr>
<td>intramedullary</td>
</tr>
<tr>
<td>intraspinal extramedullary</td>
</tr>
<tr>
<td>intraspinal extramedullary radiculomeningeal</td>
</tr>
<tr>
<td>juvenile</td>
</tr>
<tr>
<td>metameric</td>
</tr>
<tr>
<td>others</td>
</tr>
<tr>
<td>perimedullary</td>
</tr>
<tr>
<td>radiculomeningeal fistula</td>
</tr>
<tr>
<td>retromedullary</td>
</tr>
<tr>
<td>Types I, II, III, &amp; IV</td>
</tr>
<tr>
<td>varicosis spinalis</td>
</tr>
<tr>
<td>ventral</td>
</tr>
</tbody>
</table>

*Table 1: Spetzler et al. JNS (Spine) 96:145-156, 2002.*
Modified Classification of Spinal Cord Vascular Lesions

<table>
<thead>
<tr>
<th>Proposed classification of spinal cord vascular malformations</th>
</tr>
</thead>
<tbody>
<tr>
<td>neoplastic vascular lesions</td>
</tr>
<tr>
<td>hemangioblastoma</td>
</tr>
<tr>
<td>cavernous malformation</td>
</tr>
<tr>
<td>spinal aneurysms</td>
</tr>
<tr>
<td>arteriovenous fistulas</td>
</tr>
<tr>
<td>extradural</td>
</tr>
<tr>
<td>intradural</td>
</tr>
<tr>
<td>ventral*</td>
</tr>
<tr>
<td>dorsal†</td>
</tr>
<tr>
<td>AVMs</td>
</tr>
<tr>
<td>extradural–intradural</td>
</tr>
<tr>
<td>intradural</td>
</tr>
<tr>
<td>intramedullary</td>
</tr>
<tr>
<td>compact</td>
</tr>
<tr>
<td>diffuse</td>
</tr>
<tr>
<td>conus medullaris</td>
</tr>
</tbody>
</table>

* 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.

Table 2: Spetzler et al. JNS (Spine) 96:145-156, 2002.
Neoplastic Vascular Lesions

- Hemangioblastoma
- Cavernous Malformation
- Hemangiomas
- Angiosarcomas
- Hemangiopericytoma
- Angiofibroma
- Angiolipoma
- Hemangioendothelioma

Spetzler et al. JNS 2002
Zozulya et al. JNS 2006
Spinal Aneurysms

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

A-P Angiogram demonstrating SAH of artery of Adamkiewicz

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

Fig1: Spetzler et al. JNS 2002
Arteriovenous Fistulas
- Extradural
  - Intradural
    - Dorsal
    - Ventral

Arteriovenous Malformations
- Extradural-Intradural
- Intramedullary
  - Intramedullary-Extramedullary
  - Conus Medullaris

Spetzler et al. JNS 2002
Extradural AV Fistula
aka Epidural AV Fistula

Pathophysiology
- Spinal Cord compression
- Venous Congestion
- Vascular Steal

Presentation
- progressive myelopathy

Hemodynamics: High Flow Lesion
- Direct connection between 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

Extradural
Intradural
  Dorsal
  Ventral

Arteriovenous Malformations
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

Type A
Single Feeder

Type B
Multi Feeder

Fig3: Spetzler et al. JNS (Spine) 96:145-156, 2002.
Arteriovenous Fistulas
- Extradural
- Intradural
  - Dorsal
  - Ventral

Arteriovenous Malformations
- Extradural-Intradural
- Intradural
  - Intramedullary
  - Intramedullary-Extramedullary
  - Conus Medullaris
Intradural Ventral AV Fistula
aka Perimedullary Spinal AVM, Type IV

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

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

**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
- Persistence of primitive direct communications
  between arterial and venous channels

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

Fig6: Spetzler et al. JNS (Spine) 96:145-156, 2002.
Arteriovenous Fistulas
   Extradural
   Intradural
      Dorsal
      Ventral

Arteriovenous Malformations
   Extradural-Intradural
   Intradural
      Intramedullary
      Intramedullary-Extramedullary
      Conus Medullaris

Spetzler et al. JNS 2002
Intramedullary AV Malformations aka Glomus Spinal AVM, Type II

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

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

Fig7: Spetzler et al. JNS (Spine) 96:145-156, 2002.
Arteriovenous Fistulas
Extradural
Intradural
  Dorsal
  Ventral

Arteriovenous Malformations
Extradural-Intradural
Intradural
  Intramedullary
  Intramedullary-Extramedullary
  Conus Medullaris

Spetzler et al. JNS 2002
Conus Medullaris AV Malformations
aka: New School

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

<table>
<thead>
<tr>
<th>Lesion Type</th>
<th>No. of Lesions</th>
<th>Improved</th>
<th>Same</th>
<th>Worse</th>
</tr>
</thead>
<tbody>
<tr>
<td>extradural AVF</td>
<td>2</td>
<td>100</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>dorsal intradural AVF</td>
<td>32</td>
<td>80</td>
<td>10</td>
<td>10*</td>
</tr>
<tr>
<td>ventral intradural AVF</td>
<td>7</td>
<td>75</td>
<td>25</td>
<td>0</td>
</tr>
<tr>
<td>extradural–intradural AVM</td>
<td>5</td>
<td>100</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>intramedullary AVM†</td>
<td>27</td>
<td>68</td>
<td>29</td>
<td>8</td>
</tr>
<tr>
<td>conus AVM</td>
<td>16</td>
<td>35</td>
<td>65</td>
<td>0</td>
</tr>
</tbody>
</table>

* 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**

<table>
<thead>
<tr>
<th>Axial Localization</th>
<th>Structural Features of Lesions</th>
<th>Treatment Results*</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>I</td>
<td>II</td>
</tr>
<tr>
<td>I. intramedullary</td>
<td>1. glomus or compact</td>
<td>7</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>2. diffuse</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>II. intradural or perimedullary</td>
<td>1. glomus AVM</td>
<td>4</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>2. AVF</td>
<td>3</td>
<td>6</td>
</tr>
<tr>
<td>III. dural</td>
<td>1. glomus AVM</td>
<td>0</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>2. AVF</td>
<td>11</td>
<td>12</td>
</tr>
<tr>
<td>IV. epidural</td>
<td>1. glomus AVM</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>2. AVF</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>V. intravertebral</td>
<td>1. glomus AVM limited by vertebra</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>2. glomus AVM w/ paravertebral spreading</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>VI. combined</td>
<td>1. mainly intradural glomus AVM</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>2. mainly extradural glomus AVM</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td><strong>total</strong></td>
<td></td>
<td>32</td>
<td>43</td>
</tr>
</tbody>
</table>

* 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.