

SPINAL AVM: CLASSIFICATION AND MANAGEMENT STRATEGIES

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SPINAL AVM

- Spinal vascular malformations represent a rare and insufficiently studied pathological entity
- Great difficulties are caused by lack of a clear structural–hemodynamic classification of spinal AVM.

Early Observations: 1860s to 1912

- Based on autopsy material,
- Virchow provided the earliest classification of spinal vascular lesions, which he described as neoplasms.

Two large groups

Angioma cavernosum, an absence of parenchyma between the blood vessels

Angioma racemosum (hamartoma), vessels were separated by parenchyma.

- In 1910, Fedor Krause was the first to recognize a spinal lesion observed at laminectomy as a vascular abnormality.

The “Middle Ages”: 1912 to 1960

- The evolution of understanding and classification of spinal vascular lesions
- Elsberg’s classification of spinal vascular lesions

Aneurysm

Angioma,

Dilation of veins

- In their monograph published in 1928, Cushing and Bailey devoted their attention briefly to spinal vascular lesions.

Cushing & Bailey (1928)

- I. Hemangioblastomas vascular neoplasms of spinal cord (blood vessels and network of reticulum)
- II. Vascular malformations
 - a. plexus of dilated veins
 - b. aneurysmal varix
 - c. venous angioma
 - d. telangiectasiae.

The Modern Era: 1960 to the Present

- The remarkable studies that occurred in neuroimaging, pathology and in surgical technique resulted in a better understanding of the angioarchitecture and pathology of the lesions which enhanced clarity in classification of these entities.
- collaborative effort among neuroradiologists and neurosurgeons in England, France, and the US.

- **Type I. Dural (intradural or extradural) AVF** (also referred to as Type I spinal AVM or as “angioma racemosum venosum,” nidus, or true AVM), usually in the dural sleeve of a spinal root, associated with a single-coiled vessel on dorsal pial surface of the spinal cord
- **Type II. Glomus AVMs**
- **Type III. Juvenile AVMs** (nidus usually intramedullary)
- **Type IV. Direct spinal AVF**

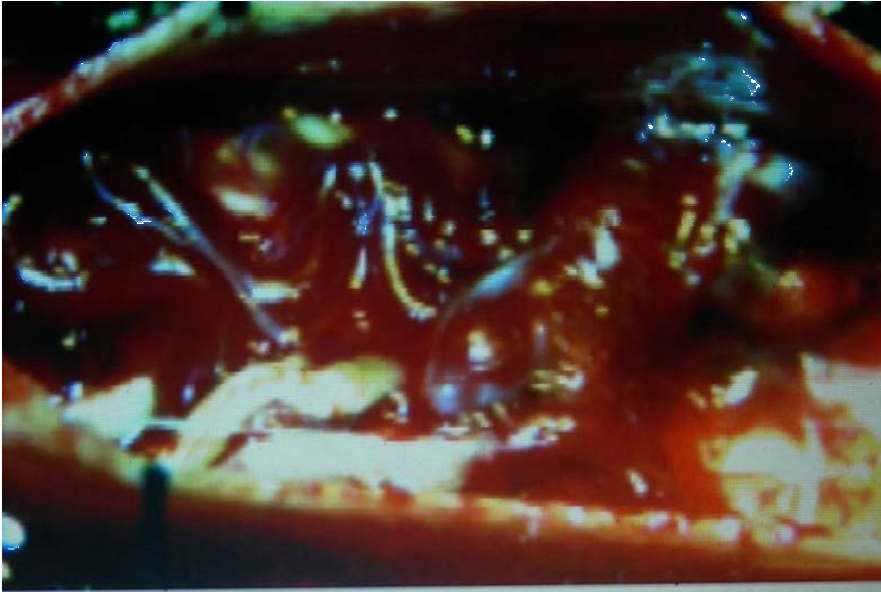
- Spetzler, Detwiler, Riina, Porter (2002)
Three Broad Categories
 1. **Neoplastic vascular lesions**
 - a. hemangioblastoma
 - b. cavernous malformation
 2. **Spinal aneurysms** (occur rarely)
 3. **Arteriovenous lesions**
 - a. AVFs
 - extradural
 - intradural (dorsal or ventral)
 - b. AVMs
 - extradural–intradural
 - intradural
 - intramedullary
 - intramedullary–extramedullary
 - conus medullaris

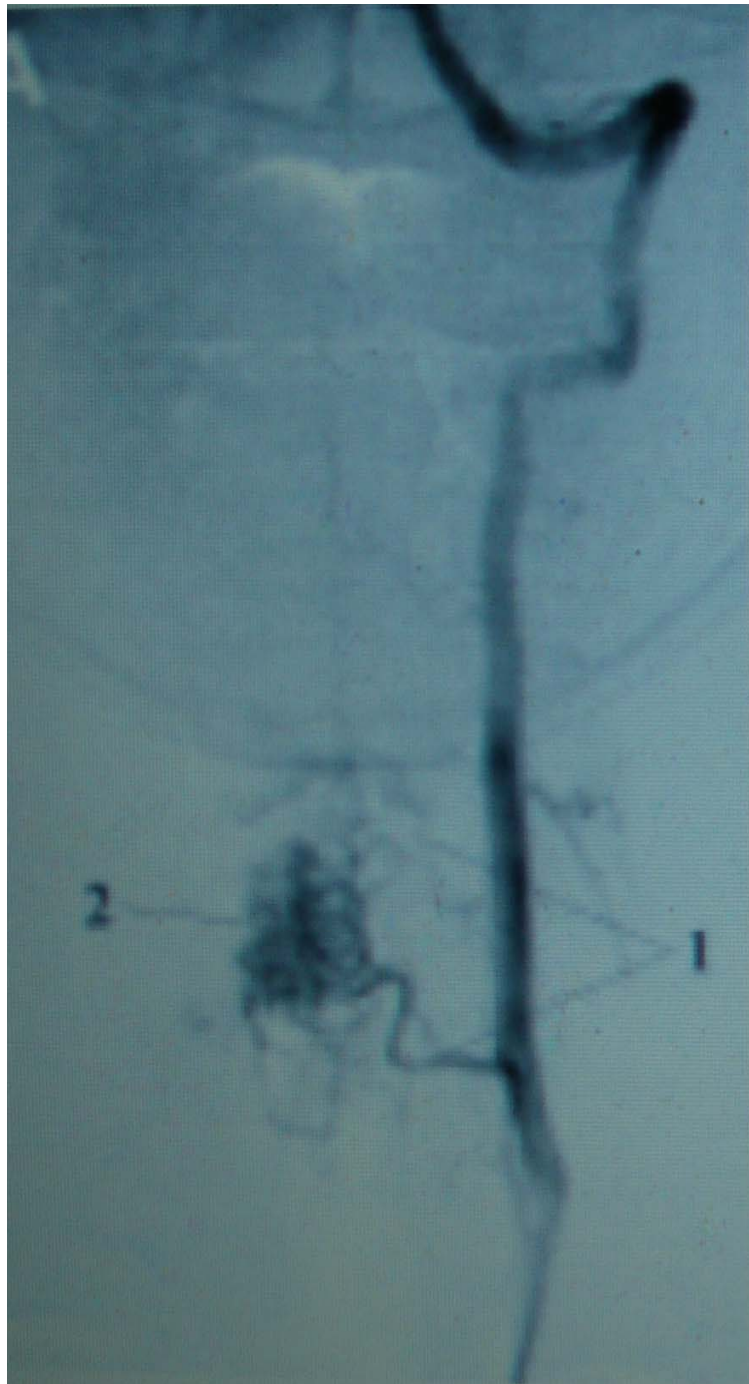
- **YURI P. ZOZULYA, EUGENE I. SLIN'KO,
AND IYAD I. AL-QASHQISH, (2006)**
 - I. intramedullary
 - II. intradural or perimedullary
 - III. dural
 - IV. epidural
 - V. intravertebral
 - VI. Combined

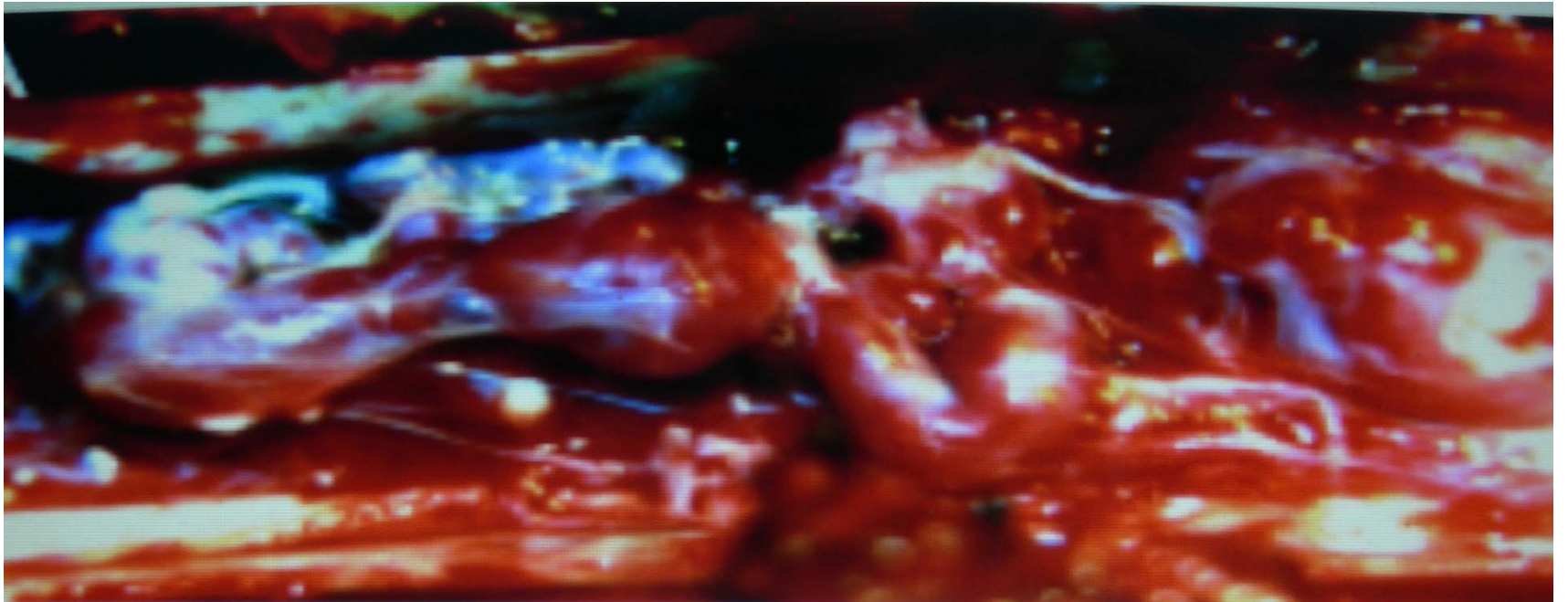
Intramedullary AVMs.

- AVM feeding vessels passed from the ventral or dorsal spinal arteries, and sometimes from the radiculopial arteries.
- The AVM was drained by the perimedullary veins.
- The spinal cord seemed expanded in the region of the malformation; sometimes expanded perimedullary draining veins are discovered around the cord on MR images.
- Changes of the spinal cord density are observed around the vascular nidus.

- The vessels are densely packed in glomus AVMs and scattered in the spinal cord in diffuse AVMs
- The selective spinal angiography studies revealed a vascular conglomerate consisting of vessels that either adjoined each other tightly (glomus type) or were scattered in the spinal cord matter (diffuse type).
- According to the MR imaging and surgical findings, intramedullary AVMs are limited by spinal cord or the conglomeration of vessels spread on the surface of the spinal cord.
- clustering zones of low-intensity MR signals in the spinal cord



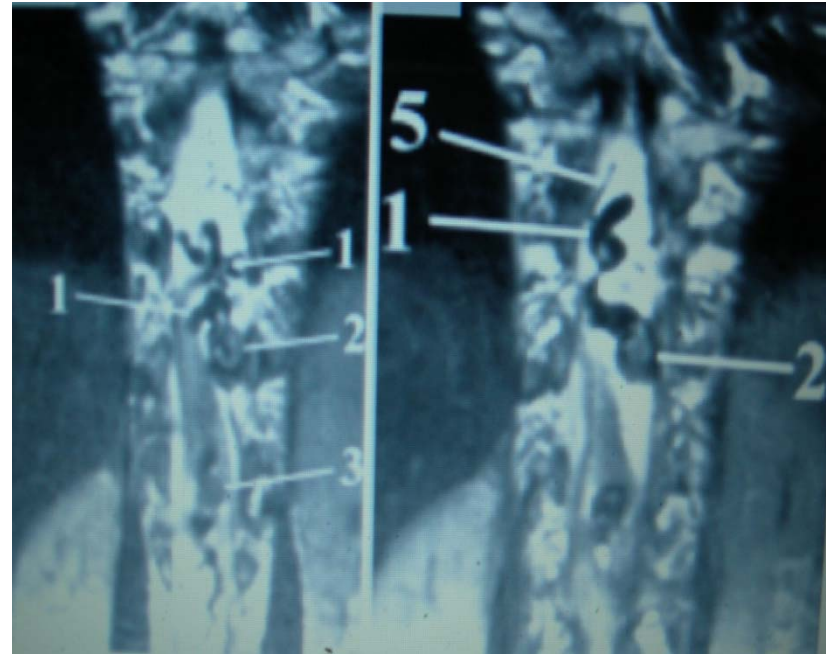


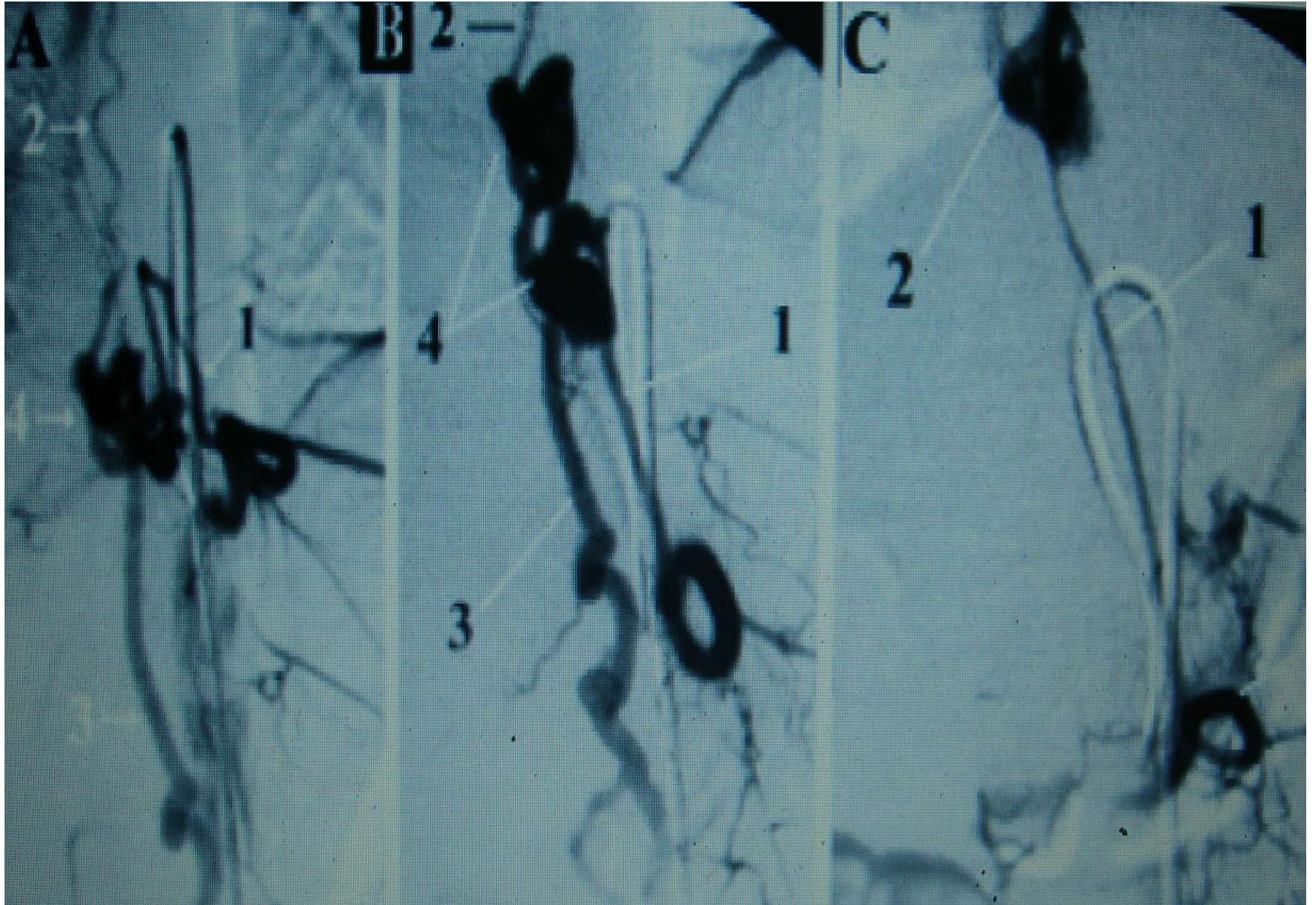


Intradural or Perimedullary AVMs.

- AVM feeding vessels passed from ventral or dorsal radiculomedullary arteries
- These vessels drained into the ventral or dorsal perimedullary veins
- These vessels can be localized on the ventral as well as on the dorsal or lateral spinal cord surface.
- These lesions are visualized on MR imaging as conglomerations of vessels in the form of low-intensity zones around the spinal cord on MR images.

- The spinal cord is not expanded; in most cases its compression and displacement by the malformation are observed.
- Spinal cord edema is rare with this type of malformation.
- The selective spinal angiography studies demonstrate feeding vessels from the ventral or dorsal radiculomedullary arteries. Comparing the MR imaging and selective spinal angiography data, found thrombosis in AVM vessels.

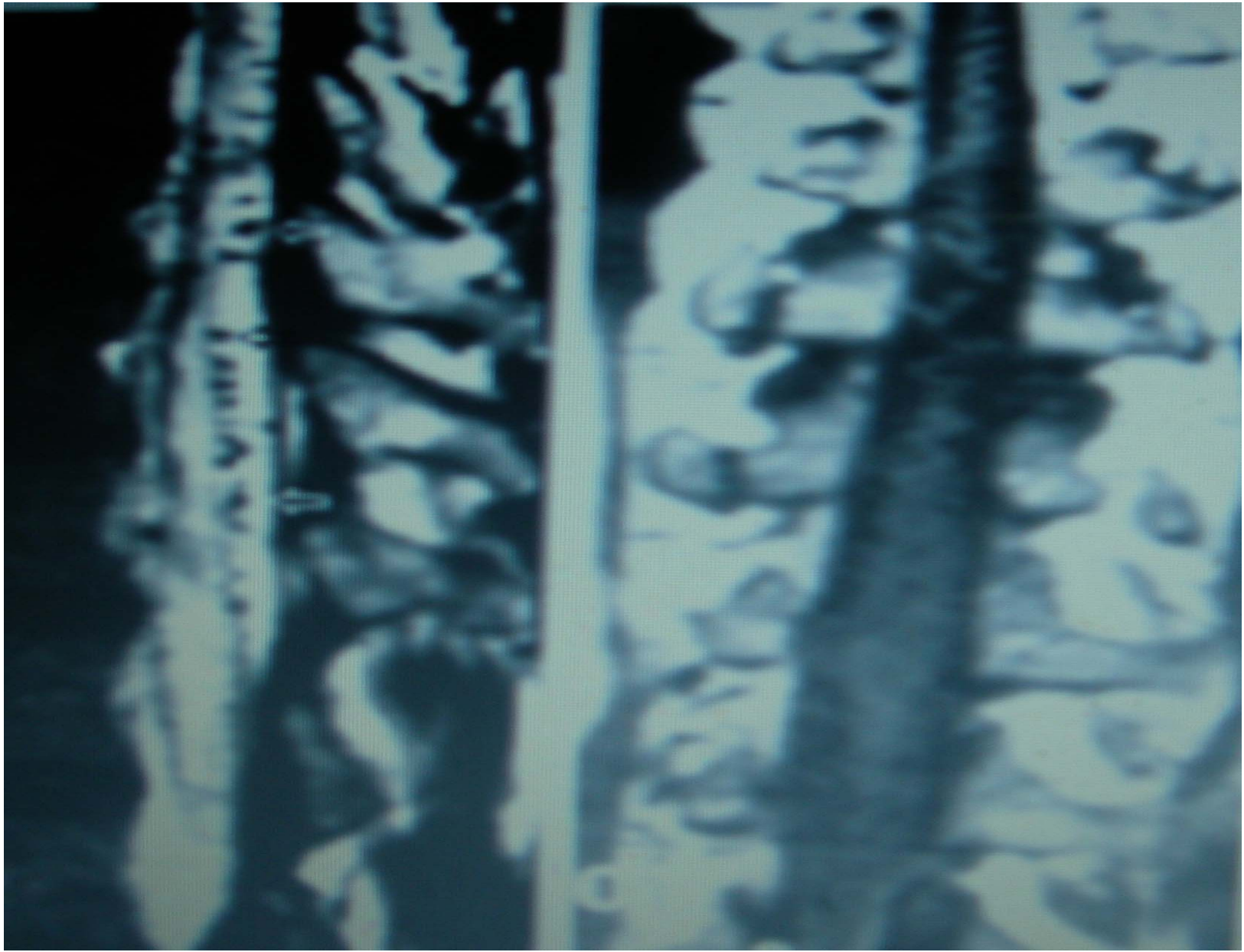


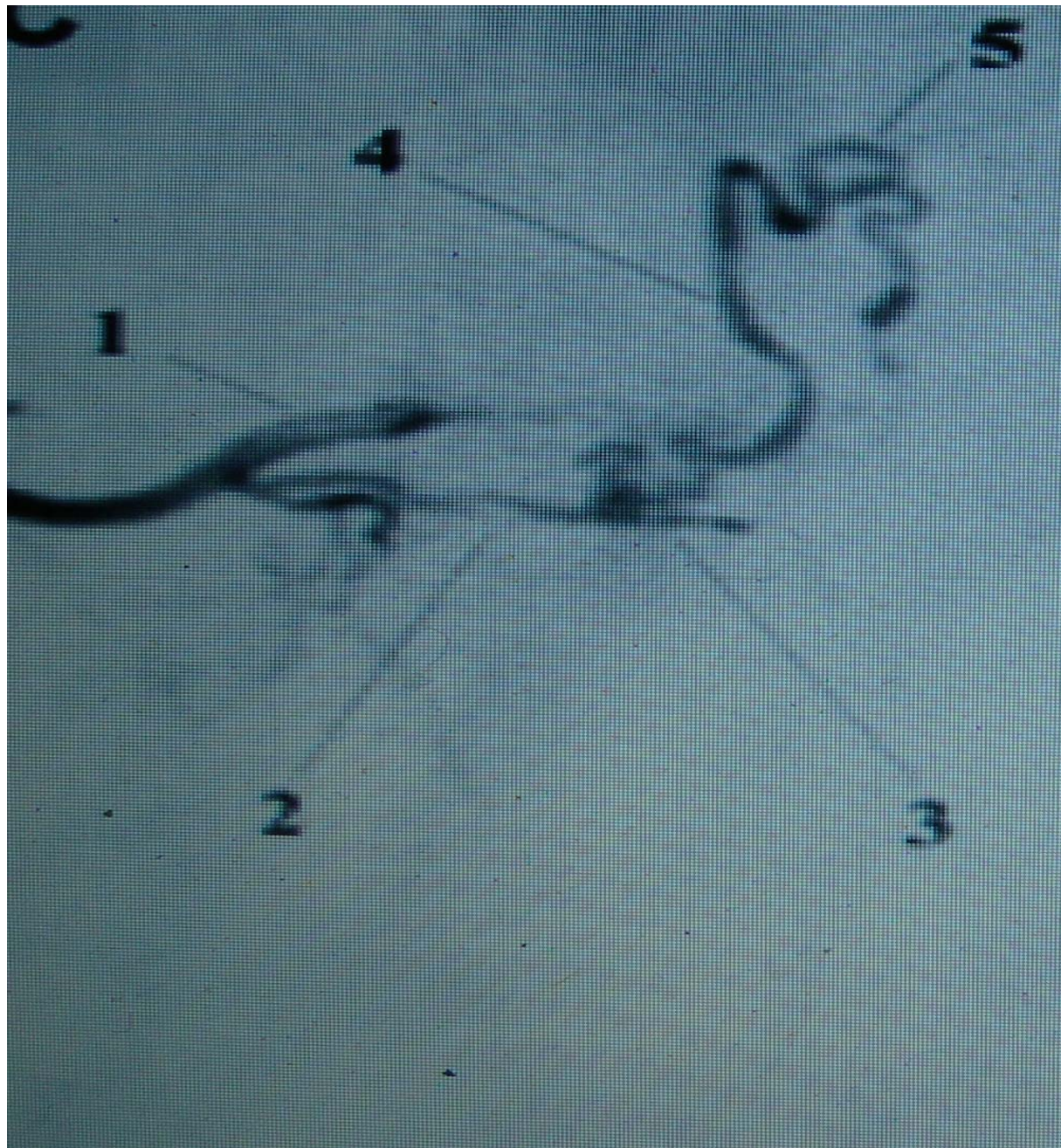


Dural AVMs With Retrograde Drainage Into Perimedullary Veins.

- In dural AVMs with retrograde drainage into perimedullary veins, expansion of these veins are found on MR imaging studies.
- In patients with an insignificant amount of blood shunting, the perimedullary vein expansion look like serpiginous flow voids on the dorsal surface of the spinal cord, most often in the middle and lower thoracic spine.
- vast spinal cord edema and thickening are typical

- Angiographic studies reveal expanded radiculomeningeal arteries, which through a vascular conglomerate in the region of the intervertebral neural foramen shunted into the expanded perimedullary veins.
- Most often, a malformation has only one tributary a nidus characterized by slow blood flow; several tributaries are rarely found.
- The blood flow in spinal cord arteries is also slower







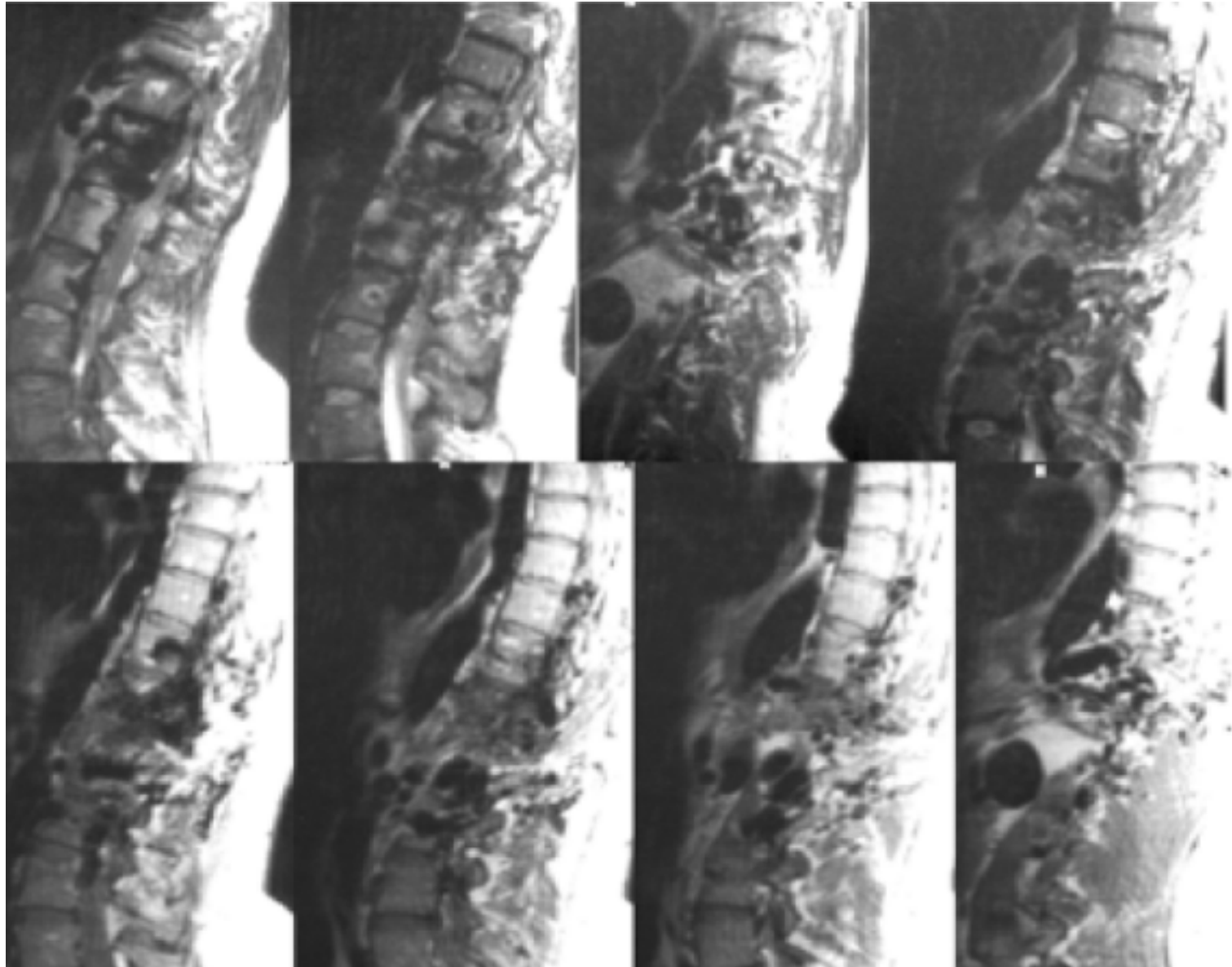
Epidural AVMs

- These lesions are characterized by low-intensity-signal zones located epidurally on MR imaging, and has caused a compression of the duramater.
- Selective spinal angiography demonstrate the feeding vessels spreading out directly from the spinal branch or from the postcentral, prelaminar branches.
- The vascular conglomerate of the AVMs are not large; it consist of small vessels.

Intravertebral AVMs

- intravertebral AVMs are discovered in the form of large vessels with intense blood flow, which are situated more often inside the vertebrae or with paravertebral spreading from these structures.
- Expanded epidural or paravertebral veins draining these AVMs are visible on MR images.

- Selective spinal angiography identify AVM feeding vessels from the ventrolateral branches of segmental arteries (postcentral and prelaminar branches).
- The AVMs are drained through the epidural or the paravertebral veins into the ascending lumbar veins, the inferior venacava, and the azygous and hemiazygous veins



Combined Malformations.

- Combined lesions are situated in several adjacent anatomical structures.
- If combined glomus AVMs are located mainly intradurally, they received tributaries chiefly from the radiculomedullary arteries and has perimedullary venous drainage.
- In case of primary extradural localization, the combined glomera of the AVMs receive tributaries from the spinal branches and are drained mainly by the epidural and paravertebral veins.
- However, these AVMs often have equally intradural and extradural locations

ANGIOGRAPHIC FINDINGS

AVM	Arterial supply	Venous drainage	type	flow
Intramedullary	ant spinal artery post spinal artery radiculopial artery combined	Perimedullary veins	Glomus diffuse	low mod high
Intradural (perimedullary)	ant spinal artery ant radiculomedullary. post radiculomedullary combined	ant perimedullary post perimedullary	glomus	low mod high
Dural	radiculomeningeal artery	retrograde into antperimedullary veins retrograde into post perimedullary veins antegrade into epidural veins	Micro glomus	low

epidural	VAs spinal branch of segmental arteries post central branches. prelaminar branches combined	epidural veins paravertebral veins	glomus	low mod high
combined	mainly from spinal branches mainly from radiculomedullary arteries	perimedullaryveins extradural veins paravertebral veins combined	mainly intradural glomus AVM . mainly epidural	low mod high
intravertebral	ventrolateral branches of segmental arteries postcentral branches prelaminar branches combined 1 one side 2 both sides	epidural veins paravertebral veins combined	glomus glomus AVM limited by vertebra glomus AVM w/ para vertebral spreading	low mod high

Clinical features

- Equal incidence Mean age-3rd decade
- Uniform distribution
- Higher incidence of association with other vascular malformation
- Congenital lesion
- Acute initial presentation
 - Haemorrhage
 - Stepwise progression of deficit
- Progressive loss of neurological deficit
- Pregnancy, exercise, minor trauma-rapid progression
- Bruit over spinal cord

Pathophysiology

- Venous congestion and hypertension
- Reduced arterial perfusion
- Ischemia
- Compressive myelopathy

author	Rosenblum et al 1987	Yasargil et al 1984	Biondi et al 1990
cases	54	41	40
Age at onset	Mean 27 yr	76%<41yr	Mean 20 yr
Initial symptom	Acute onset in 50%	SAH in 59%	SAH in 58%
At diagnosis	SAH in 52 % 74% disabled	SAH in 76%, 63% disabled	SAH in 68%, 75% disabled
Progressive evolution	-	Step wise progression- 40%	31%- relapse,with worsening
Associated with deterioration	Posture-17% Pregnancy-6% Valsalva-13% Activity-15%		

Surgical approaches

Open surgical interventions are advisable

- necessary to occlude only the feeding vessels, one has failed to embolize them endovascularly
- ,
- embolization of the tributaries threatens to occlude the arteries feeding the spinal cord.
- embolization of the main tributaries will not result in complete occlusion of the blood flow;
- selective spinal angiography does not identify all of the tributaries
- diameter is too small

Occlusion of the feeding and draining vessels and malformation resection

- Intramedullary glomus AVM
- Perimedullary AVM
- Epidural AVM
- Combined AVM

Indications for occluding only the feeding vessels

- Intramedullary diffuse AVM
- Intravertebral AVM
- Combined AVM
- Dural AVM
- Conus medullaris AVM

Combining surgical intervention with endovascular embolization

- High flow AVM and numerous large feeding vessels running into it
- After the endovascular embolization a mass effect due to AVM blood flow remains.

Intramedullary AVM

- Depended on type of feeding vessels and location of the nidus.
- ventral approaches
 - Feeder from the anterior spinal artery
 - ventral regions
 - ventral exophytic spreading
- posterior approaches
 - Feeder from the dorsal spinal arteries
 - dorsal regions
 - dorsal exophytic spreading,

Intramedullary glomus AVMs,

Two variants of nidus resection

- 1) isolate the vessels near the nidus and coagulate, then dissect the nidus and resect
- 2) the vessels are cut off in the nidus itself during its separation, and resection of the nidus.

Intramedullary diffuse AVMs,

- Cut off the feeding vessels near the nidus, then perform a myelotomy, partially isolated the vessels in the nidus, coagulate and intersected them, but left them in situ.

▪

Conusmedullaris AVM

- In intramedullary AVM of the conusmedullaris, because of the possible pelvic disturbances, only performe occlusion of feeding vessels, leaving the malformation in situ.

Perimedullary AVMs

- Occlusion of the feeding vessels right at the nidus as the first step, then cut off the draining perimedullary veins and perform total resection of the AVM
- During this procedure, try to preserve the pial vascular plexus of the spinal cord.

Dural AVMs

- two variants of surgical technique
 - 1) Occluding the malformation in the dural leaf of the spinal nerve root or cutting off the feeding vessels immediately outside the root.
 - 2) occluding the radicular vein, which provides retrograde blood shunting from the AVM into the perimedullary veins.

Epidural AVMs

- Coagulate and section the direct tributaries: postcentral, prelaminar spinal branches.
- Coagulate and section the spinal branch of the segmental artery laterally at the point of its entry in to the intervertebral foramen, coagulated the intervertebral veins, and the epidural veins.

intravertebral malformations

- combine endovascular obliteration of feeding vessels and direct surgical intervention.
- Vertebral body affected but no body expansion and dura matter compression -
vertebroplasty
- Vertebral body expansion and dura mater compression -
occlude the vessels and resect the affected VB

Combined AVMs

- Primary extradural localization - endovascular technology
- Mainly intradural location and spinal cord compression - combination of endovascular and microsurgical methods

Author	Rosenblum et al 1987	Yasargil et al 1984	Conolly et al 1998	YURI P et al 2006
Cases	43	41	15	47
Follow up	3yr	3yr	3.8yr	4mth-8yr
Improved %	33	48	40	87.2
Unchanged%	51	32	53	8.5
Worse%	14	20	7	2.1

Embolization.

Indication

- Occlude only the feeding vessels
- Combined AVM and intervertebral AVM
- AVMs with a pronounced blood flow

Two variations of the conventional technique are applied:

- 1) super selective obliteration of the feeding vessels
- 2) obliteration of the main tributary, usually the segmental artery.

- If these arteries ended in the AVM it is possible to apply selective embolization.
- If these arteries extend branches to the AVM and continued farther, feeding the spinal cord, avoid embolization.
- a nonselective technique of obliteration of the segmental main tributary, if this artery do not feed the spinal cord ,staged obliteration of tributaries with a few days between each stage

Embolic agents

- Particulate materials
 - Poly vinyl alcohol(150-250micro)
 - Gelfoam
 - Sponge microparticulate
- Balloon occlusion
- Liquid agents
 - N-butyl cyanoacrylate
 - ethylene vinyl alcohol copolymer)

embolic agent	N-butyl cyanoacrylate	Onyx (ethylene vinyl alcohol copolymer)
type	liquid	liquid
dilution	Lipiodil	DMSO and Tantalum
proximal reflux	+++	+
venous penetration	+++	+
gluing of the catheter	+++	—
delayed venous thrombosis	+++	—

- Biondi et al
Embolization with particles

Mean follow up-	6 years
Total cases-	35
Recurrent avm-	35(100%)

 outcome

Improved	63%
Unchanged	26%
Worse	11%

- [Rufus A. Corkill](#), et al
Embolization with liquid embolic agent

mean follow-up	24.3 months
Total cases-	17

 outcome

total obliteration	6 patients (37.5%),
subtotal obliteration	5 patients (31.25%),
partial obliteration	5 patients (31.25%).
Improvement	14 patients (82%).

The cause of the initial neurological deterioration following embolization

- Edema in the spinal cord following occlusion of the nidus and thrombosis
- Occlusion of the ASA due to reflux
- Direct toxic effect of DMSO
- Thrombosis of the spinal veins

Risks of open surgical or endovascular treatment

- Skin infection or cellulitis
- Bleeding
- Injury to nervous tissue, causing paralysis, bladder or bowel dysfunction, or sexual dysfunction
- Chronic pain syndromes
- Thrombosis of epidural veins and neurologic loss
- Spinal cord infarction

Complications that result from open surgical ligation or resection

- Infection of meninges (meningitis)
- Cerebrospinal fluid leak
- Wound dehiscence

Complications that result from the endovascular technique

- Femoral hematoma
- Pseudoaneurysms and thrombosis
- Arterial dissection

Stereotactic radiosurgery

- Single high dose
- Hypofractionated irradiation
- 20 to 30% rate of occlusion.
- Internal fiducial markers and image-guided radiation allow stereotactic irradiation for spinal disease with real-time verification and an accuracy of ± 1 mm for every 0.03 seconds

Thank you