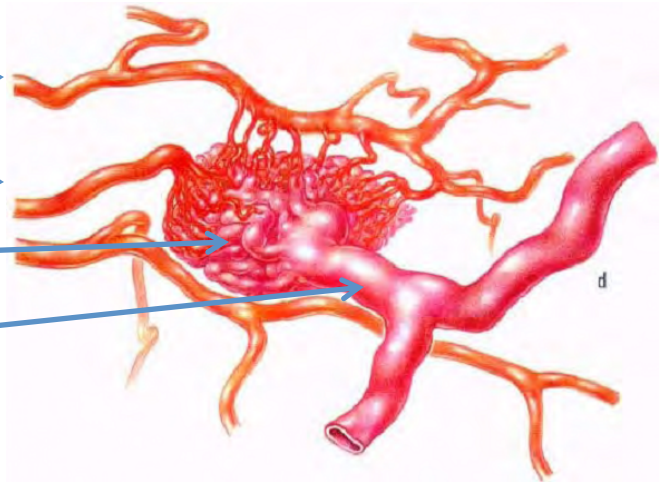
CRANIAL AVM: CLASSIFICATION AND MANAGEMENT

AV malformations

- High flow cerebrovascular lesions
- Prevalence 0.04-0.52%
- Sporadic (98%)
- Syndromic (2%)
    - Hereditary hemorrhagic telengiectasia (Osler Weber Rendu)
    - Cerebrofacial AV metameric syndromes (CAMS)

- Morphologic features
  - Feeding arteries
    - » En passage
    - » Terminal
  - Dysplastic vascular nidus
  - Draining vein
  - Perinidal capillary network



CLASSIFICATION FOR CNS VASCULAR ANOMALIES

Proliferating vascular tumor

- Hemangioma

Non proliferating vascular malformations

- Capillary malformation
- Venous malformation
- Cavernous malformation
- Arterial malformation (no shunting)
  - Angiodysplasia
  - Aneurysms
- AV shunting malformations
  - Classic cerebral AVM
  - Pial dural AVF
  - Carotid cavernous fistula
  - Dural AVF
  - Galenic AVM
- Mixed malformations
  - Venous - cavernous
  - AVM - venous
  - Cavernous – AVM
- Syndromic CNS malformations

Natural history

- Incidence 1.4-4.3% (autopsy study)
- 2% strokes, 38% ICH in 15-45 years
- Higher in Asians
- Majority supratentorial (infratentorial commoner in children)
- 3-30% occur in children
- Familial present early
- M = F or slight male preponderance
- 99% solitary
- Triangular with base towards the meninges
- Spontaneous regression 2-3%

AVM Angiogenesis

- Vascular event with thrombosis
- Venous hypertension --- HIF1 release
- VEGF stimulation ---- focal angiogenesis
- VEGF also released by (leucocyte, macrophages and MMP9 mediated from ECM)
- Angiogenesis causes IL 6 ---- recruitment of monocyte /macrophages
- Genetic alteration of TGFβ, Ang/ Tie-2 signaling

Semin Cerebrovasc Dis Stroke. 2004;4:217-225.

Genetics

- HHT (Osler Weber Rendu)
  - Type I : 9q .ENG gene mutation (TGFβ III receptor)
  - Type II : 12q. ACVRL 1 gene mutation (TGFβ I receptor)
  - Type III: 5q.
  - 20% unclassified
- CAMS (craniofacial AV metameric syndromes)
  - CAMS 1 : hypothalamus/ hypophysis and nose
  - CAMS 2 : occipital lobe, thalamus and maxilla
  - CAMS 3 : cerebellum, pons and mandible
  - Wyburn- Mason : diencephalon/ optic path or midbrain/ thalamus and retina
- VEGF R1 and 2 over expression
- Increased Ang-2 expression causing exposure of endothelial cells to VEGF and other growth factors
- Matrix Metalloproteases

Presentation

- Asymptomatic
- Haemorrhage
- Seizures
- Headache
- Neurological defecits
- Congestive heart failure

Asymptomatic

- Exact incidence unknown
- Population based studies of people with intracranial vascular malformations 40%
- Clinical studies - 2-4% detected incidentally
- Autopsy based studies only 12% were symptomatic

Haemorrhage

- Commonest presentation 38-65%
- Peak in the 5th decade
- 15% mortality, 30 – 50% disabling deficit / bleed
- Parrenchymal > IVH > SAH
- Risk of bleed 2-4%/ year
- Lifetime risk of bleed
  - 1-(risk of bleed)^{n}
    n=number of years of expected life remaining
  - 105-age (assuming a 3% risk of bleed /year)
- Risk factors
  - Previous bleed
  - Deep location
  - Deep venous drainage
  - Single draining vein
  - Size <3 / >6 cm

AVM and Aneurysms

- 8-10% (2.7-34%)
- M (41Y) > F (31Y)
- Multiple in 30-50%
- Classification
    - Flow related (85%)
        - Proximal (circle of Willis, proximal feeding vessel till primary bifurcation)
        - Distal
        - Intranidal
    - Unrelated (15%)
- Mechanisms
    - Incidental
    - Haemodynamic changes due to AVM
    - Both are congenital malformations

Seizures

- 15-35%
- Usually focal
- Increased incidence in
  - Superficial
  - Large size
  - Frontal / Temporal
- Probable causes
  - Mass effect
  - Cortical irritation
  - Steal ---- ischemia, cortical damage

Headache

- Seen in 15% at presentation
- Hemicranial / migraine like
- Occipital AVM
- Meningeal artery --- involvement/ recruitment of blood supply from it

Neurological deficits

- < 10% at presentation
- Transient, permanent, progressive
- Learning disorders in 66% of adults
- Functional decline 1.5%/ Yr (not due to bleed)
- Mechanism
    - Recurrent bleed
    - Mass effect
    - Hydrocephalus
    - Ischemia
    - Steal phenomenon

	GRAF	CRAWFORD	ONDRA	BROWN	BROWN	APSIMON	DA COSTA	HALIM
Number of patients	191	217	160	166 unruptured	91	57	678	760
Average follow-up	4.8 yr for unruptured	10.4 yr	23.7 yr	8.2 yr	6.6 yr	10 yr	2.85 yr	3.9 yr
Annual risk for hemorrhage			4%				4.61%	
Mortality from hemorrhage population studied		8.3%	23%			24.6%		
Proportion with hemorrhage experiencing morbidity-mortality from hemorrhage	13%	20% (40%)		29% (45%)				
Annual risk for death by hemorrhage			1.0%					
Morbidity and mortality from hemorrhage for the population studied			34%					
Annual morbidity and mortality			2.7%					
Annual risk for hemorrhage in the absence of a hemorrhagic history	14% at 5 yr, 39% 20 yr (2%-3%/yr)	1.7% over 10-yr period	1.7%	2.2%				3%
Annual risk for hemorrhage with a recent hemorrhagic history	Cumulative: 6% at 1 yr, 13% at 5 yr, 47% at 20 yr	3.6% over 10-yr period					7.48%	7%

Natural history

SERIES	NO. OF PATIENTS	FOLLOW-UP (yr)	ANNUAL HEMORRHAGE RATE
Graf et al., 1983	164	4.8	2%-3% in patients without hemorrhage; 6% at 1st yr after hemorrhage, then 2% in patients with hemorrhage
Crawford et al. 1986	217	10.4	2%; 36% cumulative risk at 10 yr in patients with hemorrhage; 17% in patients without hemorrhage
Brown et al.,1988	168 (all unruptured)	8.2	2.2%
Ondra et al 1990	160	23.7	4% overall; 3.9% in patients with hemorrhage; 4.3% in patients with seizures; 3.9% in patients with other symptoms
Mast et al 1997 Prospective	281	1.0	2.2% in patients without hemorrhage; 17.8% in patients with hemorrhage
Halim et al 2004	790	4.0	7% for the 1st year, then 3%

Diagnosis

- CT
  - Iso/ hyperdense serpentine vessels
  - Calcification in 20-30%
  - Strong enhancement
  - CT angio
- MRI
  - Tightly packed mass of flow voids with no mass effect
  - Little or no brain inside
  - FLAIR – flow voids with surrounding hyper signal
  - GRE blooming if haemorrhage
  - Strong contrast enhancement
  - DWI normal
  - MRA
- IADSA

Diagnosis

- IADSA
  - Super selective
  - All 4 vessels (essential to study ECA separately)
  - Must delineate
    - » Arterial feeders
    - » Venous drainage
    - » Internal architecture
    - » Associated lesions
    - » Collateral circulation
    - » Venous drainage of normal brain
  - Dural supply leptomeningeal / transdural

Classification

- Luessenhop and Gennareli
- Spetzler Martin
- Nataf
- Garreston
- Vienna

Spetzler Martin grading

- Determination of AVM grade

Graded feature	Points assigned
Size of AVM	
Small (<3cm)	1
Medium (3-6 cm)	2
Large (>6 cm)	3
Eloquence of adjacent brain	
Non Eloquent	0
Eloquent	1
Pattern of venous drainage	
Superficial only	0
Deep	1

Management

- Observation
- Microsurgery
- Gamma knife
- Embolization
- Combination
- One modality or a sequential combination is the ideal treatment for a patient, different modalities are not interchangeable

Microsurgery

- Patient related
  - » Age
  - » General condition
  - » Neurological status
  - » Occupation and lifestyle
- AVM related
  - » Size and configuration
  - » Location
  - » AVM anatomy and aneurysms
- Surgeon related
  - » Experience
  - » Availability and familiarity with all modalities

Microsurgery

- Always elective surgery
- If hematoma – conservative evacuation
- All brain is eloquent, some is more eloquent
- Large craniotomy for superficial lesions
- Positioning to minimize retraction
- Major draining veins controlled last

Dissection technique

- Open arachnoid, sulci and fissures
- Circumferential dissection
- Arteries tackled first
- Follow till the nidus and confirm the entry to the AVM
- Transect close to nidus
- No tamponade except on AVM
- Skeletonize superficial major draining vein
- Post resection
    - Hypertensive challenge
    - Cottonoid rub
    - Intraop / postop angiography

Microsurgery complications

- Intra operative
  - Bleeding
  - Parenchymal damage
  - Retraction injury
  - Visual radiation injury
- Post operative
  - Hemorrhage
  - New onset Seizures 15% (55% improve, 35% unchanged)
  - NPPB
  - Retrograde venous/ arterial thrombosis
  - Vasospasm (rare)

Normal perfusion pressure breakthrough

- Incidence 3%
- Mechanism
  - Chronic low pressure flow causes maximal dilatation of vessels and paresis of autoregulation
  - Return of normal pressure flow caused hyperemia and haemorrhage
- Presentation
  - Neurological deterioration
- Management
  - Pre op β blockers (MAP ≤ 70)
  - Intensive monitoring X 7 days post op
  - Maintain CPP>60 at MAP < 70 (CT to exclude SOL, burst suppression)
  - If clinical assessment not possible ICP monitoring
  - AED
  - Fluid balance

Surgery outcome

- Risk of surgery is quite well estimated by the Spetzler-Martin grading system, with a favorable outcome in

  92%–100% grade I

  95% grade II

  88% grade III

  73% grade IV

  57% grade V

  (Spetzler and Martin 1986;Heros et al. 1990)

Adjuvant Embolization

- Pre operative
  - Reduce blood loss, operating time, morbidity
  - Reduce blood flow
  - Control deep feeders
  - Wait 1-3 weeks before surgery
- Pre GK
  - Reduce size
  - Targeted (aneurysm)
- Agents used
  - NBCA, Onyx (EVOH copolymer DMSO)
  - PVA, silk, gelfoam, silastic, clots

Curative Embolization

- Mortality 1-4%
- Morbidity 0 - 50%
- Defecits 10 – 14% (disabling 2-5%)
- Cure rates 5-20% (0-70%, gyral 12.5% sulcal 60%)
- Success
    - Nidus accessible to catheter
    - <3 feeders
    - Nidus < 3 cm

Radiosurgery

- Curative in lesions < 3cm
- Younger respond better and faster
- On average the time to cure is 2 years from the initial treatment and may be upto 4 years
- Likelihood of obliteration

35.67 X marginal dose – 39.66

- Optimal dose 25 Gy
- Risk of bleeding after GK is the same

Radiosurgery

- Radiation dose causes endothelial damage, smooth muscle cell proliferation, progressive sclerosis and subsequent thrombosis of nidal channels over time
- The success of stereotactic radiosurgery depends on AVM size and the radiation dose delivered
- **Modified Pollock Flickinger AVM score**

AVM score = (0.1) (volume, ml) + (0.02) (age, yr) + (0.5) (location)

basal ganglia/thalamus/ brainstem = 1

AVM score	Excellent outcome	Decline in MRS
≤1.00	89%	0%
1.00 - 1.50	70%	13%
1.51 – 2.00	64%	20%
> 2.00	46%	36%

Neurosurgery 63:239–243, 2008

Giant AVM

- > 6 cm
- Deep component has a 9.56% annual rate of bleed

  Neurosurgery 53:1-13, 2003
- More likely to have deep venous drainage, ventricular component
- Staged therapy
- Obliteration of > 25% , higher complications
- Induced hypotension after a partial size reduction
- Indications of therapy
  - Haemorrhage
  - Progressive major defecits
  - Intractable seizures
- Sequential use of GK/ embolization /surgery

Comparison of treatment modalities

	Ablation	Time	Seizures		New defecits
			Old	new	
Surgery	96%	Immediate	66 -76%	4-15%	2.5 – 17%
Curative embolization	5-20%	Immediate			10 - 14 %
Radiosurgery	80% at 2 Yrs at marginal dose of 25 Gy	Years			5 – 10 %

J Neurosurg. 2009 May;110(5):1003-9.
Outcome after hemorrhage following Gamma Knife surgery for cerebral arteriovenous malformations.
Kasliwal MK, Kale SS, Gupta A, Kiran NA, Sharma MS, Sharma BS, Mahapatra AK.

J Neurosurg. 2007 Dec;107(6 Suppl):479-84.
Gamma Knife surgery for intracranial arteriovenous malformations in children: a retrospective study in 103 patients.
Kiran NA, Kale SS, Vaishya S, Kasliwal MK, Gupta A, Sharma MS, Sharma BS, Mahapatra AK.

For many patients with large AVMs, discretion may be the better part of valour. As patients and their surgeons age, the vigour with which multimodality management strategies are pursued begins to wane.

L Dade Lunsford
Comments
Neurosurgery 53:1-13, 2003

We now recommend no treatment for most Grade IV and V AVMs. In fact, partial treatment may even worsen outcomes compared with the natural history of AVMs. We do not support palliative treatment of AVMs except in the specific circumstances of arterial or intranidal aneurysms or progressive neurological deficits related to vascular steal.

Robert F Spetzler
Comments
Neurosurgery 53:1-13, 2003

Most Grade V AVMs and many Grade IV AVMs should be treated conservatively since they are generally too large for radiosurgery, present unacceptable surgical morbidity, can only rarely be completely occluded by embolization and incomplete embolization, which is risky, does not improve and may worsen the natural history.

Roberto C Heros
Youmans Neurological Surgery 6th edition

THANK YOU