Arteriovenous Malformation of the Brain: Everything You Need to Know

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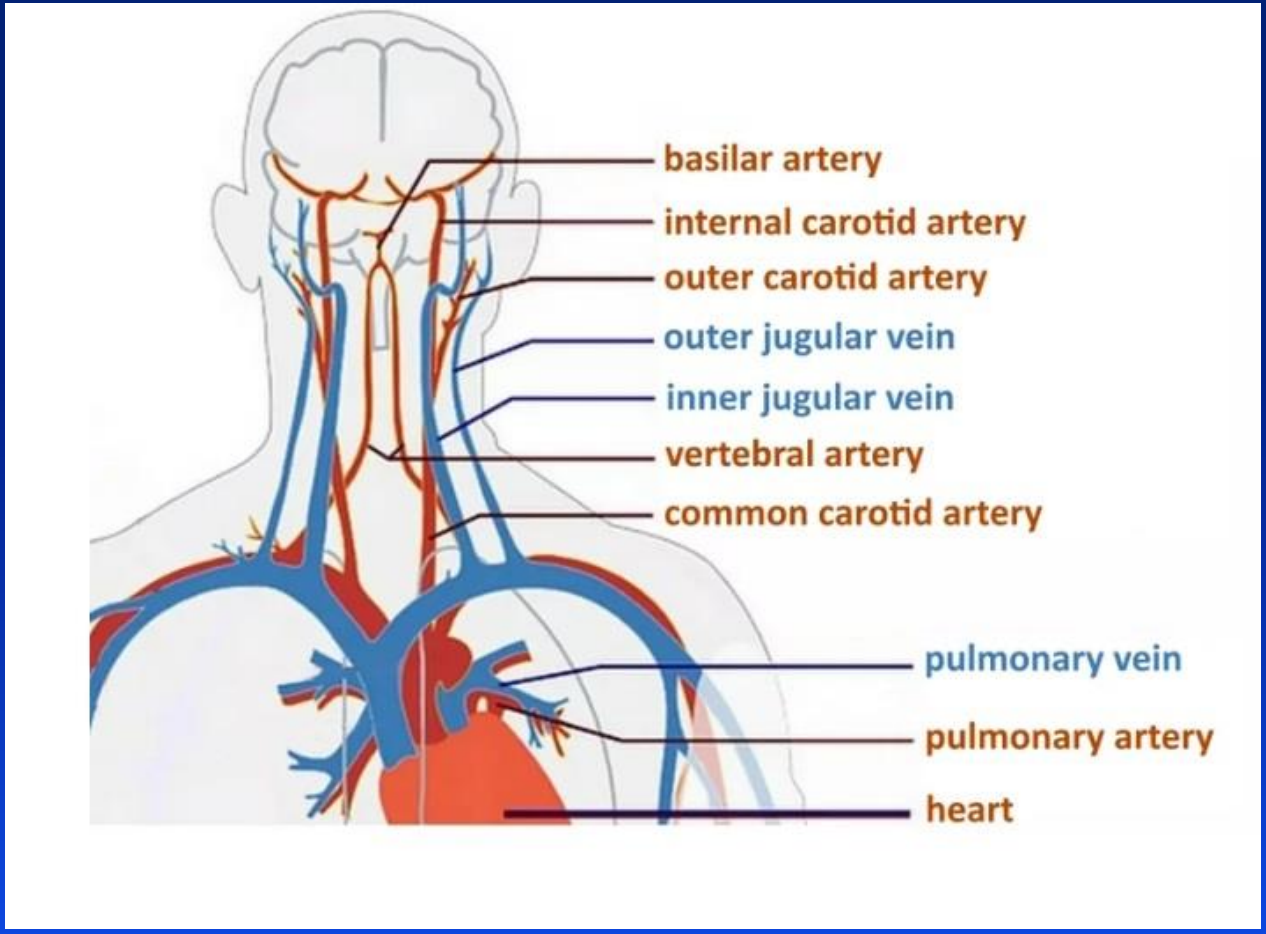
Financial Disclosures

- [None]
- Looking at you, Medtronic
- Ball's in your court

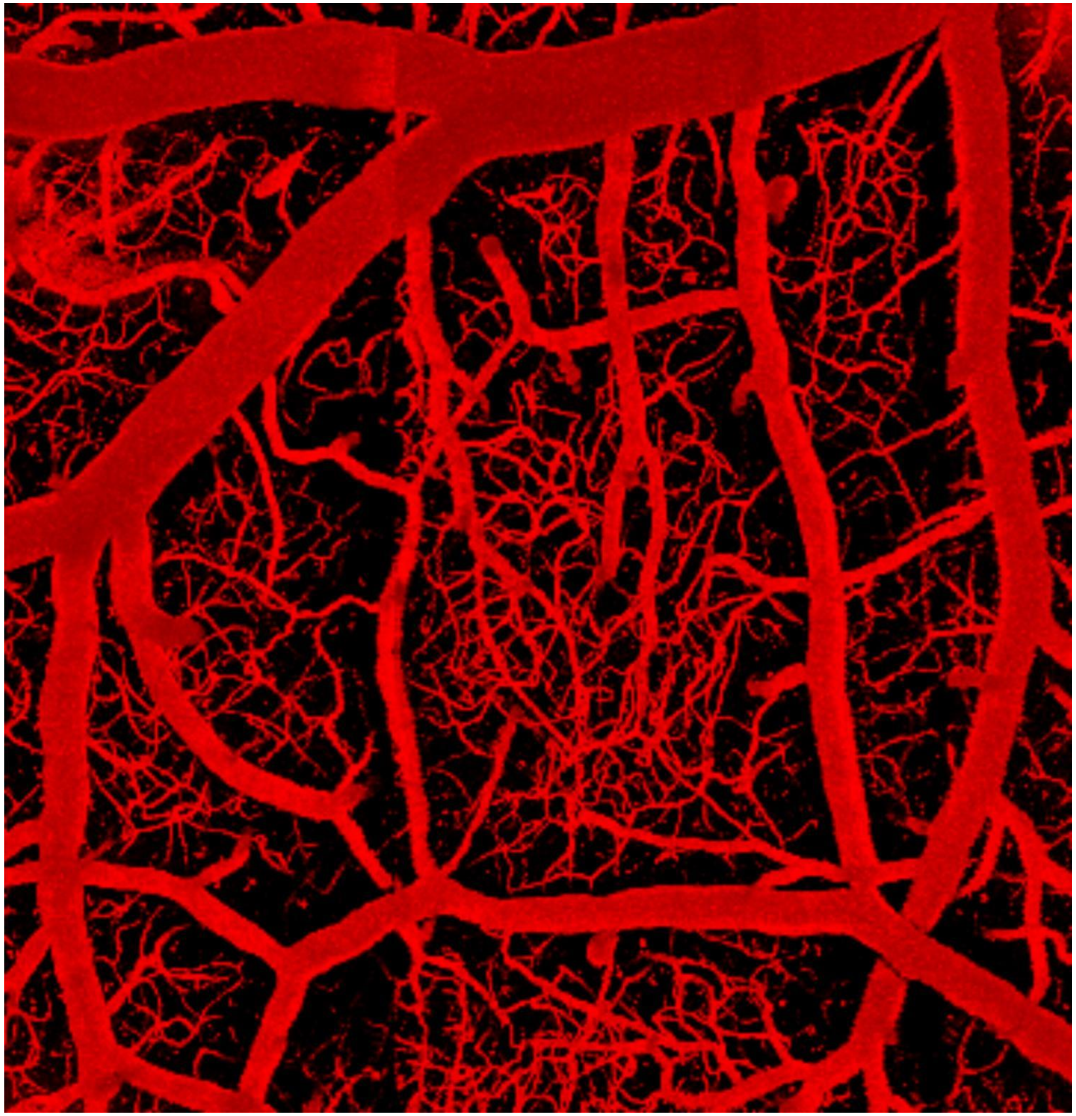
Arteries vs Veins

- Arteries carry blood to capillaries, veins drain blood from capillaries
- Arteries are high pressure, veins are low pressure
- Arteries supply a strictly defined territory, veins share territories

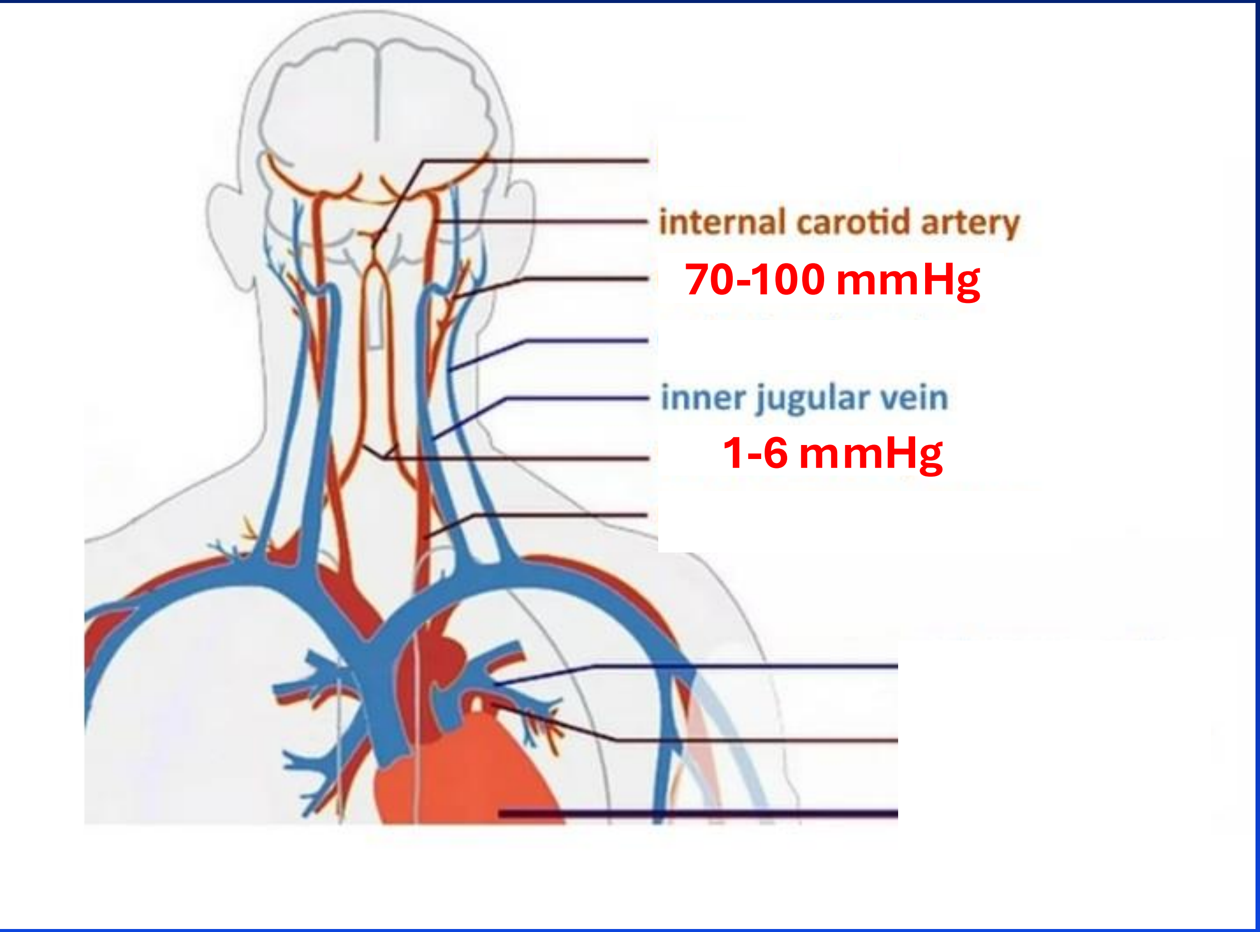
Arteries vs Veins



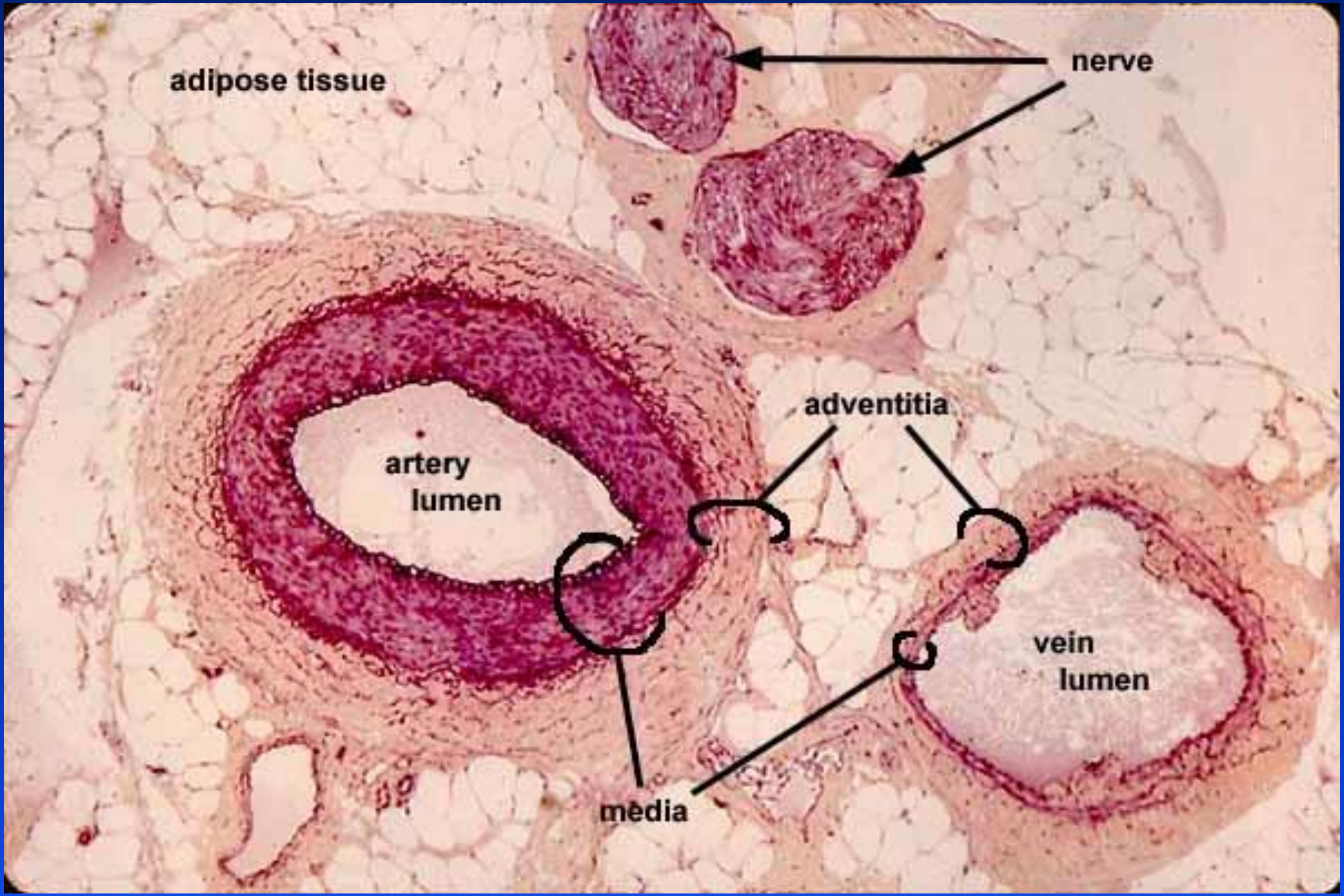
Arterial Pressure Drives Perfusion



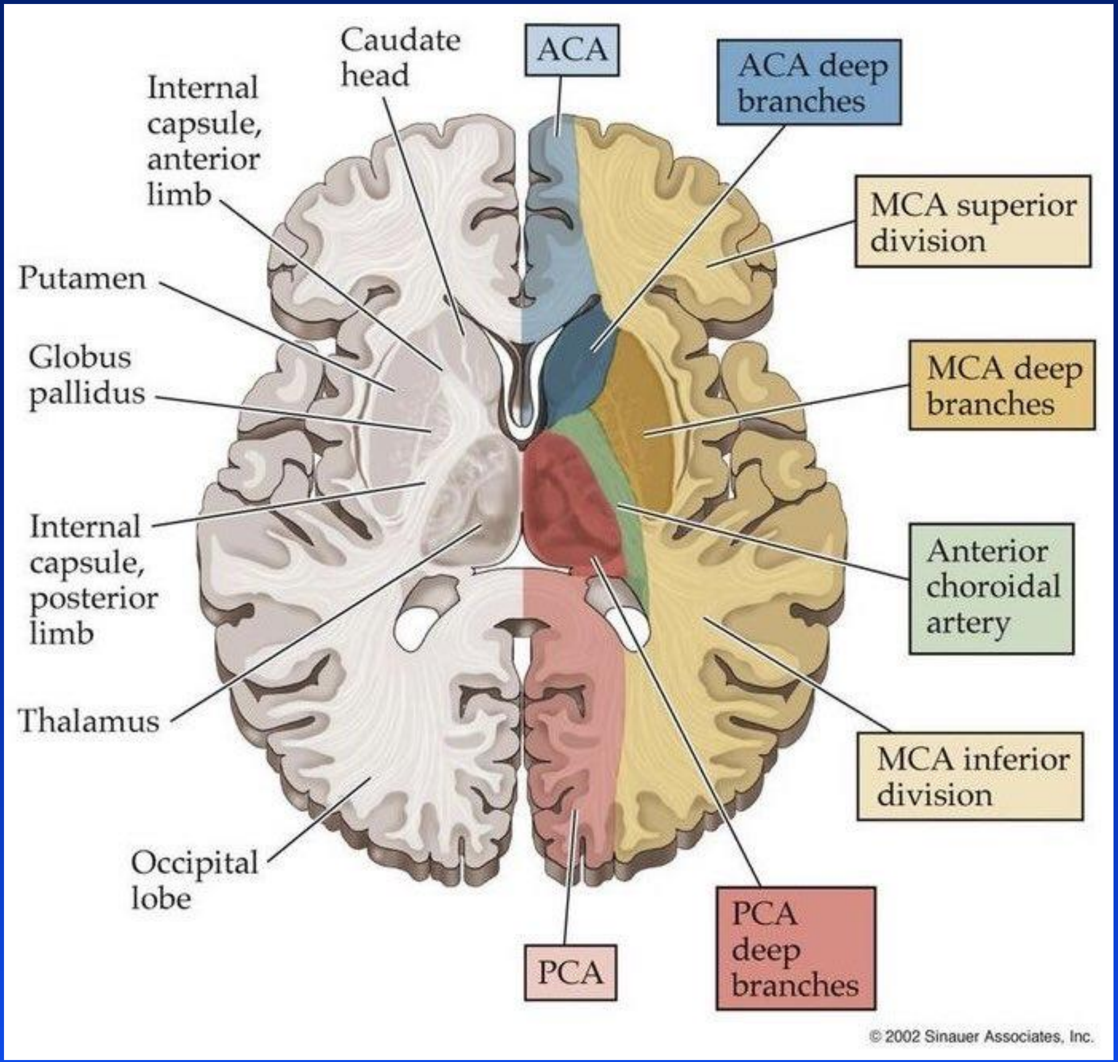
Arteries vs Veins



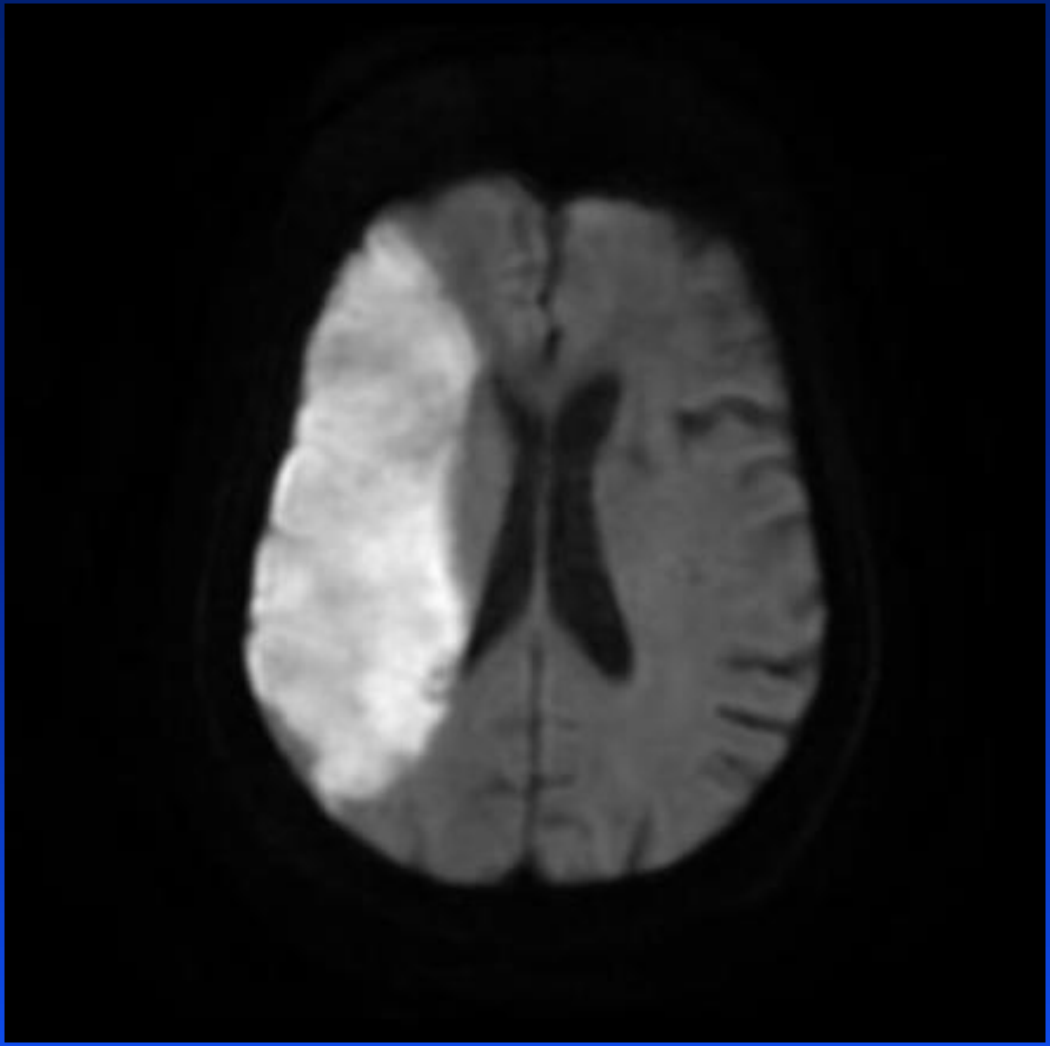
Arteries vs Veins



Arteries vs Veins

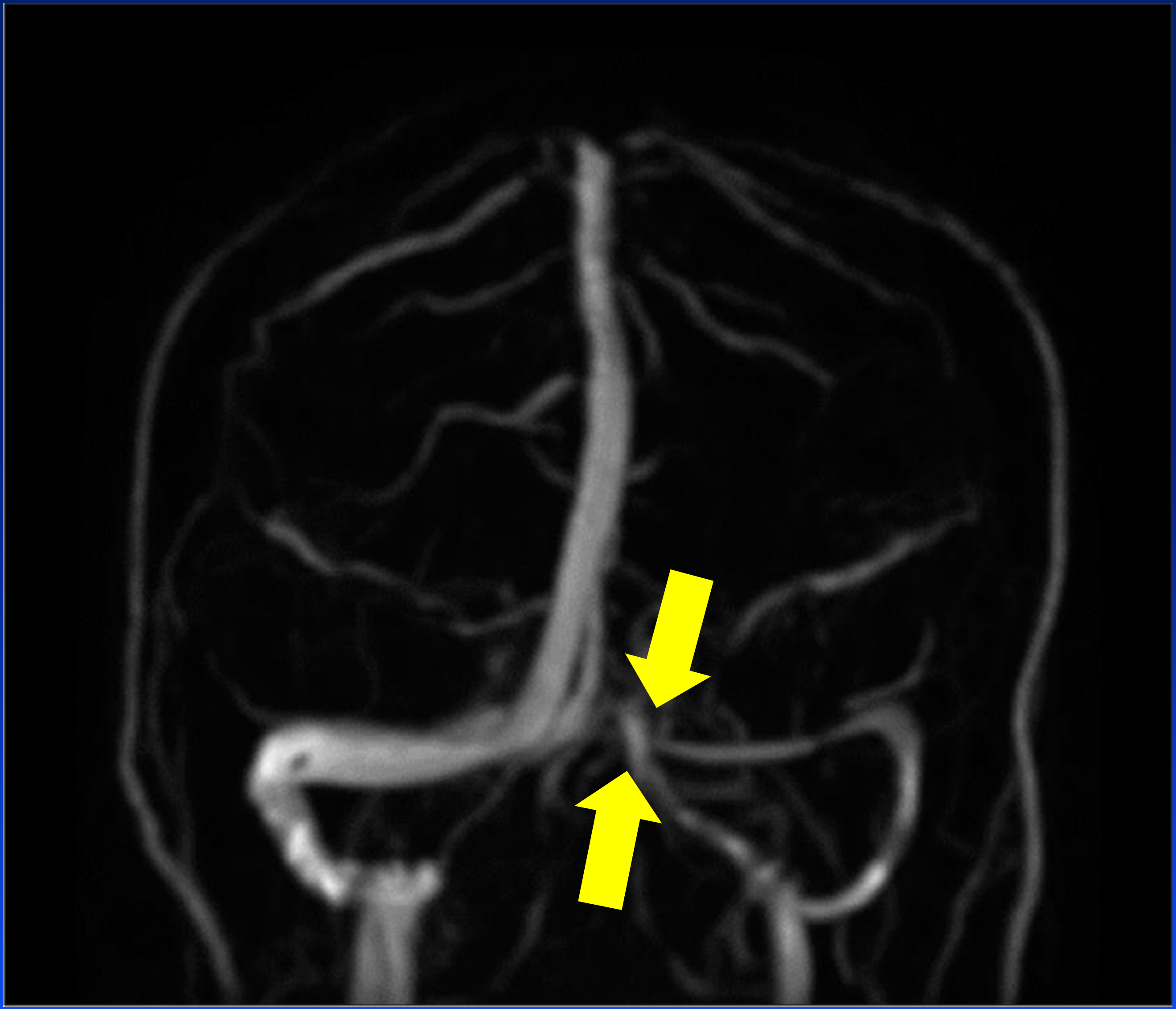


Arteries vs Veins



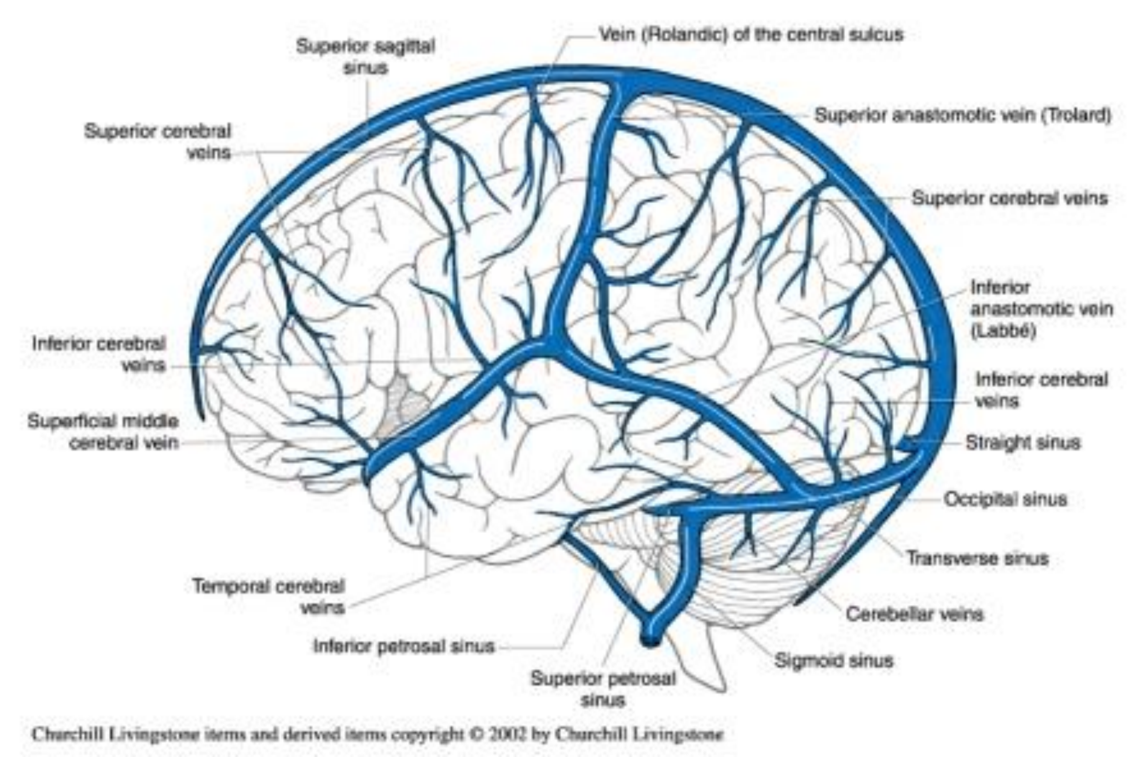
- Flow disruption of the R MCA
- Diffusion weighted MRI shows infarct
- L hemiplegia, L homonymous vision loss, L hemispatial neglect
- Neurons are dead, never coming back

Arteries vs Veins



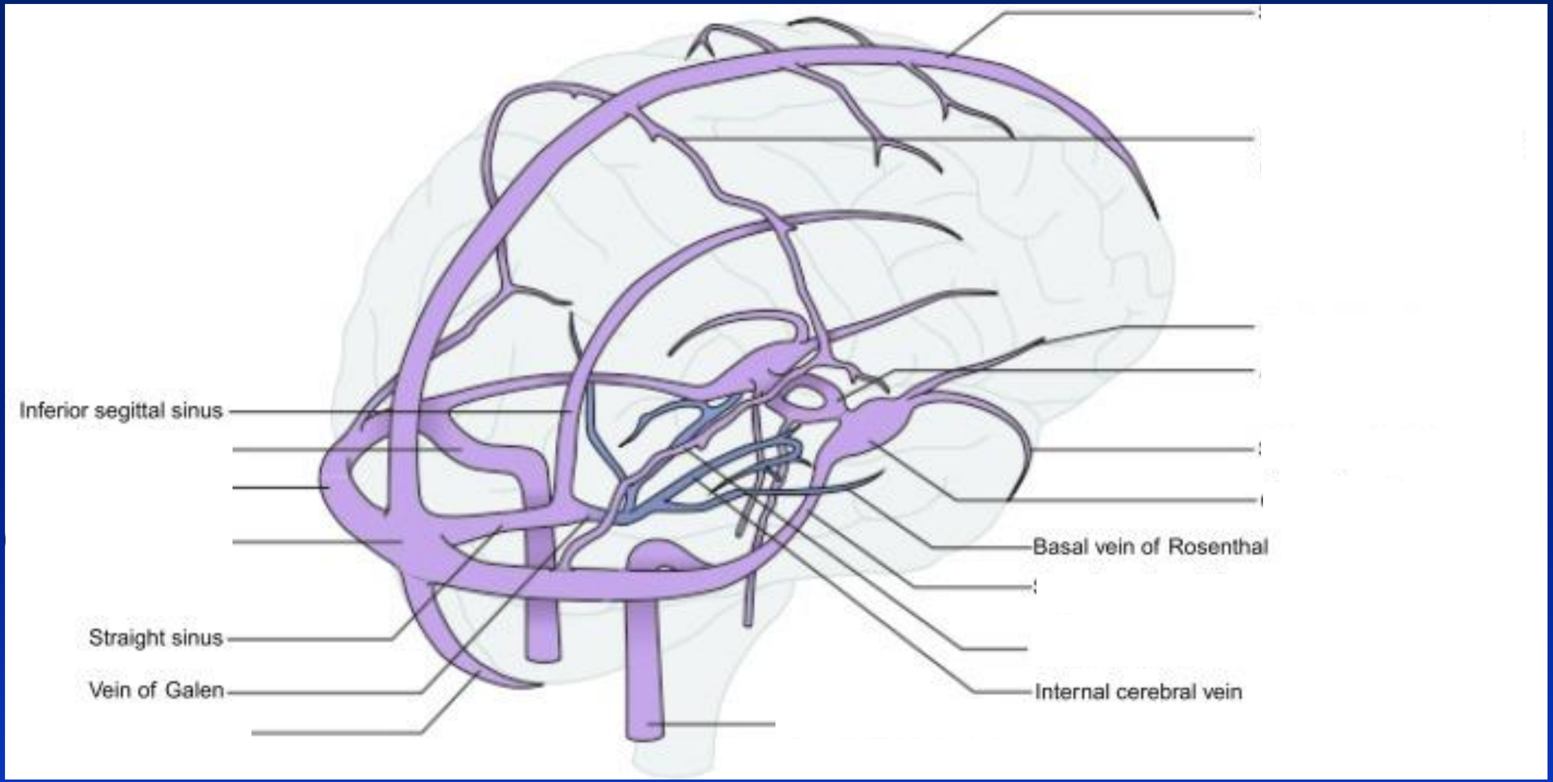
- Flow disruption of the L TS
- What clinical symptoms would you expect?
- NONE! The patient is fine!
- There is redundancy of the superficial* venous system
- Other veins take over!

Superficial aka "Dural" Venous System

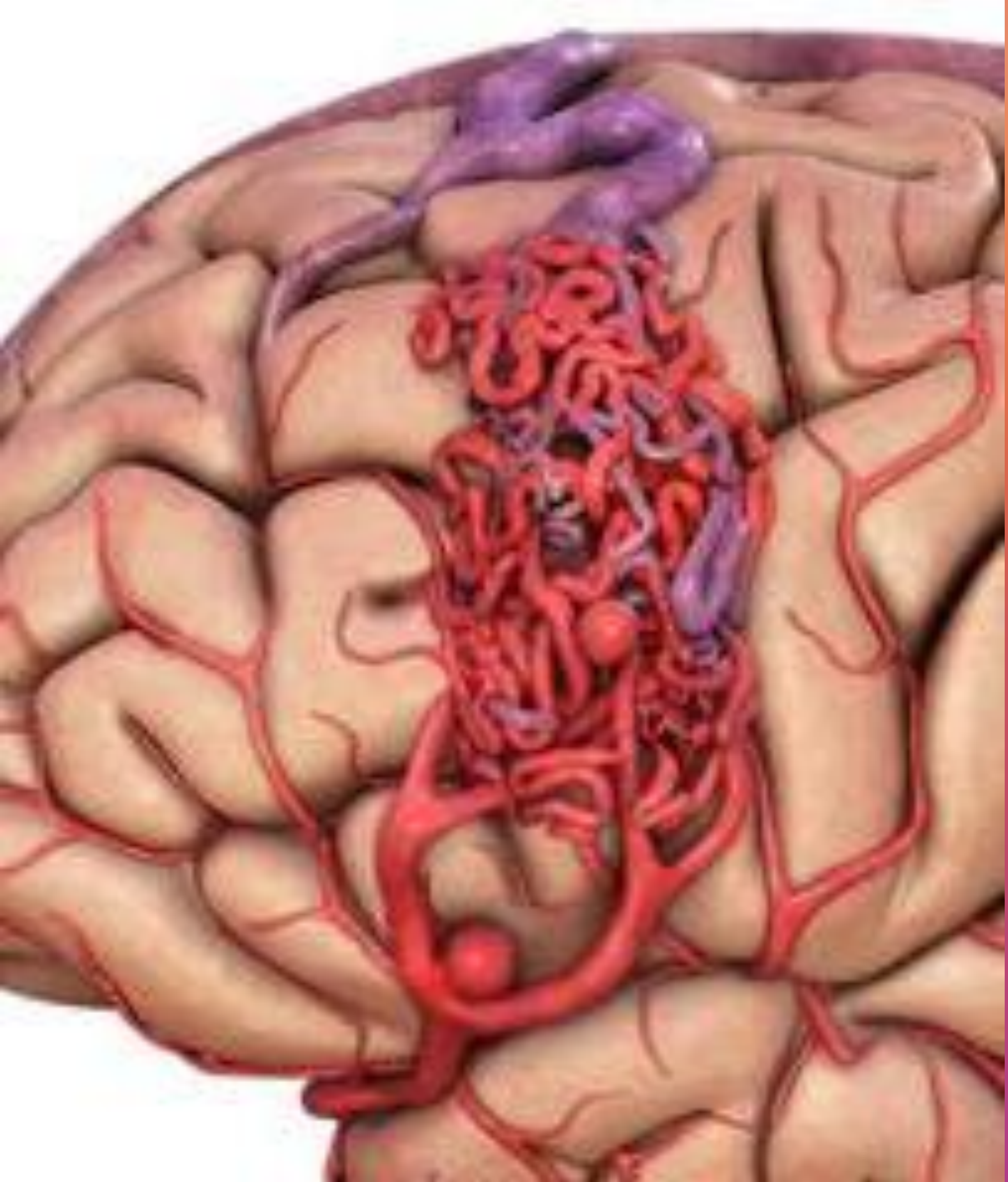


- Very forgiving
- If occluded, blood can find alternative routes
- Dangerous exceptions:
  1. Cortical veins
  2. The confluence of sinuses (torcula)
  3. The posterior third of the superior sagittal sinus

Deep Venous System



- Much less forgiving
- Occlusion often deadly
- Lacks redundancy



So what is an AVM?

Brain AVMs are abnormal <u>high-flow</u> artery-to-vein shunts through a nidus <u>without an intervening capillary bed</u>.

Presentation: what you'll see in practice

Most referrals begin with an event or an incidental imaging finding.

Hemorrhage

Sudden severe headache, vomiting, altered consciousness, focal deficit, seizure; CT/CTA first in acute settings.

Seizure

New focal or generalized seizure, especially in a younger adult without prior epilepsy.

Headache / migraine mimic

Headache alone is nonspecific; vascular imaging is driven by red flags, abnormal neurologic exam, or atypical course.

Incidental finding

Detected on MRI/CTA ordered for unrelated symptoms; still warrants vascular-neurosurgery review.

Action threshold:

Urgent ED evaluation for acute neurologic symptoms or imaging findings of hemorrhage; nonurgent referral to a cerebrovascular neurosurgeon/interventional neuroradiology team for stable patients.

Derdeyn et al., Stroke 2017;
Choi & Mohr, Lancet Neurol 2005;
BMJ Best Practice 2023

Natural history: risk is not uniform

Annual hemorrhage risk depends on prior rupture and anatomy

~1–3%/yr

All unruptured AVMs

~4–5%/yr

Previously ruptured AVMs

Higher

deep location, deep drainage, associated aneurysm, prior hemorrhage

Translation**:**

"Unruptured" does <u>not</u> mean benign, but the treatment risk may still exceed natural-history risk. "Ruptured" generally changes the risk-benefit discussion toward eventual obliteration if feasible.

Gross & Du, J Neurosurg 2013;
Rutledge et al., Neurosurg Focus 2014;
Derdeyn et al., Stroke 2017.

Grading: why treatment modality varies

Spetzler–Martin estimates microsurgical risk; newer adjunct scales refine selection.

Spetzler–Martin components

Size — <3 cm = 1 | 3–6 cm = 2 | >6 cm = 3

Eloquence — Non-eloquent = 0 | eloquent = 1

Venous drainage — Superficial only = 0 | deep = 1

Clinical meaning by SM grade

I-II — often surgical candidates

III — individualized

IV-V — conservative/SRS/ selective surgery

Key Limitation:

Grade is <u>not</u> hemorrhage risk. It is mostly treatment-risk language.

Spetzler & Martin, J Neurosurg 1986;
Kim et al., Neurosurgery 2015.

Grading: features specialists care about

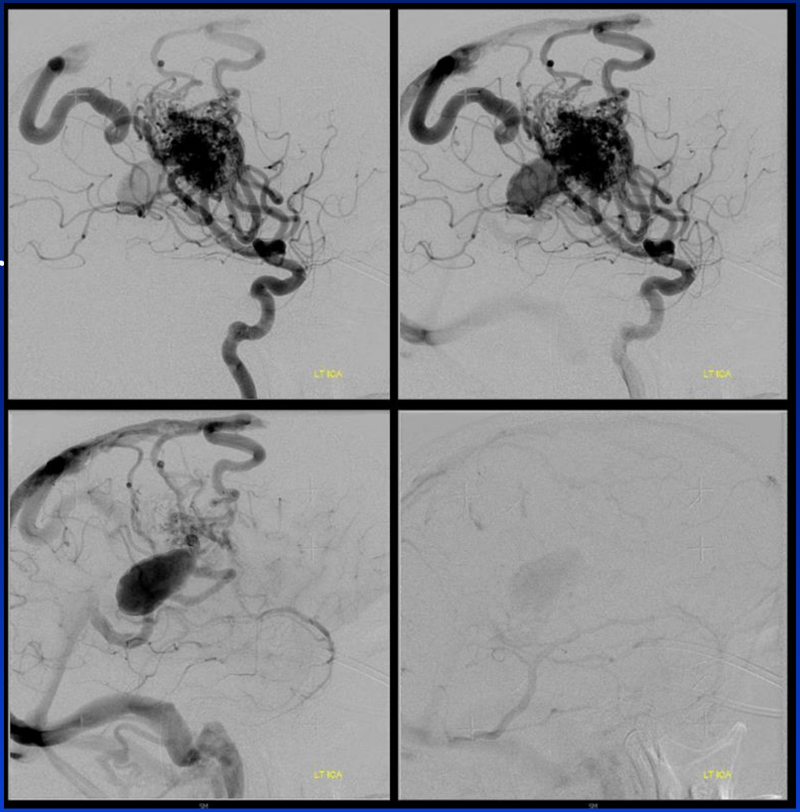
The Spetzler–Martin grading scale does not capture all surgical considerations

Compact vs diffuse nidus
- Compact nidus is easier to obliterate surgically

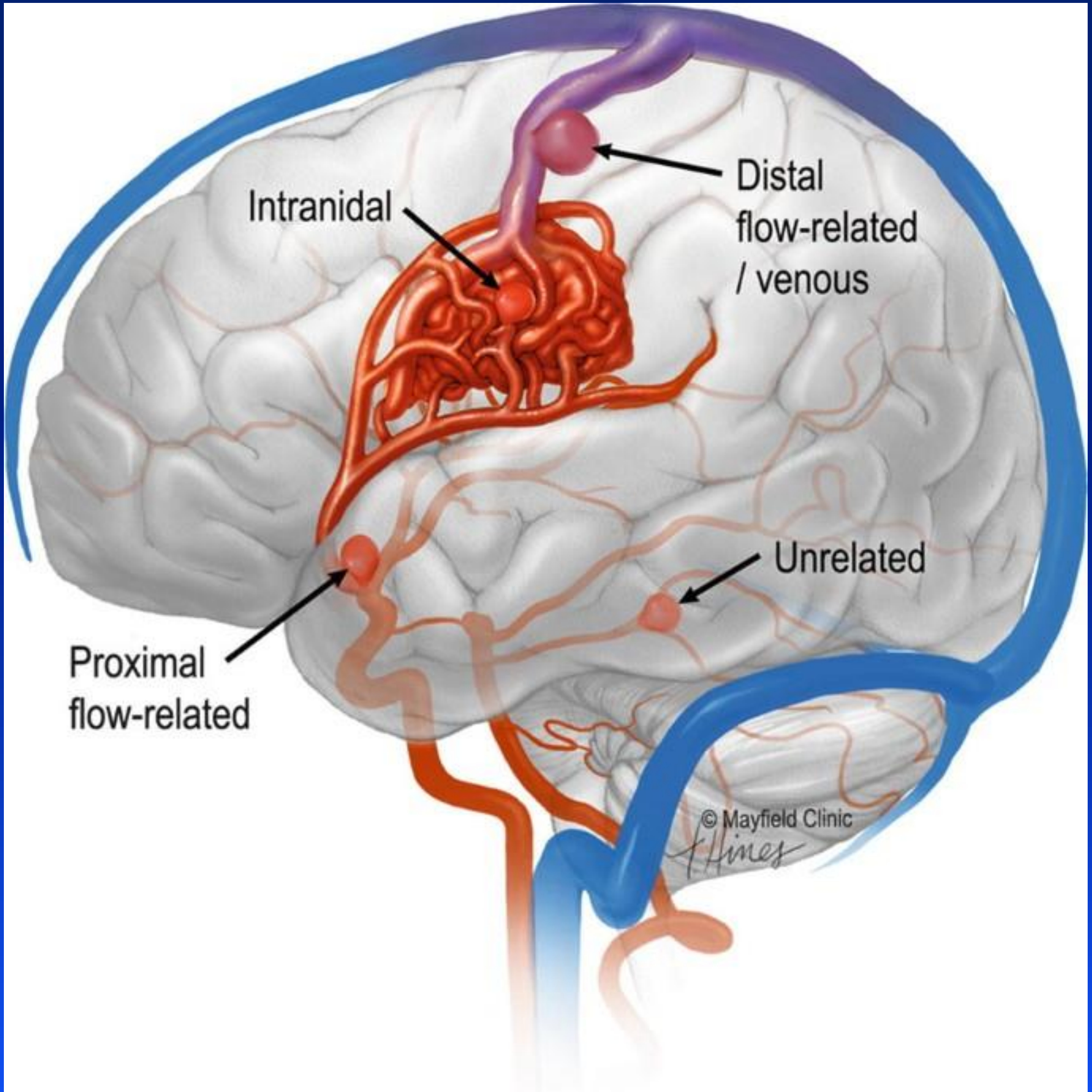
Presence of a venous varix
- Venous aneurysm is a high risk feature for hemorrhage and may push towards urgent treatment

Surgical corridor
- Even some deep lesions can be safely approached

Endovascular access
- Tortuosity
- Transarterial vs transvenous embolization

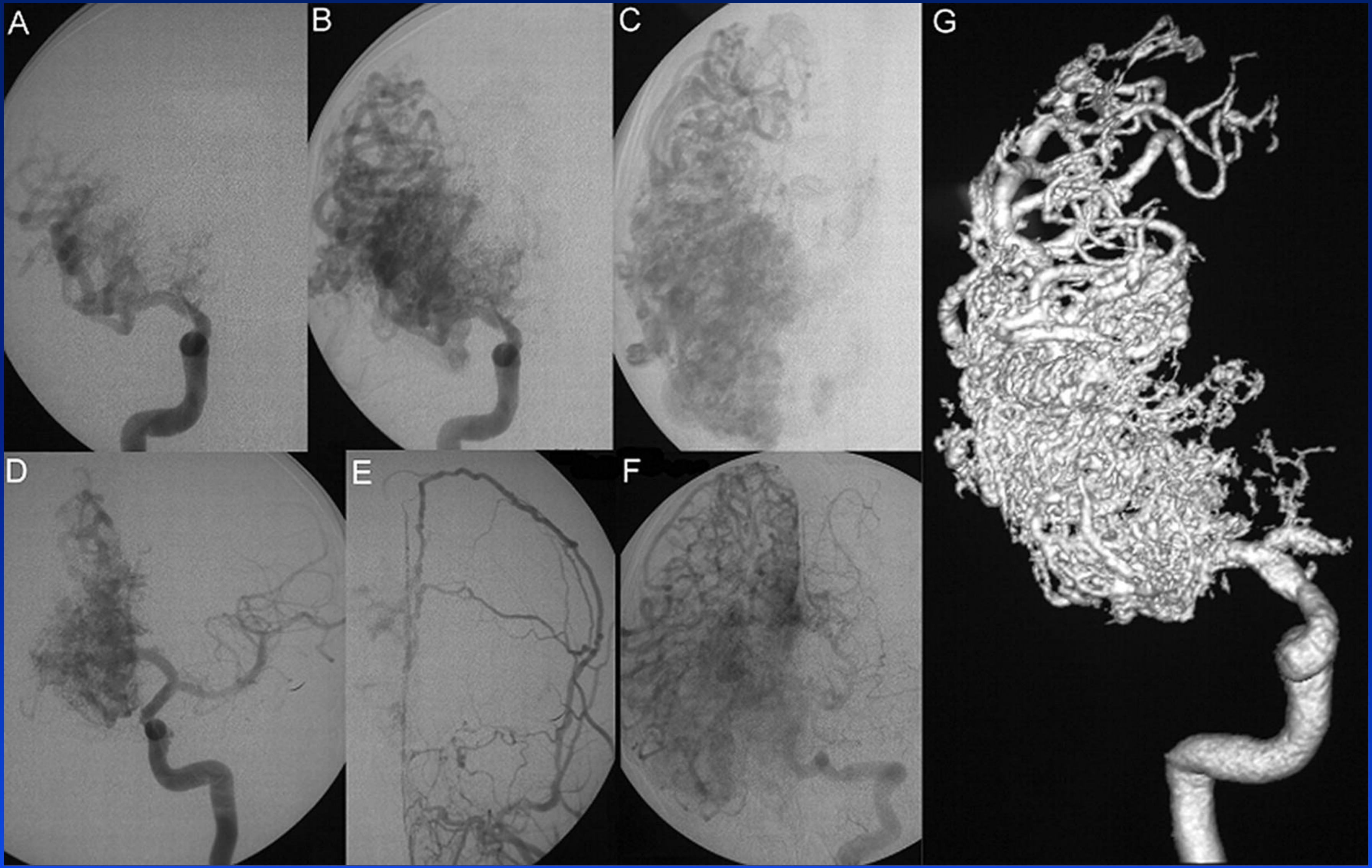


A note on AVM related aneurysms



Cerebral proliferative angiopathy

The extreme end of diffuse nidus



Treatment goals and modalities

A treatment plan is built around complete obliteration with acceptable morbidity.

Microsurgery

Immediate cure when resection is complete; best for low-grade, superficial, surgically accessible AVMs.

Stereotactic radiosurgery

Non-open option for small/deep AVMs; obliteration takes years, so hemorrhage risk persists during latency.

Endovascular embolization

Adjunct to surgery/SRS or targeted treatment of high-risk angioarchitecture; rarely definitive alone.

Observation / medical management

BP control, seizure management, counseling, and surveillance when treatment risk is high or evidence favors conservative care.

Derdeyn et al., Stroke 2017;
Serrone et al.,
Neurosurg Focus 2014.

The Infamous Aruba Trial

Still the best RCT data we have for surgery for unruptured AVMs

ARUBA randomized unruptured AVMs to medical management alone vs. medical management + intervention

What it showed

- Stopped early after higher death/symptomatic stroke in the interventional group
- Extended follow-up continued to favor medical management alone
- A major reason many unruptured AVMs are observed initially

Why controversy remains

- Short follow-up relative to lifetime hemorrhage risk
- Heterogeneous interventions and center expertise
- Does not mean “never treat”—rather, treat selectively in experienced centers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Medical management with or without interventional therapy for unruptured brain arteriovenous malformations (ARUBA): a multicentre, non-blinded, randomised trial

Prof J P Mohr, MD [a,*] · Prof Michael K Parides, PhD [b,*] · Prof Christian Stapf, MD [a,c,d,*] · Ellen Moquete, RN [b] · Claudia S Moy, PhD [g] · Jessica R Overbey, MS [b] · et al. Show more

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Rupture: acute care first, cure second

Rupture changes urgency of treatment, but not every AVM is obliterated emergently

0–24 h

Stabilize: ICH/IVH care, BP management, hydrocephalus treatment, seizure care, CTA/DSA as appropriate.

Days–weeks

Define anatomy and associated aneurysms/varices; treat ruptured flow-related aneurysm or high-risk feature when indicated.

Weeks–months

Plan definitive obliteration after hematoma resolves when safer—surgery, SRS, embolization, or multimodality.

Primary care follow up goals:

Confirm neurosurgical plan, monitor neurologic recovery, review driving/seizure restrictions, reconcile antithrombotics individually, and support rehab.

Derdeyn et al., Stroke 2017; AHA/ASA ICH principles extrapolated to rupture management

Microsurgery: The Fastest Cure

Low-grade AVMs are where surgery has its clearest role.

Best-fit profile

- Spetzler–Martin I–II; select III
- Non-eloquent or safely accessible eloquent lesion
- Prior hemorrhage may favor cure if morbidity acceptable
- Surgery eliminates risk immediately only if complete

Counseling cautions

- Surgical risk increases with size, eloquence, deep drainage, diffuseness, age
- Institutional experience matters
- Neuropsychological and visual/language deficits may be highly consequential even when mRS is "good"

Spetzler & Martin, J Neurosurg 1986;
Kim et al., Neurosurgery 2015;
Darsaut et al., J Neurosurg/TOBAS surgery registry 2022.

Radiosurgery: Delayed Cure Strategy

Best for compact, deeply draining lesions where surgery is riskier.

Focused radiation causes progressive vessel wall injury and eventual nidus obliteration

Latency

Obliteration usually takes 2–4 years; hemorrhage risk persists until angiographic cure.

Risks

Radiation-induced imaging changes, edema, cysts, delayed deficits; incomplete obliteration may need repeat therapy.

Ideal lesions

Small volume, compact nidus; deep/eloquent location may favor SRS over surgery.

Friedman et al., J Neurosurg 1996;
Shin et al., Stroke 2005.

Embolization: powerful but usually adjunctive

The catheter is often part of a staged strategy—not the whole treatment.

Preoperative adjunct

Reduce flow, occlude deep feeders, treat intranidal or flow-related aneurysms, simplify resection.

Targeted palliation

High-risk angioarchitecture or symptoms when cure is not feasible.

Before/with SRS

Reduce nidal volume in selected cases; may complicate target definition depending on agent and residual nidus.

Standalone cure

Possible in select small AVMs, but not the default evidence-based assumption.

Transvenous is probably more efficacious than transarterial

“embolized” ≠ “cured” unless complete obliteration is documented.

Plasencia & Santillan, Surg Neurol Int 2012;
Lauren et al., 2025 systematic review.

Pushing AVM knowledge forward at BIDMC

Work spanning open, endovascular, and radiation strategies.

Role and clinical focus

Dr. Ogilvy is Professor of Neurosurgery at Harvard Medical School; BIDMC clinical interests include brain and spinal AVMs, vascular malformations, aneurysms, moyamoya, and stroke.

1 Multimodal AVM care

Coauthored 12-year experience comparing multimodal treatment outcomes with ARUBA-era benchmarks; emphasized careful selection and multidisciplinary treatment.

2 Pediatric AVM treatment

Earlier pediatric nongalenic AVM work described combined surgery, radiosurgery, and embolization approaches to improve outcomes.

3 Radiosurgery / proton beam

Contributed to pediatric and proton-beam stereotactic radiosurgery series evaluating obliteration, hemorrhage, and complications.

4 Risk stratification

Participated in multicenter validation of the supplemented Spetzler–Martin system and contemporary MISTA consortium propensity-score analyses.

The Algorithm Simplified

The management question is urgency first, then rupture status, then treatment candidacy.

Acute symptoms? → **CT/CTA ± DSA** → **Specialist plan**

Ruptured	Acute ICH management → anatomy → definitive obliteration if feasible.
Unruptured, low-grade	Discuss observation vs treatment; surgery/SRS selected by anatomy and expertise.
Unruptured, high-grade	Observation often favored; targeted treatment only for compelling high-risk features.

Do not skip the "specialist plan" box: AVM decisions are evidence-constrained and center-dependent.

Gross & Du, J Neurosurg 2013;
Rutledge et al., Neurosurg Focus 2014;
Derdeyn et al., Stroke 2017.

The value of "dual trained" neurosurgeons

- Cerebrovascular neurosurgeon
  - A neurosurgeon who specializes in craniotomies for resection or ligation of vascular anomalies like aneurysms, fistulae, or malformations
- Neurointerventionalist
  - A radiologist, neurosurgeon, neurologist, or rarely even cardiologist who performs catheter-based procedures on the blood vessels of the brain
- Interest in endovascular training in neurosurgery is growing

Selected references

Core evidence and further reading.

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