Update on Endovascular Treatment of Arteriovenous Malformations/Fistulas

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Intracranial AVMs/AVFs:

- Short circuit between arteries and veins via abnormal blood vessels. This abnormal flow can cause bleeding in the brain

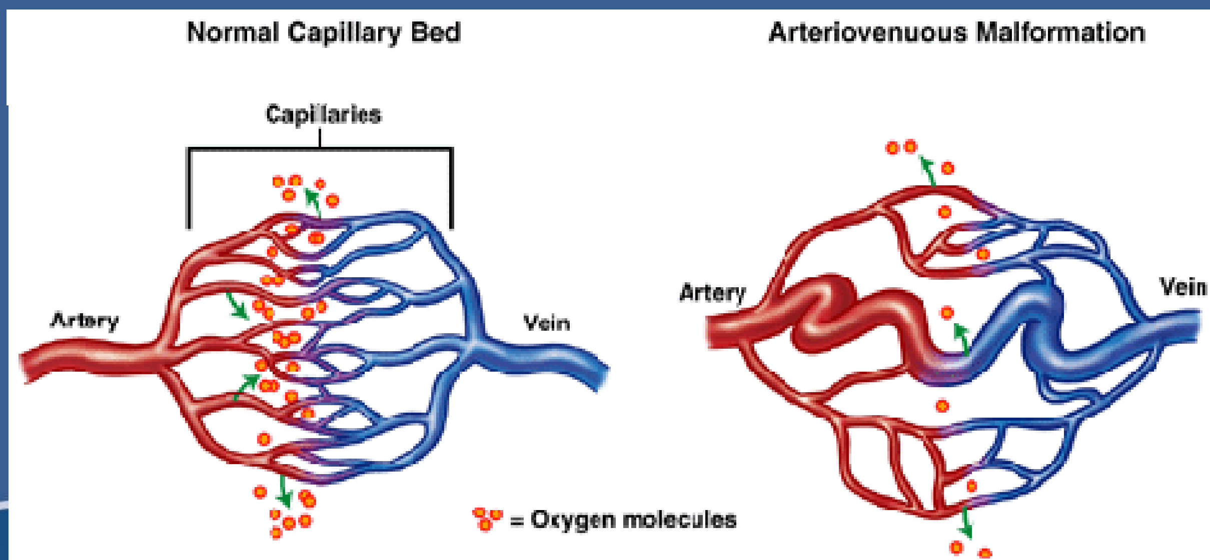
Intracranial AVMs/AVFs:

-Agenesis of the capillary network

-Nidus (dysplastic core); tangle of abnormal blood vessels

-Feeding arteries

-Draining veins



Intracranial AVMs: *General Considerations*

- Most common intracranial vascular malformation
- Incidence is about 0.14% of the population
- Average age at discovery: 33
- 64% are discovered before age 40

Intracranial AVMs:
General Considerations

- Presenting symptoms:
  - Hemorrhage
  - Seizures
  - Neurologic deficit
  - Hydrocephalus
  - Headache

Intracranial AVMs:
General Considerations

- Hemorrhage
  - Most common presentation (50%)
  - Peak age for bleeding 15-20 years
  - From each bleed:
    - 10% Mortality
    - 30-50% Morbidity
  - Small AVMs more commonly present with hemorrhage

Intracranial AVMs:
General Considerations

- Hemorrhage
  - Risk of bleeding is 2-5% per year
  - Risk of rebleeding is 6% in the first year then decreases to 2-5% per year

Intracranial AVMs:
General Considerations

- Evaluation
  - Catheter Angiography
    - Enlarged arterial feeders
    - Early venous drainage
    - Enlarged draining veins
    - Tangle of vessels
    - Aneurysms:
      - Feeding vessel aneurysm
      - Intranidal aneurysm

Intracranial AVMs:
Spetzler-Martin Grading

Spetzler-Martin AVM Grading Scale

Size	
0–3 cm	1
3.1–6.0 cm	2
>6 cm	3
Location	
Noneloquent	0
Eloquent	1
Deep venous drainage	
Not present	0
Present	1

Intracranial AVMs: *Spetzler-Martin Grading*

TABLE 2

*Correlation of AVM grade with surgical results**

Grade	No. of Cases	No Deficit		Minor Deficit		Major Deficit		Death (%)
		No.	%	No.	%	No.	%	
I	23	23	100	0	0	0	0	0
II	21	20	95	1	5	0	0	0
III	25	21	84	3	12	1	4	0
IV	15	11	73	3	20	1	7	0
V	16	11	69	3	19	2	12	0
total	100	86	86	10	10	4	4	0

* See also Fig. 11. AVM = arteriovenous malformation.

Spetzler RF et al. J Neurosurg 108:186–193, 2008

Unruptures Intracranial AVMs:
To Treat or To Observe?

http://www.arubastudy.org/

Intracranial AVMs: *General Considerations*

- My opinion - AVMs occur in a young productive age group with high morbidity and mortality and therefore an aggressive therapeutic approach is reasonable
- AVM Treatment:
  - Surgery
  - Radiosurgery
  - Embolization

Intracranial AVMs: Embolization

- Rarely curative alone
- Often performed in conjunction with radiosurgery or surgery
- Understanding of AVM angioarchitecture is paramount to safe embolization

Intracranial AVMs: Embolization

- AVM Angioarchitecture:
  - AVM nidus consisting of small AV shunts (less than 500 μ)
  - AV fistulas (AV shunts > 500 μ)
  - Aneurysms
    - Intranidal
    - Flow related aneurysms on feeding arterial vessels

Intracranial AVMs: Embolization

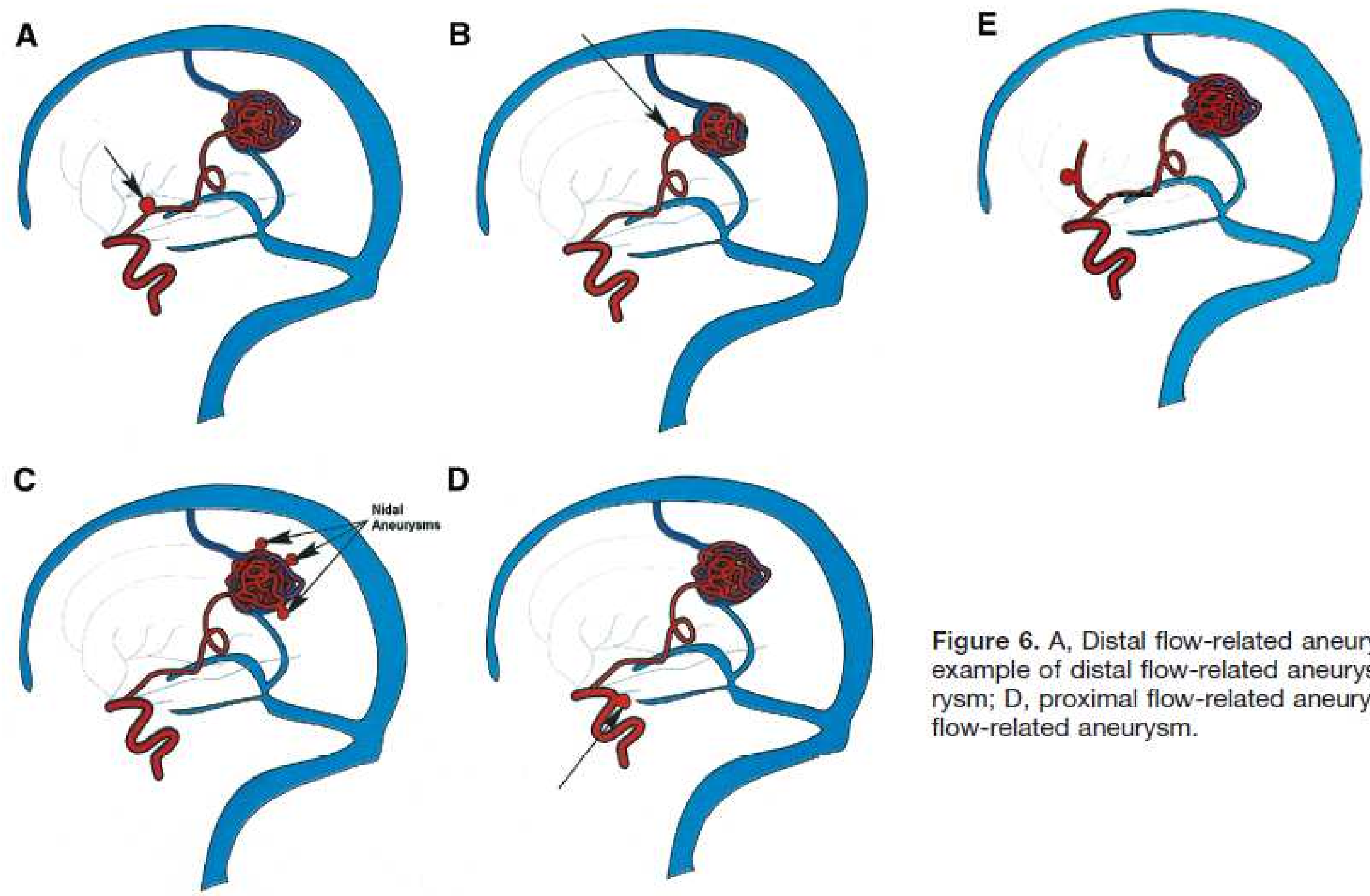
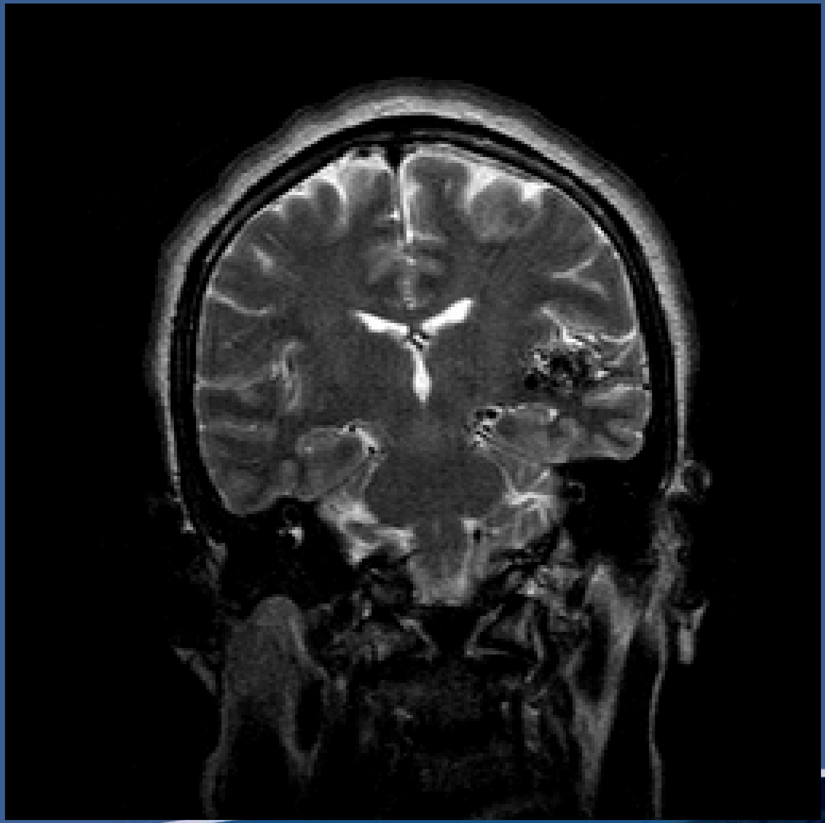
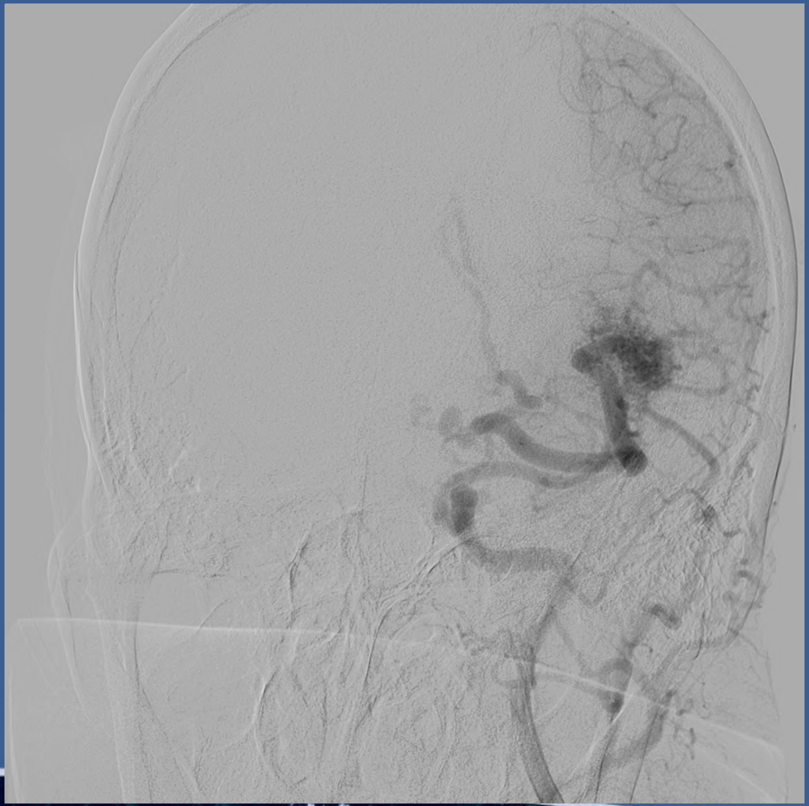


Figure 6. A, Distal flow-related aneurysm; B, additional example of distal flow-related aneurysm; C, nidal aneurysm; D, proximal flow-related aneurysm; and E, non–flow-related aneurysm.

Intracranial AVMs:





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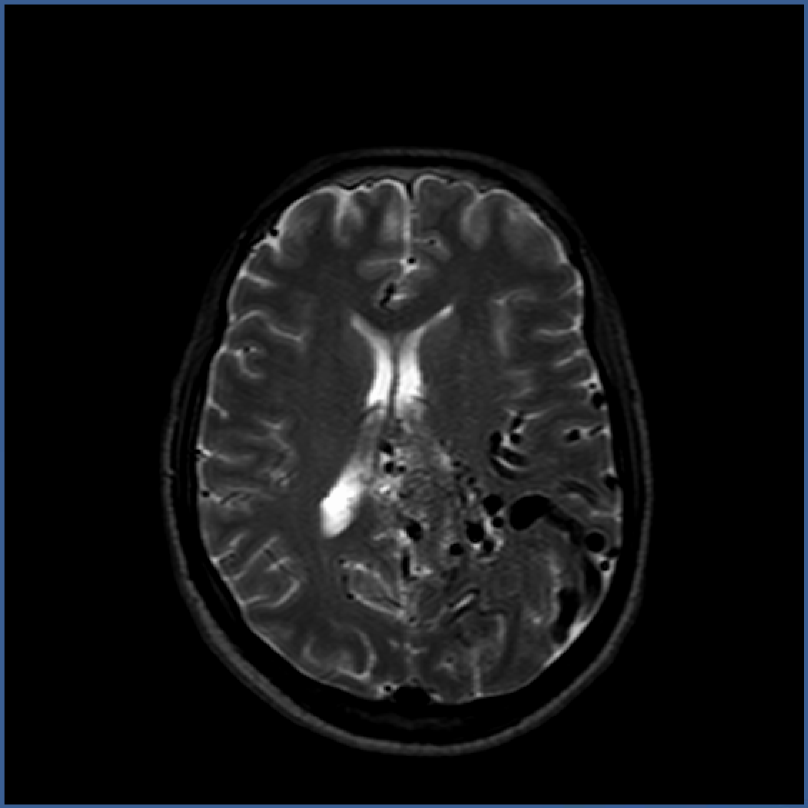
Intracranial AVMs:



Intracranial AVMs: Embolization

- Causes of Hemorrhage:
  - Rupture of AVM nidus
  - Rupture of veins
  - Aneurysm rupture
  - Venous stenosis
  - Venous thrombosis
- Embolization must address the cause of hemorrhage

Intracranial AVMs: Embolization

- Goals of Therapy
  - Occlude nidus and arterial feeders to AVM
  - Occlude high flow fistulas
  - Treat intranidal or flow related aneurysms

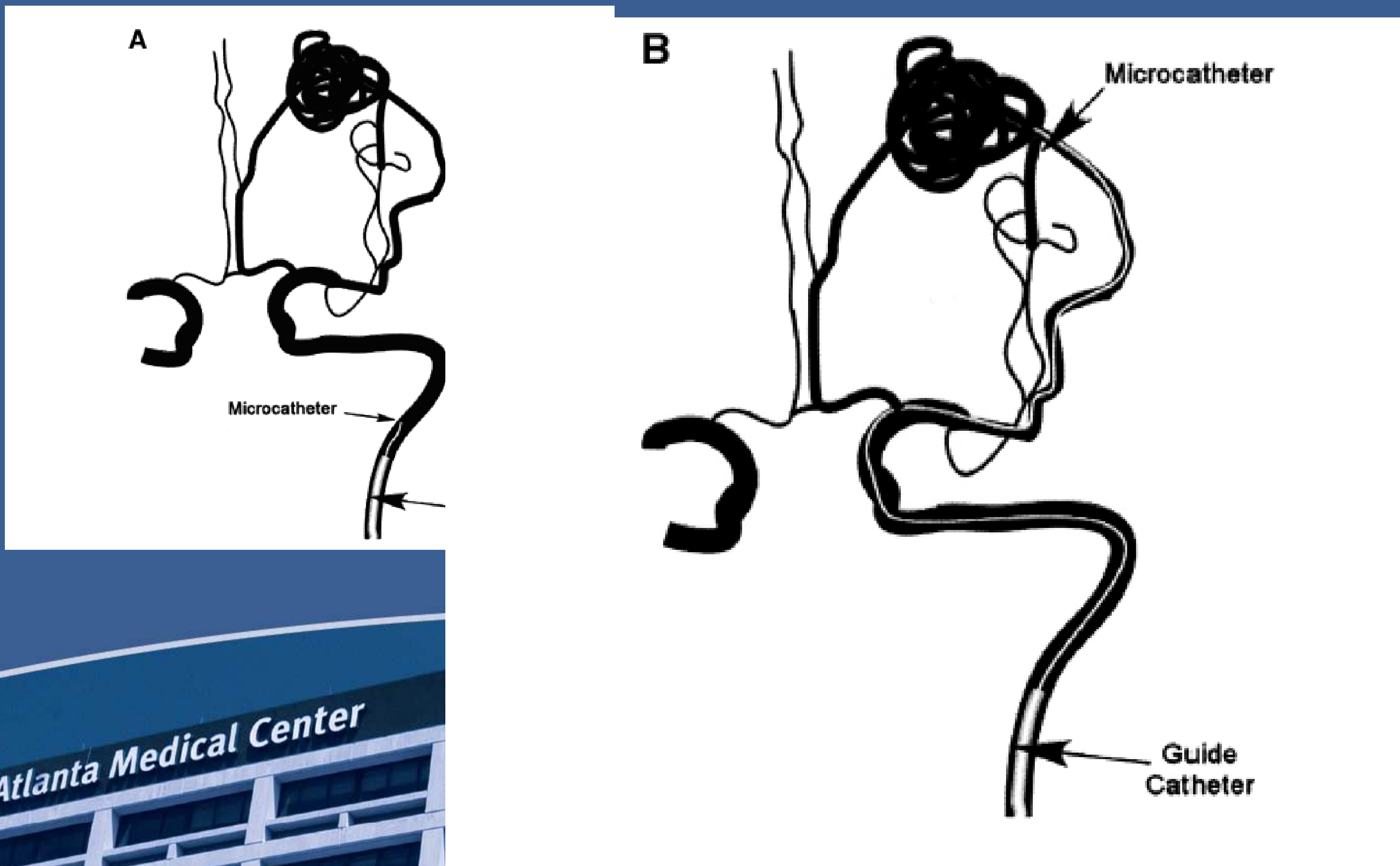
Intracranial AVMs: Embolization

- Technique of AVM embolization
  - Transfemoral route
  - Initial evaluation with 4 vessel angiogram
    - Evaluate arterial feeders, venous drainage, aneurysms, fistulas
    - High risk lesions: aneurysms, fistulas, venous stenosis

Intracranial AVMs: Embolization

- Technique of AVM embolization
  - Co-axial technique:
    - Guidecatheter
    - Flow directed catheter
    - Guidewire directed catheters
  - Embolic agents
    - Coils
    - Particles (PVA, Embospheres, silk thread)
    - Liquid embolic agents (NBCA, Onyx)

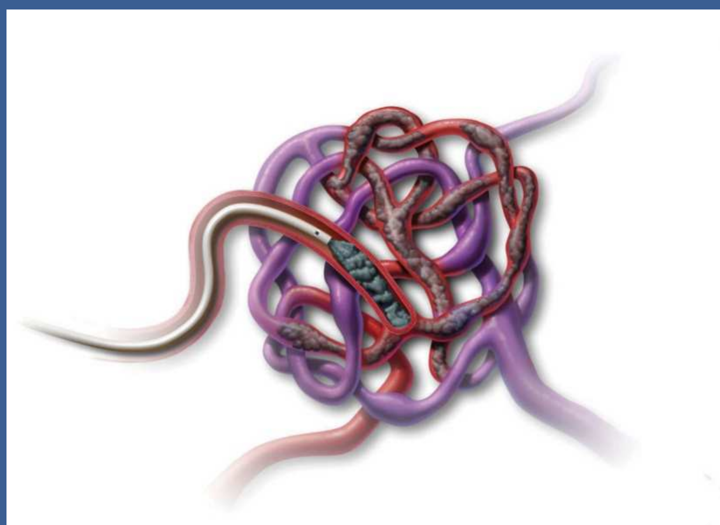
Intracranial AVMs: Embolization



Intracranial AVMs: Ideal Embolic Agent

Non-toxic, non-allergenic, non-carcinogenic
Non-clumping and cohesive to minimize fragmentation
Non-adhesive to catheter tip, although adherence to tissue is OK
Low viscosity that allows injection through a small catheter and good penetration into the nidus
Solidification in contact with pathologic tissue, but not saline
Durable, permanent occlusion without recanalization
Good surgical handling properties (not hard, brittle)
Controllable and reliable solidification rate
Non-exothermic solidification
Limited inflammatory response
Relatively inexpensive

Intracranial AVMs: Embolization Tools



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Intracranial AVMs: Embolization

- <u>Particles:</u>
  - Advantages:
    - Particles carried by flow to AVM with less chance of blocking side branches
    - No gluing of catheter to vessel
  - Disadvantages:
    - Must use guidewire directed catheter with catheter large enough to accept particles of various size
    - Particle size to occlude AVM nidus difficult to estimate and as a result particles may go through the nidus to the lungs
    - Recanalization can occur with particles

Intracranial AVMs: Embolization

- Liquid embolic agents:
  - Advantages:
    - Can use flow directed catheters which are less traumatic
    - More permanent embolic agent compared to particles
  - Disadvantages:
    - Can glue catheter to vessel
    - Migration of agent into the vein may occur with venous outlet obstruction
    - Requires experienced operator

Intracranial AVMs: Embolization

- NBCA versus PVA Trial
  (AJNR Am J Neuroradiol 23:748-755)
  - 104 patients randomized to NBCA or PVA prior to planned microsurgical therapy (10/96-3/99)
  - Primary objective: to verify that NBCA is as safe and effective as conventional treatment (PVA) in preoperative embolization

Study Conclusions

- NBCA/ethiodized oil equivalent to PVA/coils in achieving primary & secondary endpoints
- Clinical safety endpoints equivalent

Onyx Era

- Copolymer:
- - **ONYX**, Ethylene vinyl alcohol + dimethyl sulfoxide(DMSO)
- - **Solidification** occurs in a “outside-in” manner
- - It is soft and **spongelike** after solidification
- - Two formulaitons available in the US
- - Onyx 18, **6%** Ethylene Vinyl alcohol and Onyx 34, **8%**
- - DMSO may cause severe **inflammation**, **vasospasm** and **endothelial necrosis** (high rate/volume)

Onyx

1. Shake Vials 20 min

2. Flush Catheter

3. Load dead space with DMSO

4. Overwash catheter hub

5. Connect Onyx Syringe vertically

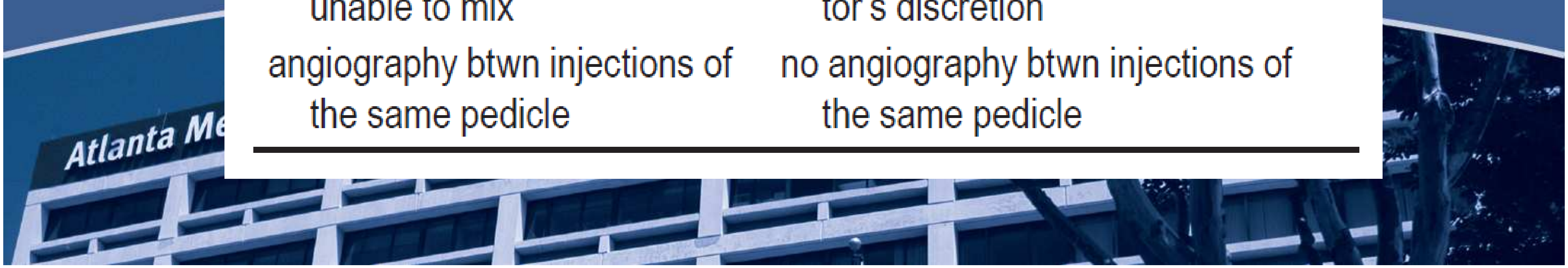
6. Displace DMSO 0.25ml / 90 secs

7. Fluoro just prior to filling deadspace

NBCA vs ONYX

TABLE 1: Differences between Onyx and NBCA

Onyx	NBCA
precipitates	polymerizes (exothermic)
cohesive	adhesive
slow injection	fast injection
low thrombogenicity	high thrombogenicity
spongy cast	hard cast
1.3 Fr compatible microcatheter not truly flow-directed	compatible w/ 1.2 Fr flow-guided microcatheters
only 2 concentrations available, unable to mix	Ethiodol/NBCA ratio up to the operator's discretion
angiography btwn injections of the same pedicle	no angiography btwn injections of the same pedicle



NBCA vs ONYX

TABLE 5: Secondary end point summary*

Parameter	Onyx Group	NBCA Group
blood loss index†		
no. of patients w/ data	49	52
mean ± SD in ml	1022.5 ± 1341	887.4 ± 1025
median in ml (range)	500 (50–6550)	500 (100–5000)
resection time‡		
no. of patients w/ data	48	52
mean ± SD in min	393.5 ± 173.4	403 ± 191.4
median in min (range)	362 (82–940)	344 (150–1019)

* One hundred one patients underwent resection of a brain AVM (either total or partial), 52 patients in the NBCA group and 49 in the Onyx group.

† $p = 0.5693$.

‡ $p = 0.7960$.

Loh Y et al. J Neurosurg 113:733–741, 2010

NBCA vs ONYX

TABLE 4: Embolization procedure details*

Parameter	Onyx Group	NBCA Group
no. of patients	54	63
no. of procedures	104	112
no. of injections	235	258
average no. of injections/procedure	2.3	2.3
mean vol injection (ml)	0.50	0.39
mean injection time (min)	5.42	NA
no. of coil procedures	8†	29

* NA = not applicable.
† p = 0.0004.

Loh Y et al. J Neurosurg 113:733–741, 2010

Saatci, et al. (J Neurosurg 2011)

Onyx® LES Long-Term Results in 350 Patients

Study Objective

Long-term angiographic and clinical follow-up in 350 patients with bAVMs treated with Onyx LES using a prolonged intranidal injection technique.

Key Outcomes:

- 51% angiographic obliteration with only endovascular treatment (98% in S-M Grade I-II AVMs)
- All surviving patients with endovascular AVM obliteration (178) showed stable occlusion with long-term follow-up (1-8 years)
- 136 patients (39%) underwent radiosurgery after Onyx LES embolization
- 28 (8%) retained catheters – 8 were intentional; with no associated permanent morbidity
- 1.4% mortality; 7.1% permanent morbidity

Onyx+

Neurosurgery Publish Ahead of Print
DOI: 10.1227/NEU.0b013e31828d602b

Endovascular Balloon-Assisted Embolization of Intracranial and Cervical Arteriovenous Malformations Using Dual Lumen Co-axial Balloon Microcatheters and Onyx: Initial Experience

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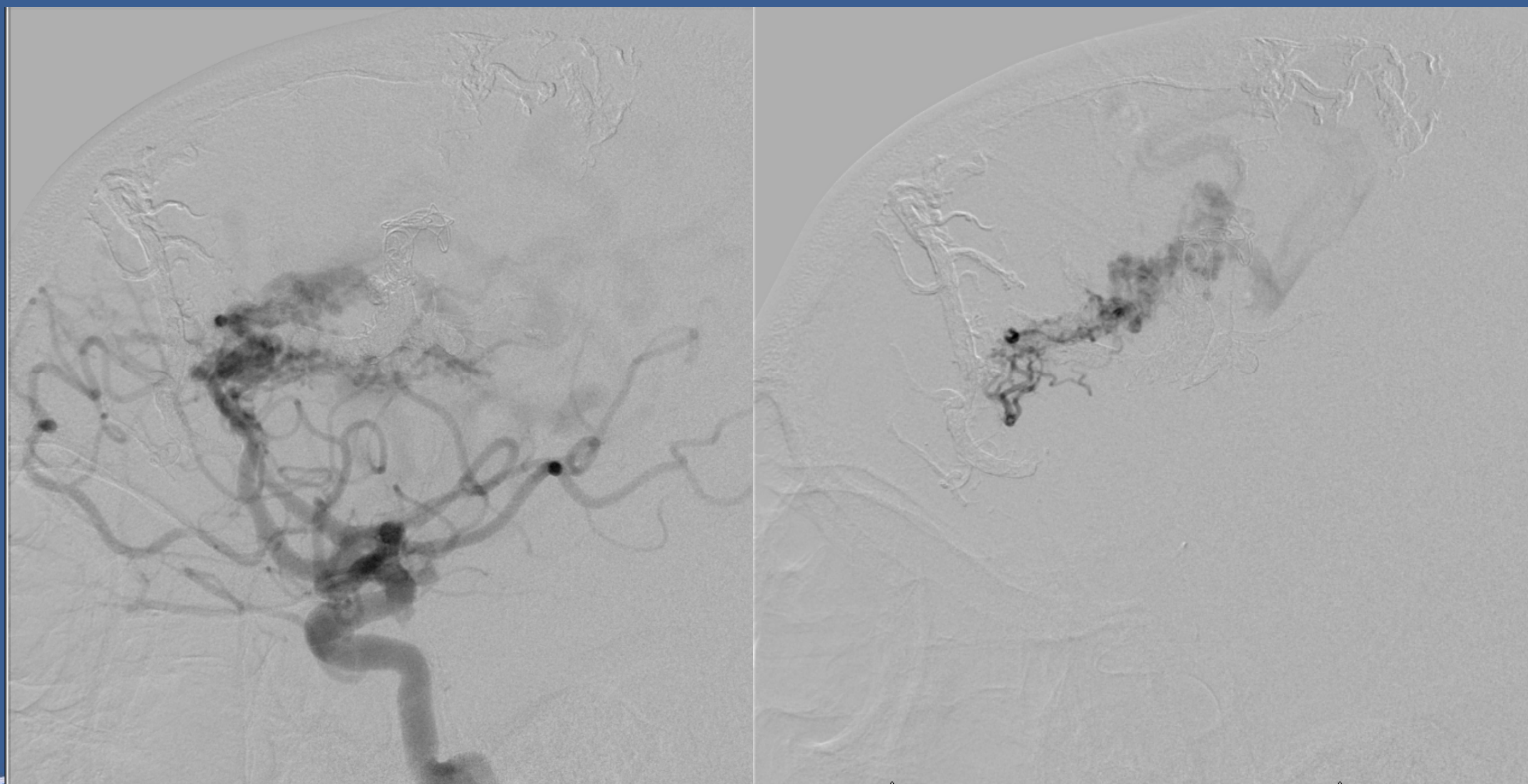
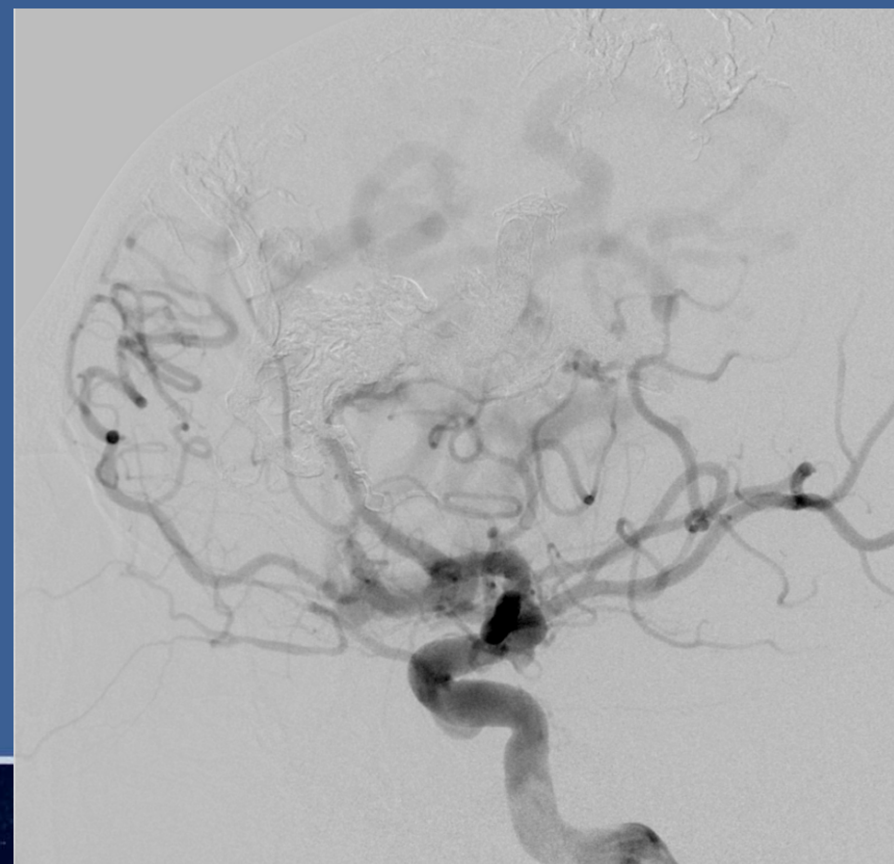
Onyx in AVM



Onyx in AVM



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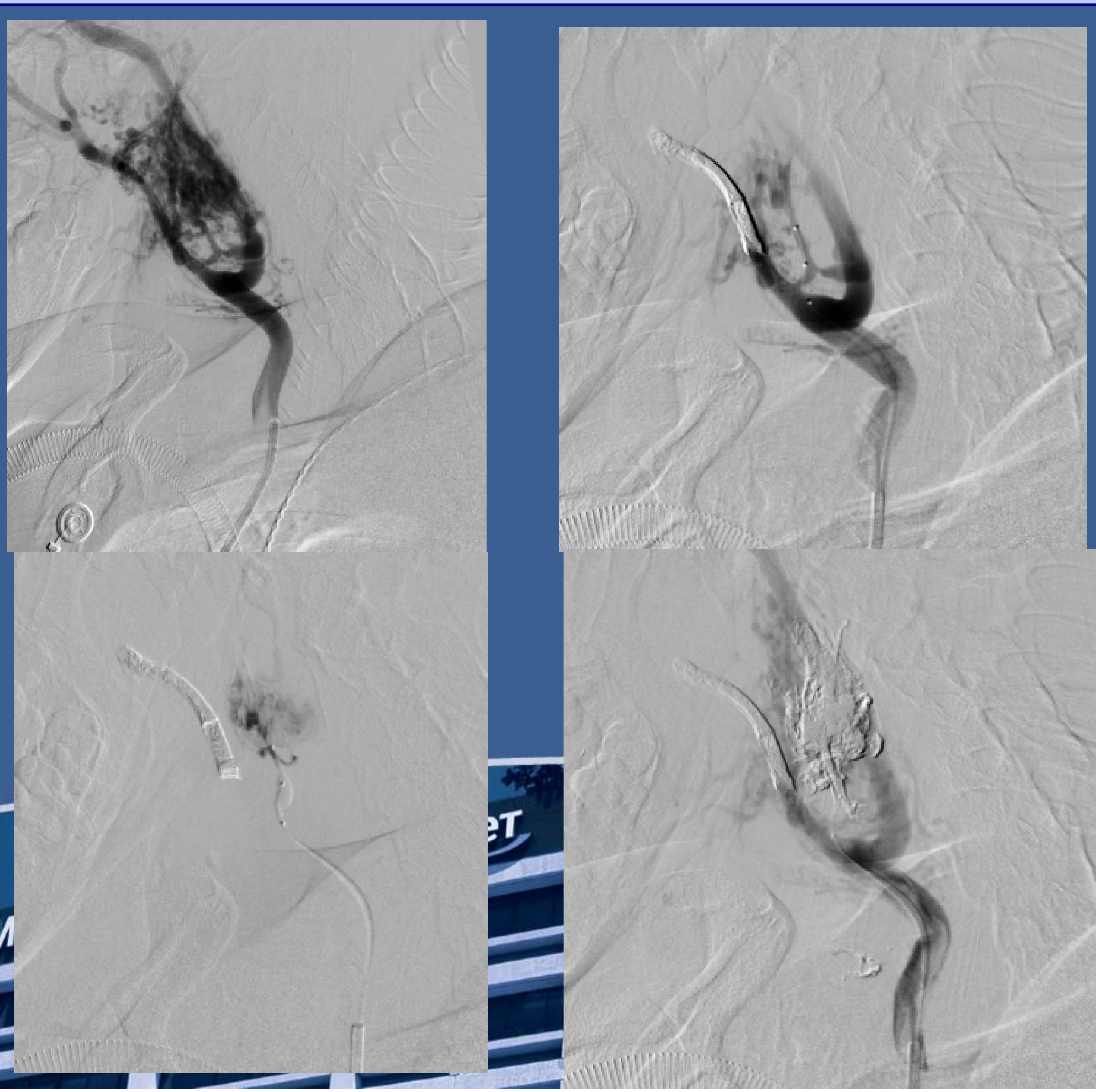
Onyx in AVM



Onyx in dAVF

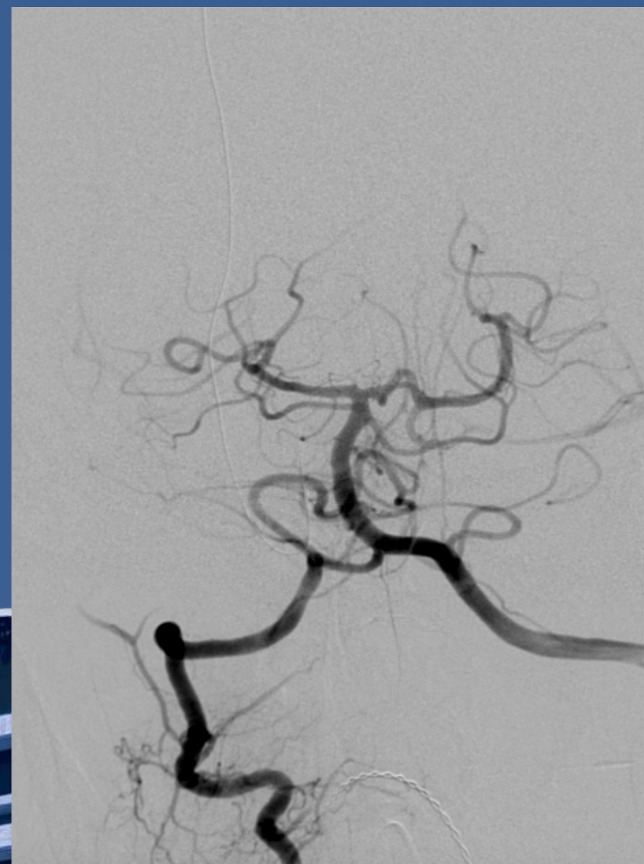
44 y/o with pulsatile tinnitus and headaches

Onyx in dAVF

1.8 ml of Onyx 18

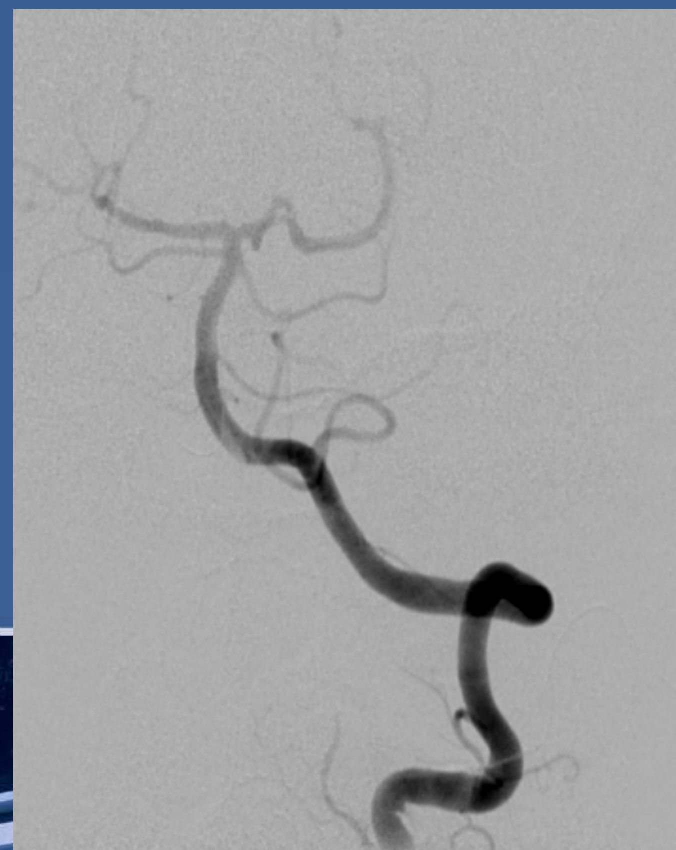
Onyx in dAVF

55 y/o with severe disabling tinnitus



Onyx in dAVF

1.0 ml of Onyx 18



Intracranial AVMs: Embolization

- Complications of embolization
  - Premature venous occlusion leading to AVM rupture
  - Inadvertent occlusion of normal arteries
  - Vessel perforation during embolization
  - Gluing of catheter into cerebral vessels

Conclusions

- Intracranial AVMs occur in a young productive age group with associated high morbidity and mortality
- Treatment options include embolization, surgical resection or radiosurgery
- Embolization can rarely be curative or can facilitate treatment by occluding feeding vessels, blocking nidus, treating flow related and intranidal aneurysms and blocking large arteriovenous shunts
- There is still a need to improve and develop the "ideal liquid embolic" agent

Thank You!