Treatment of Intracranial Aneurysms

Jared Knopman, MD
Assistant Professor
Cerebrovascular Surgery/Interventional Neuroradiology
Department of Neurological Surgery
Weill Medical College of Cornell University
jak9030@med.cornell.edu

Epidemiology

- Unruptured intracranial aneurysms:
  - 3.6% in autopsy series
  - 2% in meta-analysis of autopsy/ angiography series
  - female/ male = 1.3
  - peak age: 60-79 years
- Aneurysmal SAH
  - global annual incidence 1:10000
  - 20,000- 30,000 new cases annually in the US
  - mean age: 55 years
  - female/men = 1.6
  - blacks/ whites = 1.6
  - smoking, connective tissue disorders, HTN
- Multiple aneurysms: 15-30%
  - female, smoking, hypertension, post-menopausal, family history

Non-modifiable Risk Factors

- Personal history of SAH
  - risk of new aneurysm 2%
  - annual incidence of SAH 6:10,000
- Family history of SAH/ Familial aneurysms
  - first-degree relatives with 1 affected member: 2-4%
  - first-degree relatives with 2 affected members: 10%
  - multiple, rupture at younger age and have poorer outcome
  - screening with MRA/CTA if 2 first-degree relatives have aneurysms
- Female gender
  - risk less than men until 50s
  - risk increases in post-menopausal women
- Age
  - rare in children

Non-modifiable Risk Factors

- Connective tissue disorders
  - Autosomal dominant polycystic kidney disease
    - 5-10% have aneurysms; screening advised
  - Ehlers-Danlos IV
  - Marfan
  - Neurofibromatosis-1
  - a1-Antitrypsin deficiency
  - Fibromuscular dysplasia
- Anatomic variants
  - persistent trigeminal artery
  - fenestrations
  - azygous ACA

Fenestration

Modifiable Risk Factors

- Smoking
  - consistently identified in many population studies
  - increased elastase activity
  - larger, multiple, rupture, vasospasm
- Hypertension
  - aneurysm formation and SAH
- Atherosclerosis/ Hypercholesterolemia

Types of aneurysms

- Appearance or Etiology?

- Saccular (berry)
  - arterial bifurcation or accentuated curves of the vessels of the circle of Willis
  - > 90% of all aneurysms
- Non-Saccular
  - arise from arterial trunks unrelated to branching sites
  - uncommon
  - external trauma
  - weakening from atherosclerosis, dissection, infection, inflammation, neoplasm, radiation

Saccular aneurysms - pathogenesis

- Hemodynamic stress
  - increased flow:
    - 10-20% of patients with AVM have aneurysms
  - increased wall shear stress
    - fragments internal elastic lamina/ initiates aneurysm formation
- Abnormal vascular remodeling
  - structural anomalies in extracellular matrix
- Inflammation
  - intimal thickening proximal and distal to branch points
- Histology:
  - internal elastic lamina is absent; the media is thin or absent
  - sac layers: intima and adventitia

Saccular aneurysms

- Typically found at branch points
  - gap in the media, internal elastic lamina
- Location:
  - Anterior circulation: 90%
    - anterior communicating: ≈30%
    - internal carotid artery: ≈30%
      - posterior communicating
      - ophthalmic artery (female, bilateral 20%, large or giant)
      - terminus
    - middle cerebral: ≈30%
  - Posterior circulation 10%
    - basilar tip: ≈6%
- Multiple lobes:
  - unruptured 9%, ruptured 40%
- Daughter sac:
  - unruptured 16%, ruptured 57%

Natural History

- Juvela et al. 2000
  - unruptured aneurysms diagnosed 1956-1978
  - 142 patients; 18.1 yrs follow-up
  - Annual rate of rupture:
    - Incidental aneurysm with history SAH: 1.3%
    - Incidental aneurysm, no history SAH: 1.0%
    - Symptomatic aneurysm: 2.6%
    - Size:
      - 2 - 6mm: 1.1%
      - 7 – 9mm: 2.3%
      - 10 – 26mm: 2.8%
  - Mortality rate with rupture: 52%
  - Weakness: small number of patients; most (90%) with SAH

Natural History

- Rinkel 1998
  - meta-analysis totaling 3,907 patients
  - overall annual risk of rupture: 1.9%
    - female: 2.6%
    - symptomatic aneurysm: 6.5%
    - asymptomatic, history of SAH: 1.4%
    - posterior circulation: 4.4%
    - ≥10mm: 4.0, <10mm: 0.7
- Morita 2005
  - meta-analysis totaling 3,801 patients (Japan only)
  - overall annual risk of rupture: 2.7%
  - higher risk if ≥10mm, posterior circulation, symptomatic

Natural History

- International Study of Unruptured Intracranial Aneurysms (ISUIA)
  - 4,060 patients (history of SAH vs. no history of SAH)
  - mean follow-up 4.1 year

Annual rupture rates	<7mm		7-12mm	13-24mm	≥25mm
	no prior SAH	prior SAH			
anterior circulation	0%	0.3%	0.5%	2.9%	8.0%
posterior circulation	0.5%	0.7%	2.9%	3.68%	10%
cavernous ICA	0%/ 0%	0%	0%	0.6%	1.28%

Controversial results:

- average size of ruptured aneurysms is 6-7mm
- these rates predict 5600 cases of SAH, instead of true number of 21-33000 cases/ year
- selection bias of the retrospective component?

Diagnosis

- SAH
  - CT: sensitivity decreases with time (and anemia)
  - LP: enough time for xanthochromia to occur?
  - MRI: FLAIR imaging better than CT for older bleeds
    - great for CT (-), LP (+)
- Aneurysm imaging
  - CTA:
    - very high sensitivity, even if SAH
    - sensitivity varies with size
    - negative study requires catheter angiography
  - MRA:
    - no radiation
    - very sensitive >2-3mm
    - flow related artifacts
    - excellent for follow-up after coiling

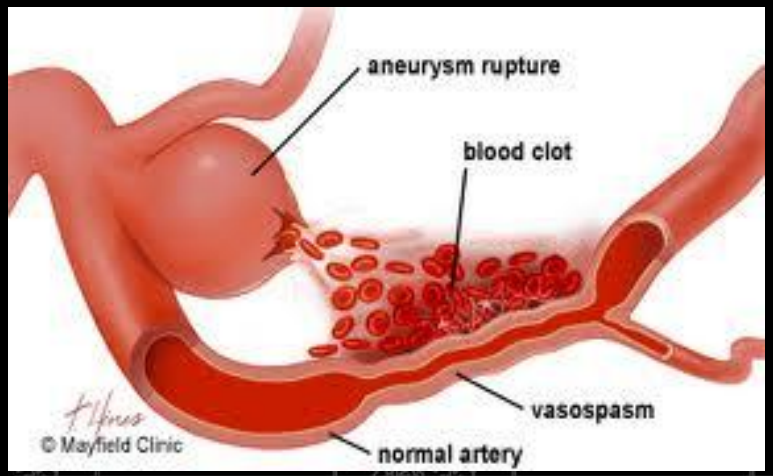
Catheter Angiography

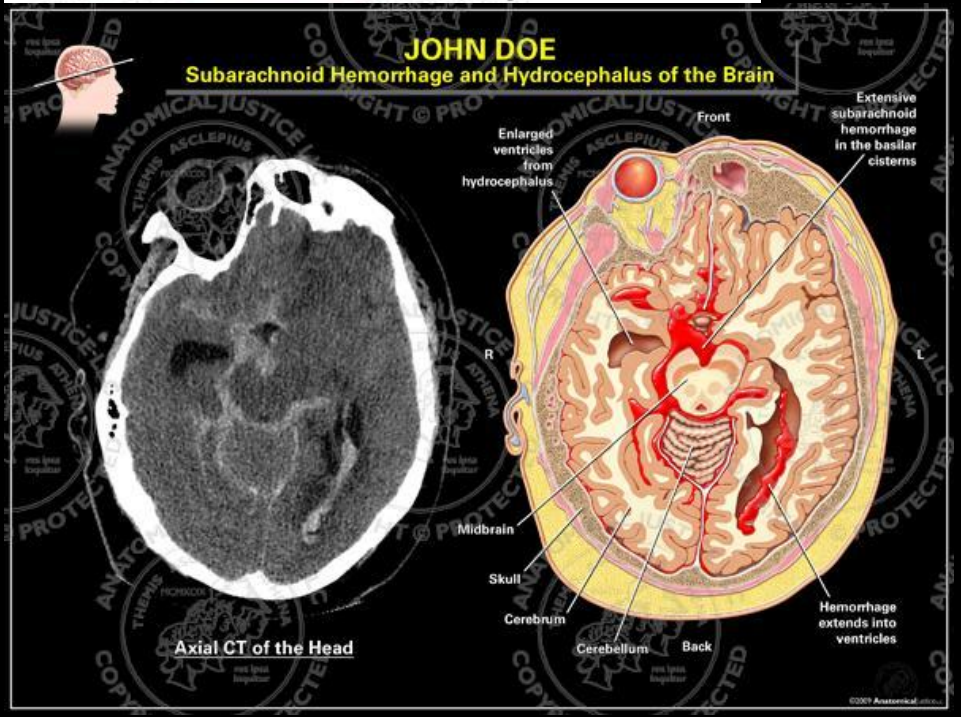
- Gold standard
- Carries a risk of complications:
  - 0.9% reversible neurologic
  - 0.5% permanent neurologic
  - high-risk patients: carotid atherosclerosis, advanced age, long procedure, hypertension, diabetes
    - *Willinsky RA, Radiology 2003*
- Detects very small aneurysms
- Detailed evaluation:
  - neck, dome
  - suspected rupture sites
  - collateral circulation distal to the aneurysm
  - hemodynamics

Treatment options

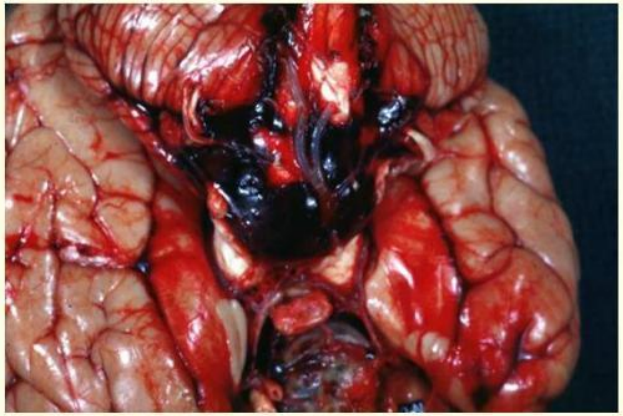
- No treatment
  - monitor
    - imaging (MRA)
    - new headache or cranial nerve palsy
  - modify risk factors (smoking, hypertension)
  - growing or newly symptomatic aneurysms should be treated
- Microsurgery
- Endovascular

Subarachnoid hemorrhage





Subarachnoid Hemorrhage



* Restricted use. PEIR; University of Alabama at Birmingham, Department of Pathology

28

Subarachnoid hemorrhage grades:

- 0=Unruptured
- 1=Mild H/A
- 2=Severe H/A, neck pain/rigidity, CN palsy
- 3=Lethargy/confusion
- 4=Stupor, hemiparesis
- 5=Deep coma, decerebrate posturing

- Overall mortality rate is around 50%
- About 1/3 of survivors have moderate/severe disability

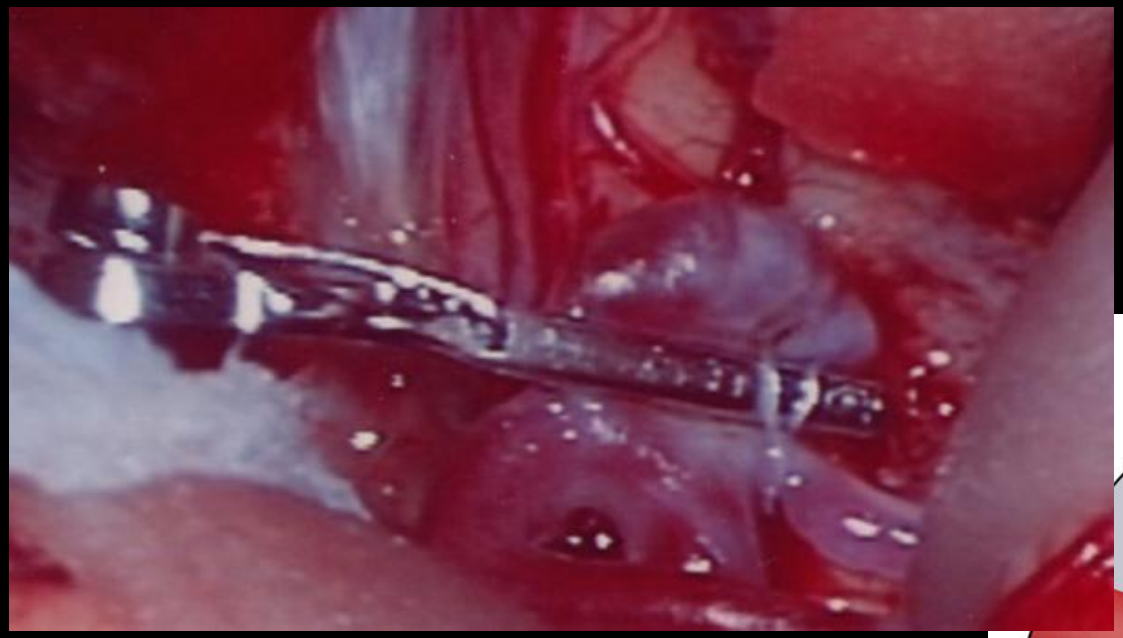
Symptoms of SAH

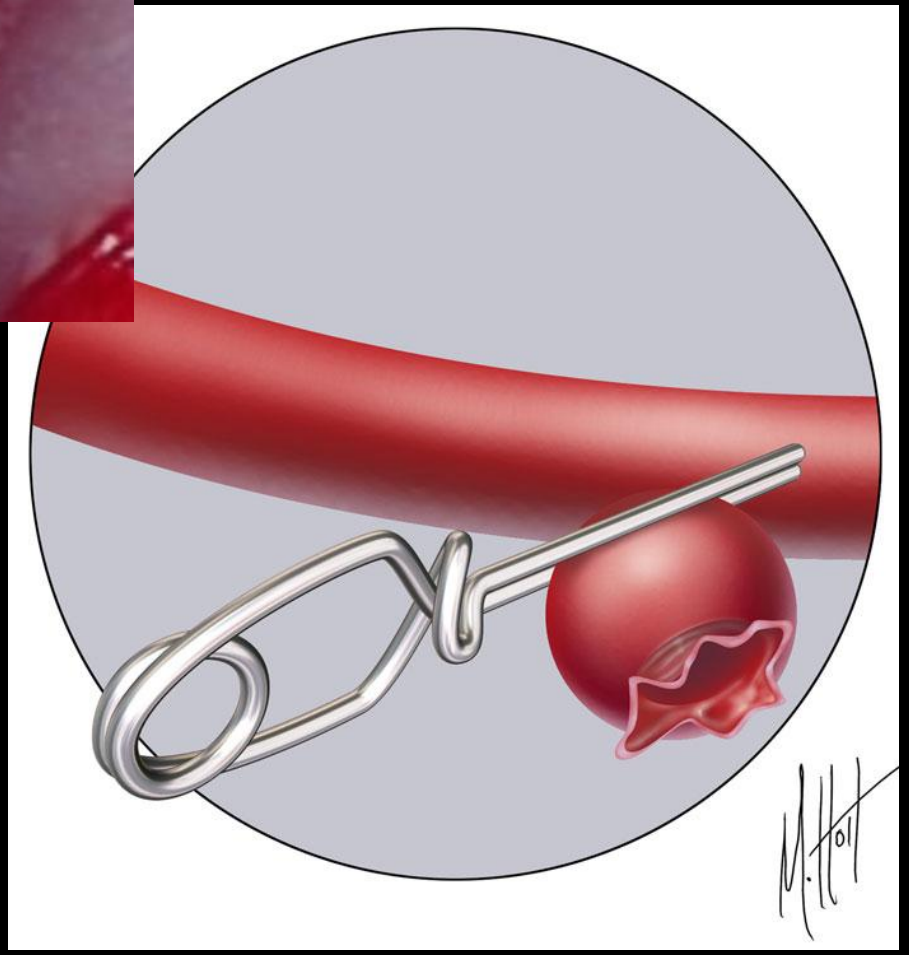
- H/A ("worst headache of life")
  - Sentinel headace in 30-60% patients
- N/V
- Syncope
- Neck pain (meningismus)
- Photophobia
- Focal CN palsy (IIIrd nerve palsy)
- LBP

Clip or Coil?

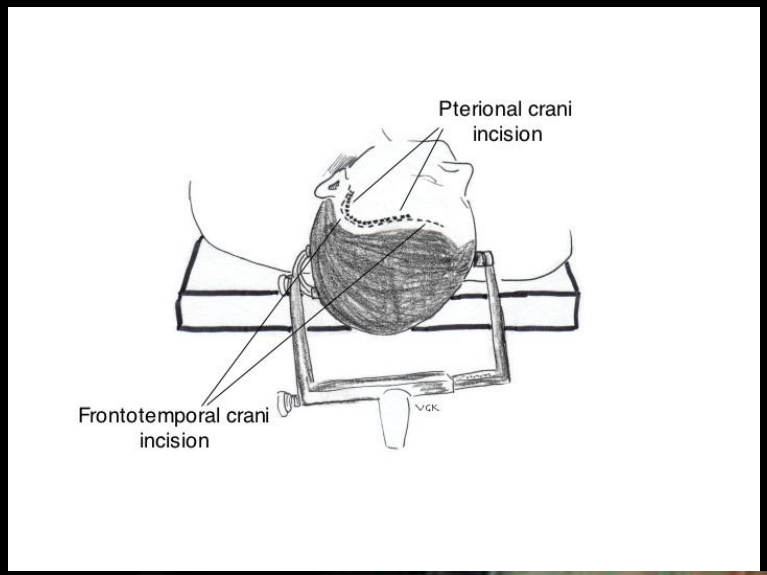
Relative Indications	Relative Contraindications
Coil	
Poor surgical candidate	Elongated aortic arch
Favorable aneurysm anatomy	Giant aneurysm
Favorable vascular access	Cervical or intracranial arterial stenosis
Need for long-term anticoagulation	Aortic, femoral artery occlusion
Posterior circulation aneurysms	Intolerance to iodinated contrast
Vasospasm	Intolerance to heparin/ antiplatelet agents
Clip	
Younger patient	Advanced age
No prior cranial surgery	Giant aneurysm
Middle cerebral artery aneurysm	Atherosclerotic or calcified aneurysm neck

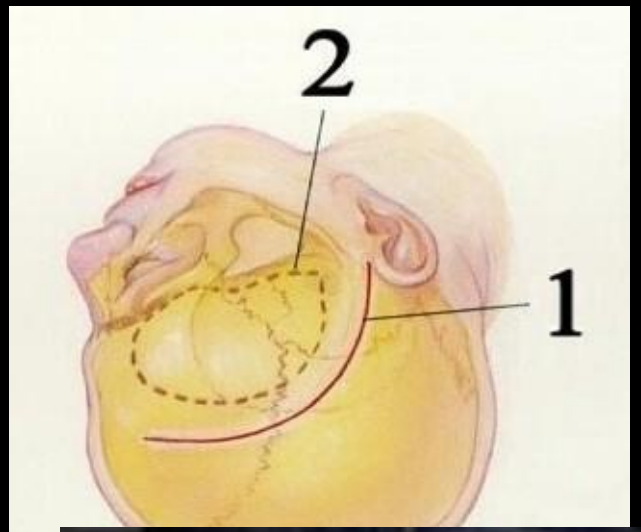
Microsurgical clipping





Craniotomy/clipping





Craniotomy/clipping

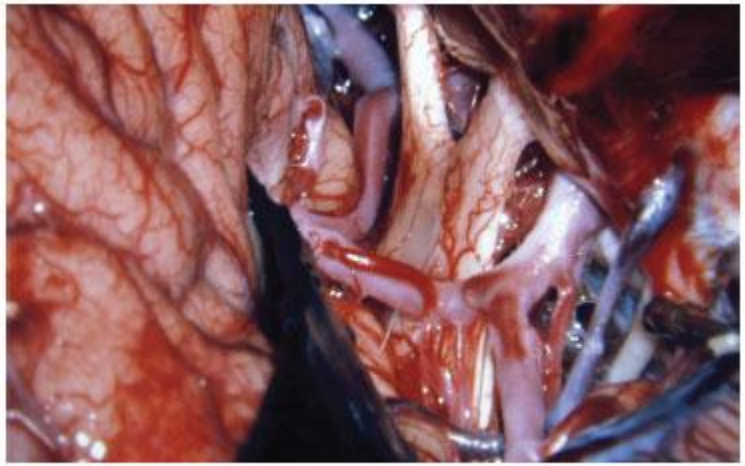
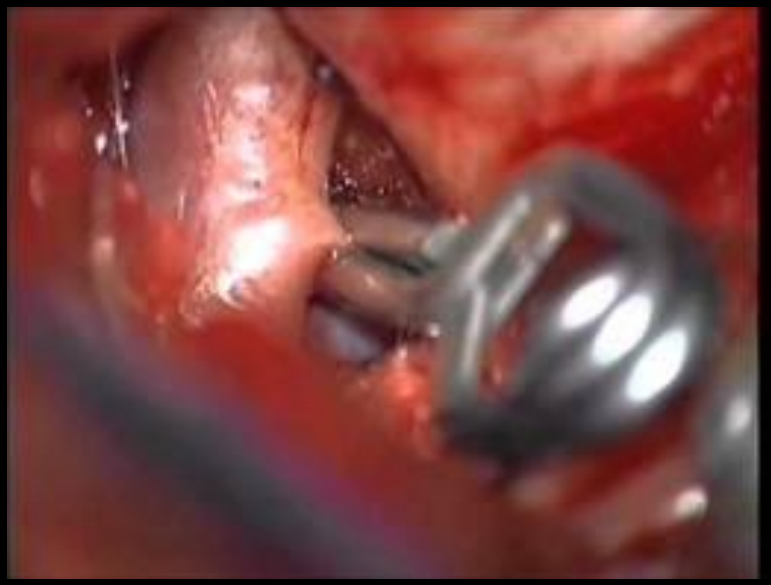
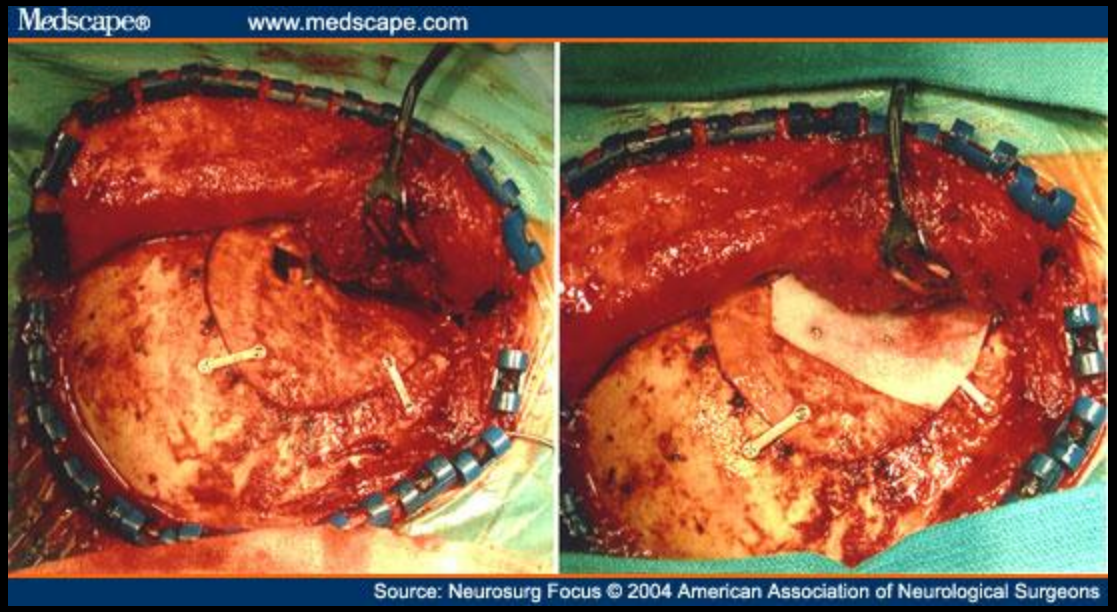


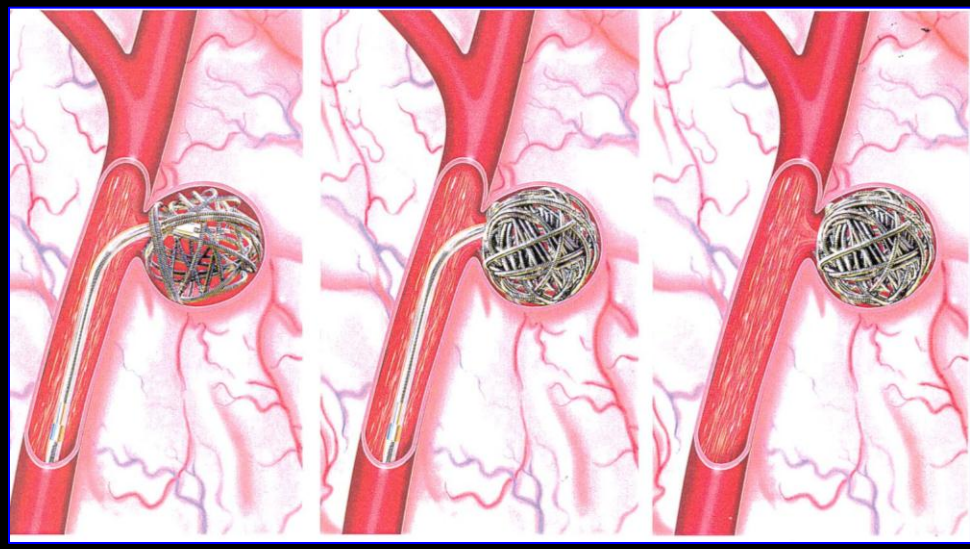
Fig 7. The carotid cistern, the chiasmatic cistern, the sphenoid compartment of the sylvian fissure and the lamina terminalis cistern.





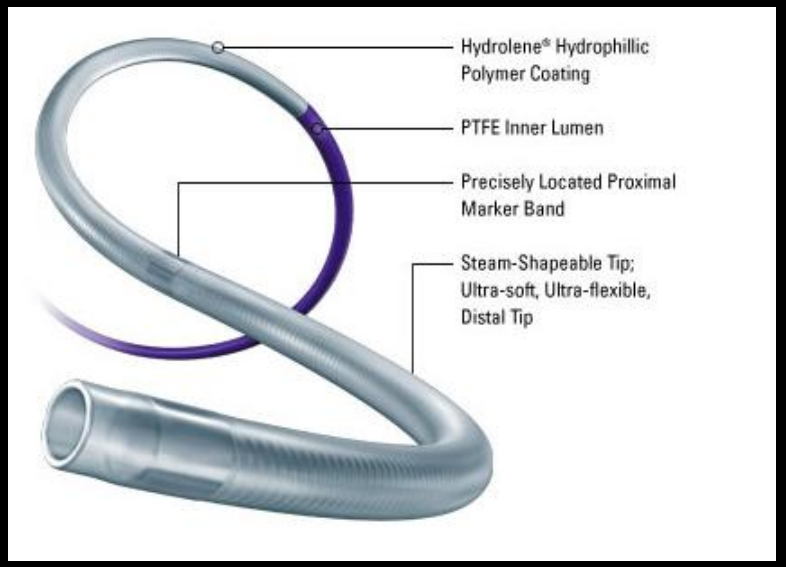
Endovascular Treatment

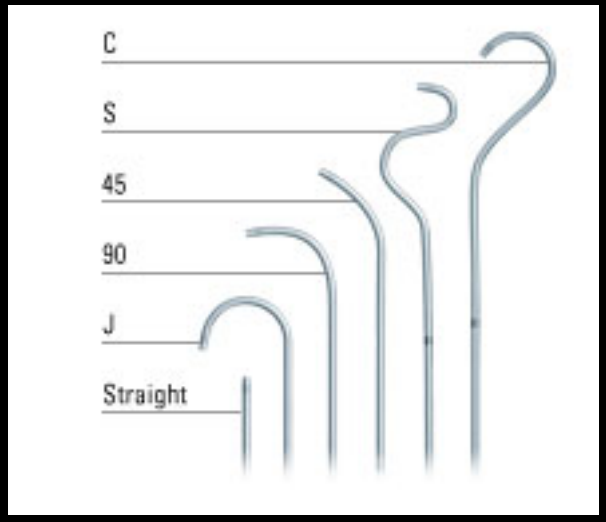
- Coils
  - bare platinum
  - coated
- Balloon remodeling
- Stent assisted coiling
- Low porosity stents
- Parent vessel occlusion
- Onyx

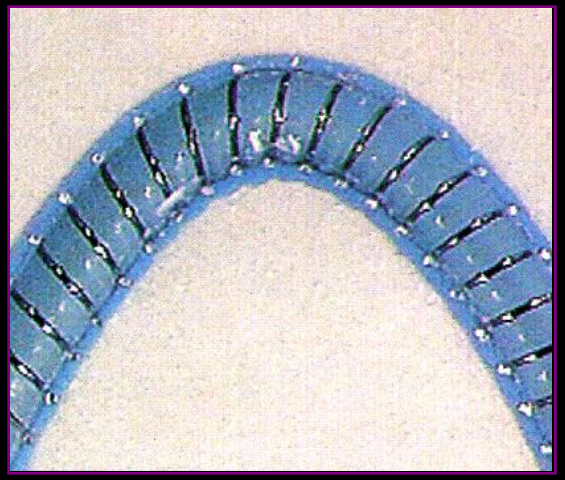


Microcatheters

- Soft atraumatic tip
- Steam shapeable

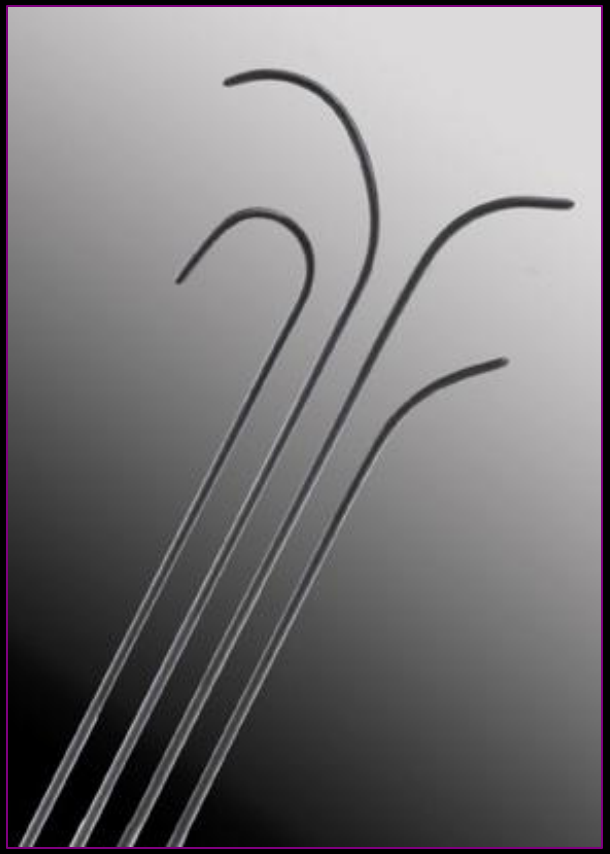


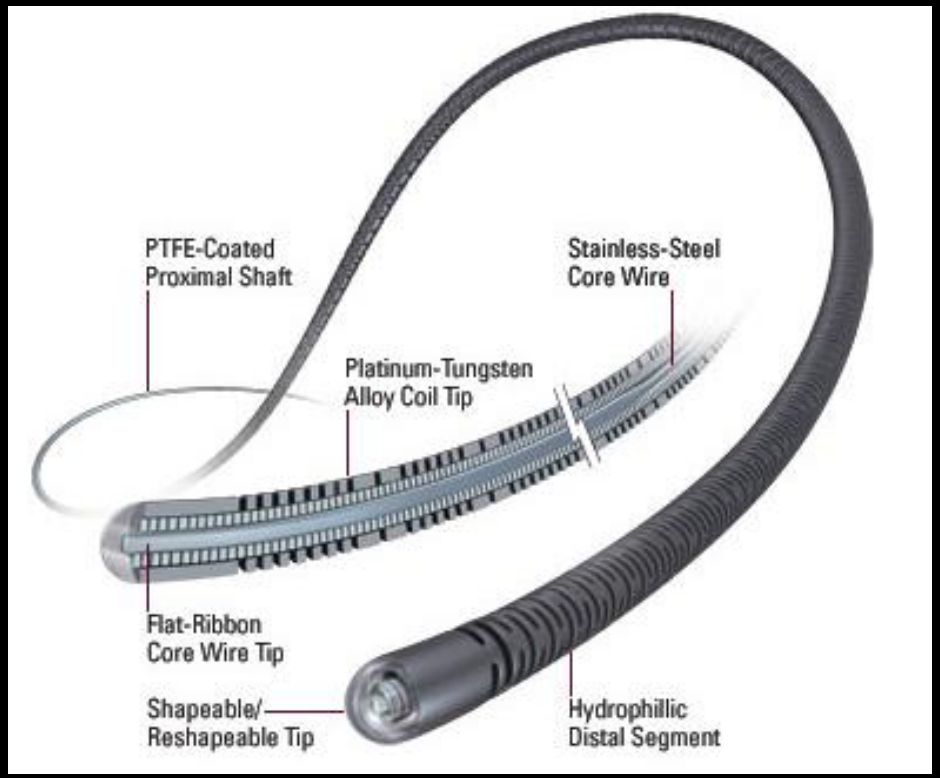




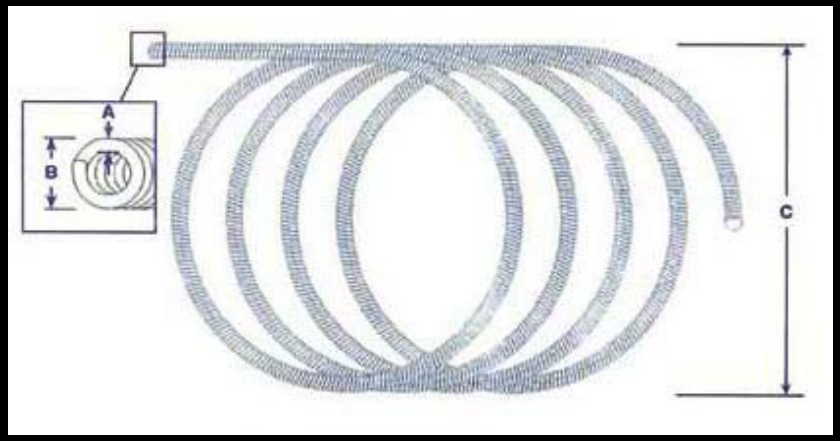
Micro(guide)wires

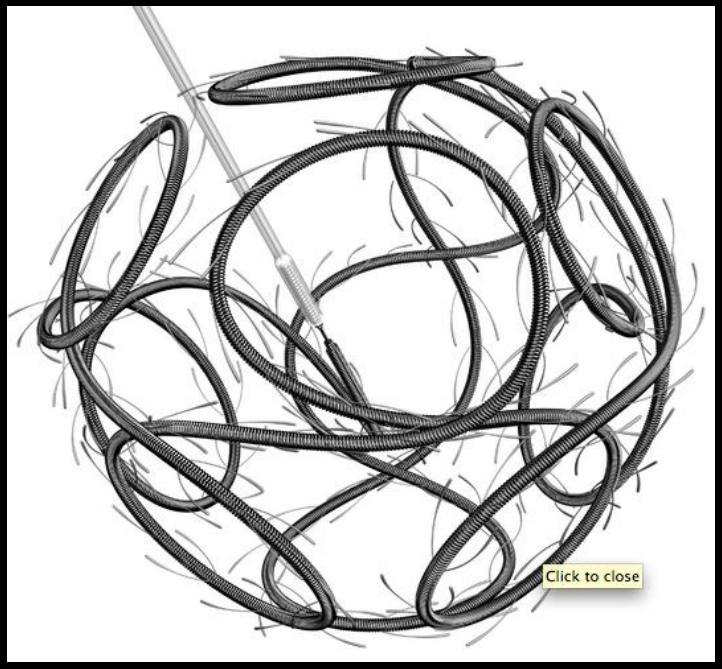
- Shapeable
- Steerable (Torque)



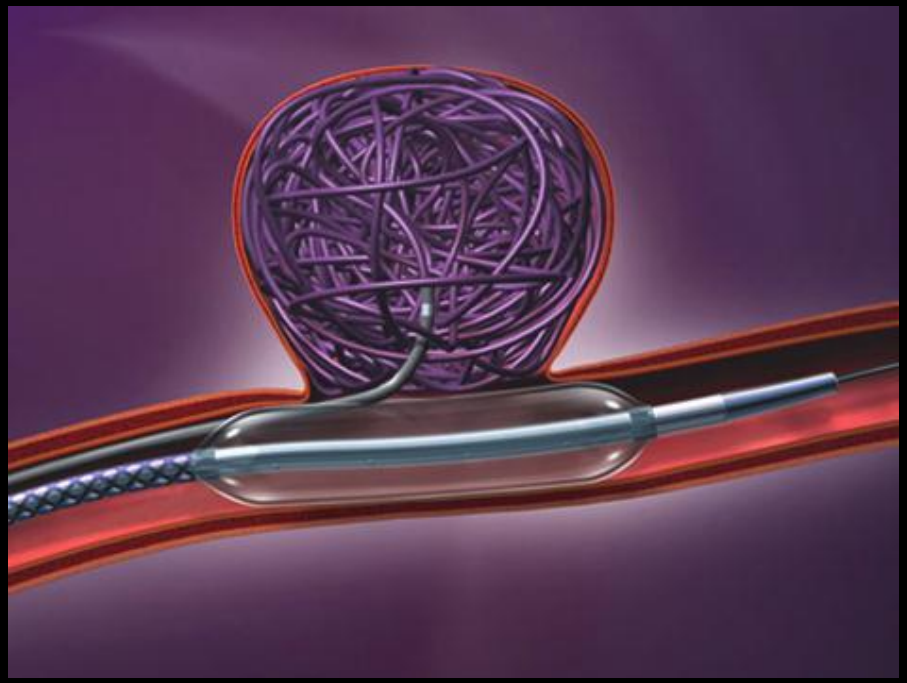


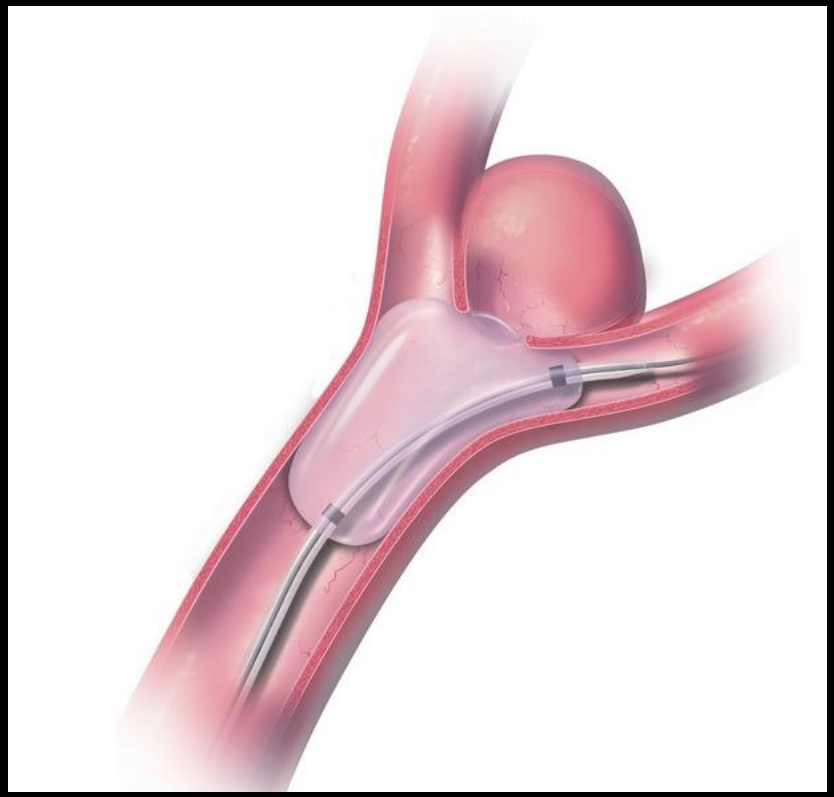
Detachable Coils



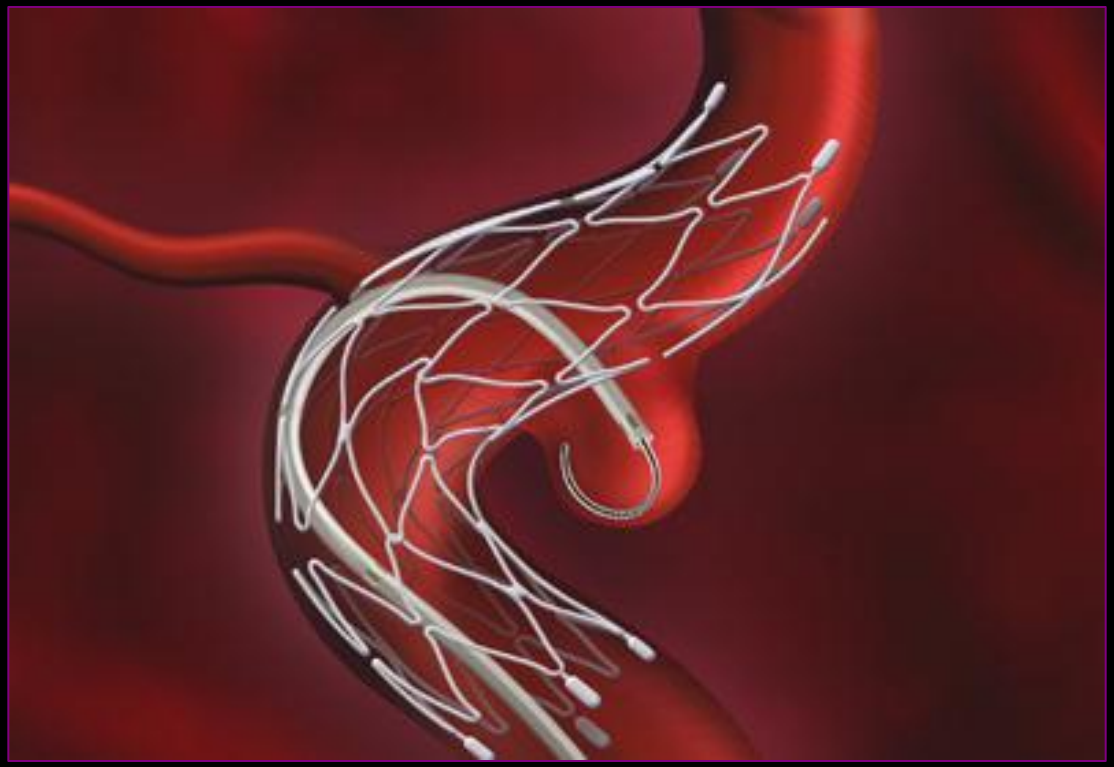


Balloon remodeling

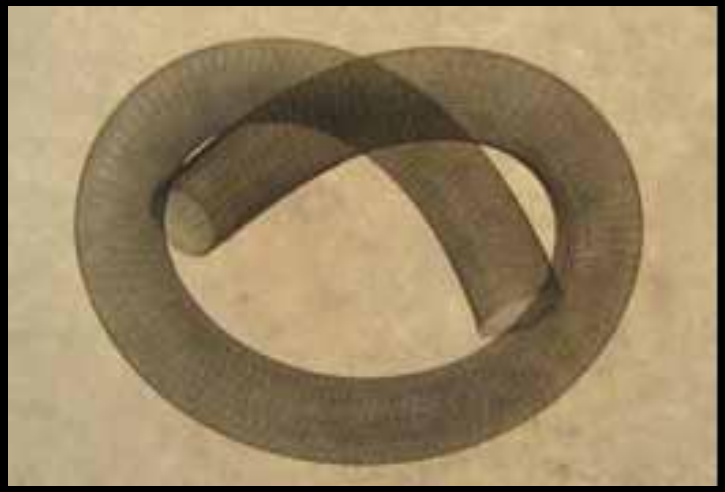


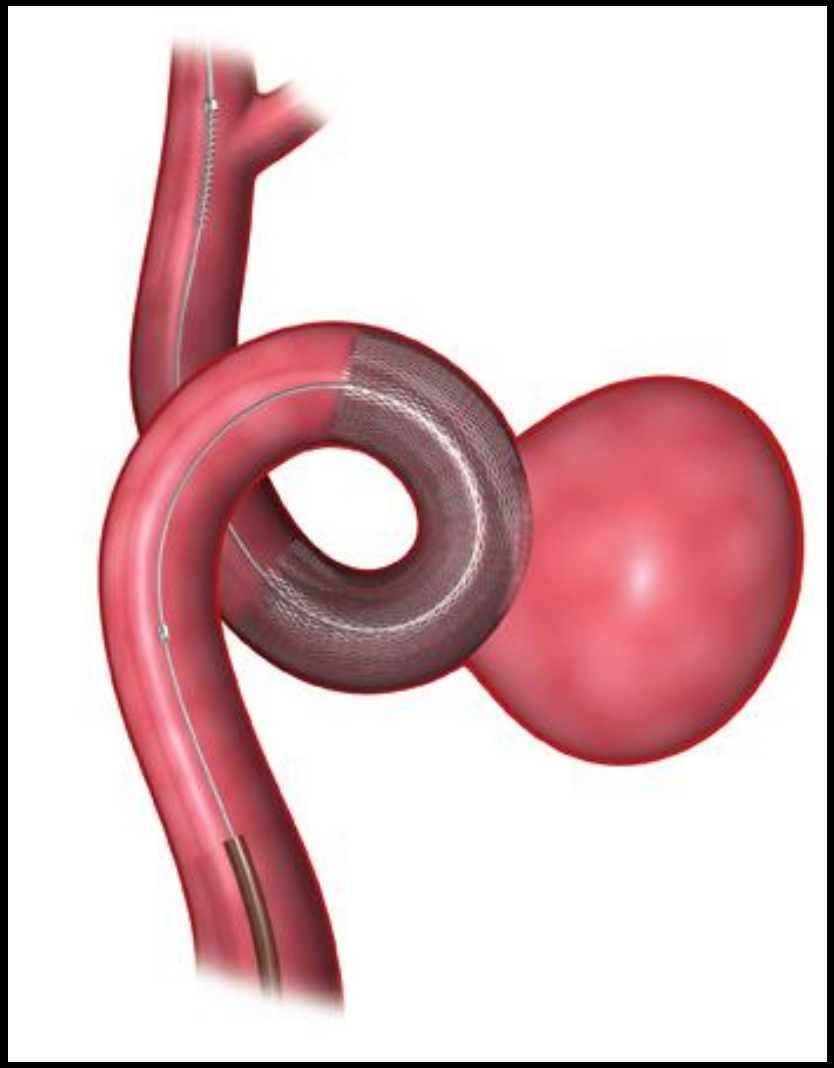


Stent assisted coiling



Flow diversion – Low porosity stents

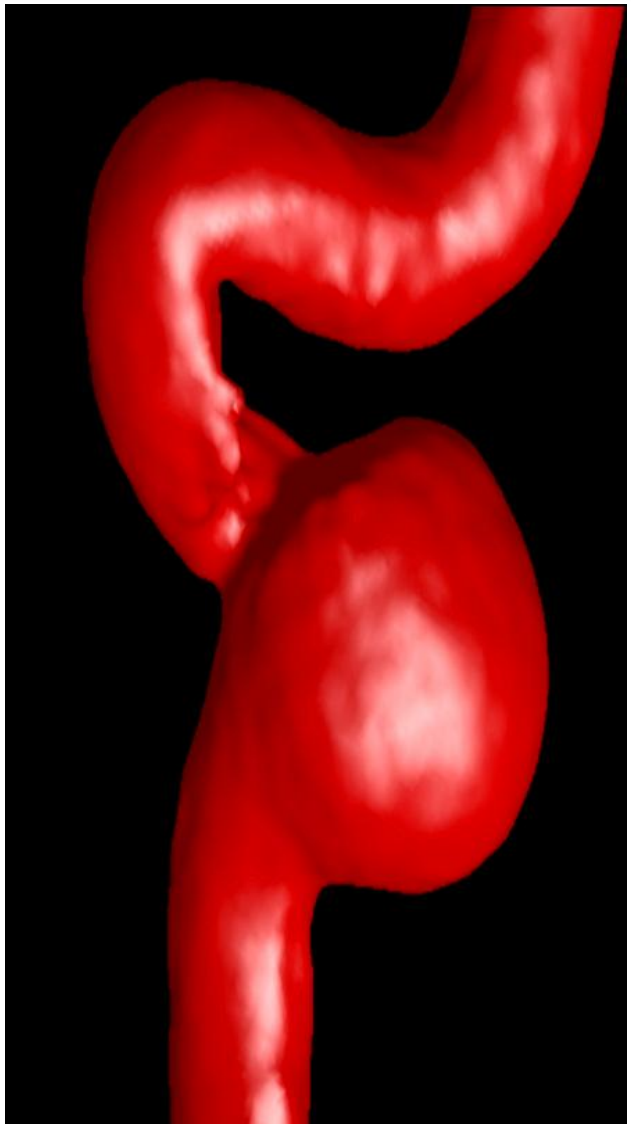


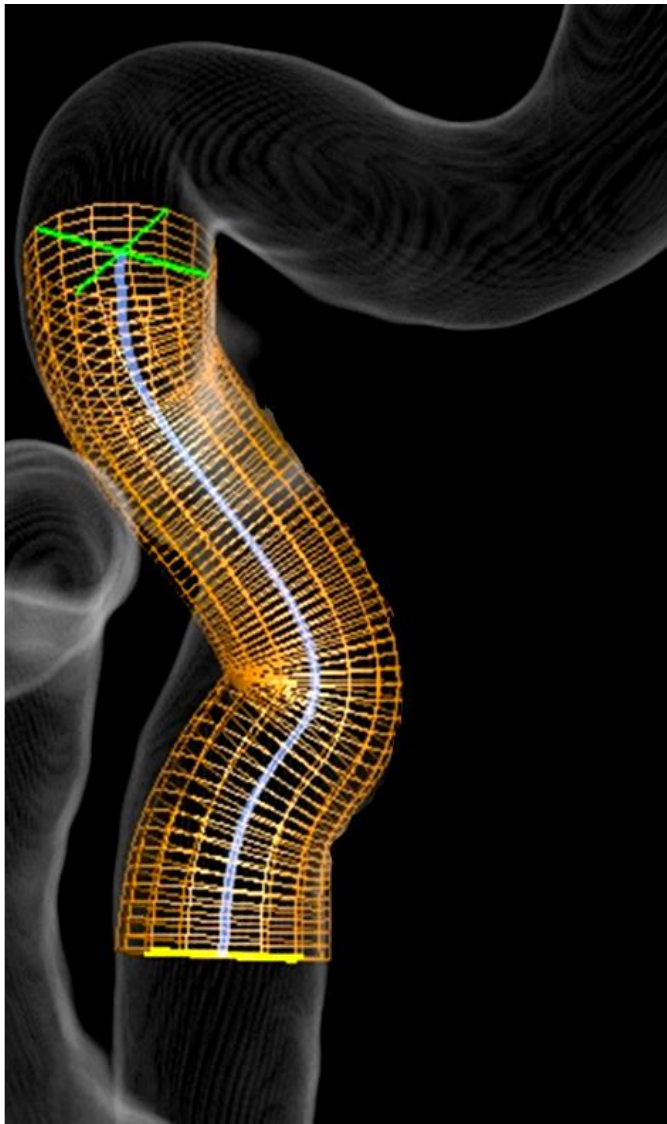


Intracranial Aneurysms

Flow Diverter Devices

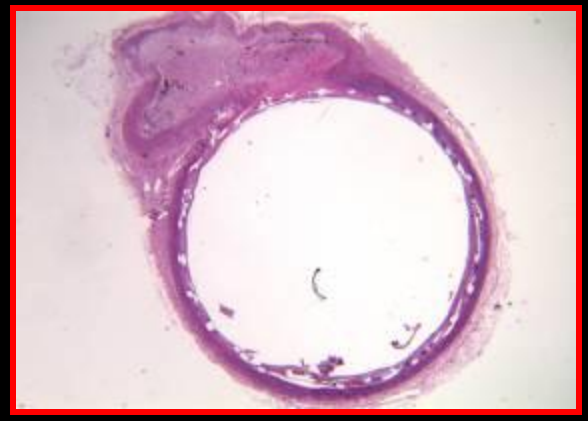
Endovascular Reconstruction





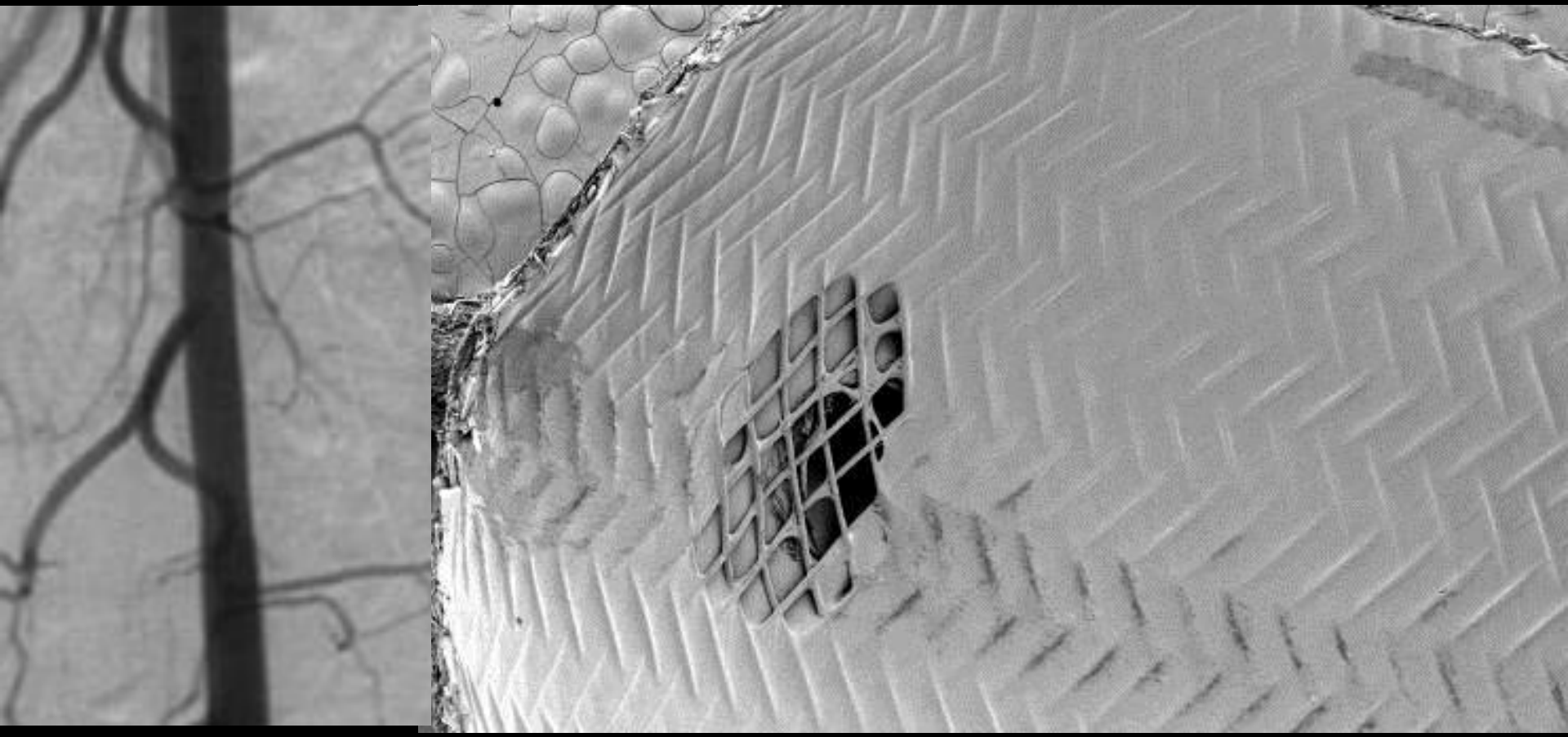
Pre-Tx Post-Tx Sacrifice

Rabbit 783B06



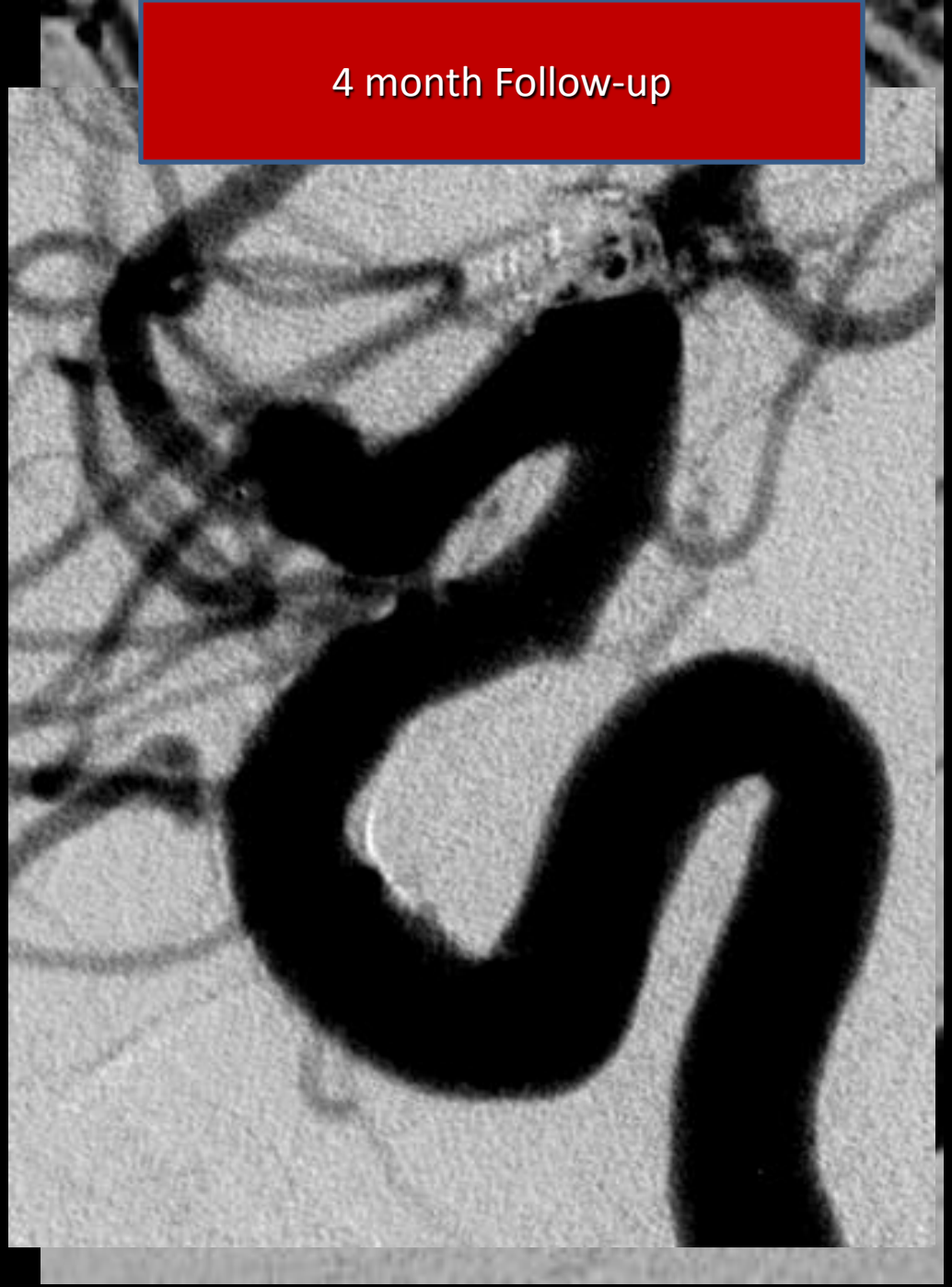
Kallmes et al. Stroke 2007

Lumbar Arteries Remain Open



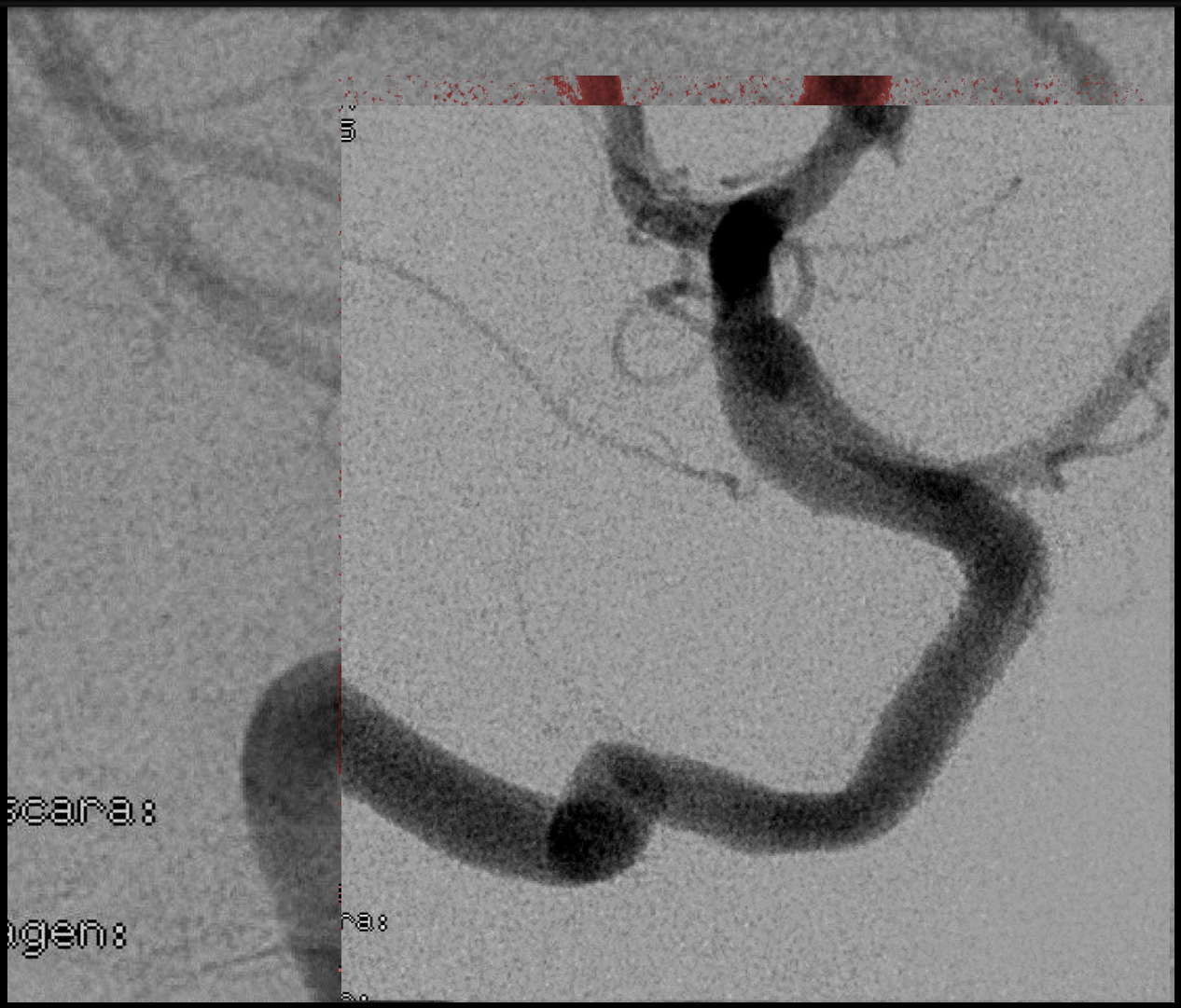
Kallmes et al. Stroke 2007

Jailed Ophthalmic Artery



4 month Follow-up

Endovascular Reconstruction



6 mo FU

Pipeline Embolization Device (PED)

- PITA trial: wide necked unruptured aneurysms (>4mm) with dome/neck <1.5 were enrolled at 4 centers. Aneurysms treated with PED w/w/o adjunctive coiling, clinical analysis at 30 days, 180 days, angiography at 180 days
- Mean aneurysm size 11.5 mm, mean neck 5.8 mm, 38.7% of treated lesions had failed previous endovascular treatment
- 31 aneurysms
  - 28 from ICA, 1 MCA, 1 VA, 1 VB junction
    - 5 cavernous, 15 peri-ophth, 4 sup. hyp, 4 Pcomm

PITA trial

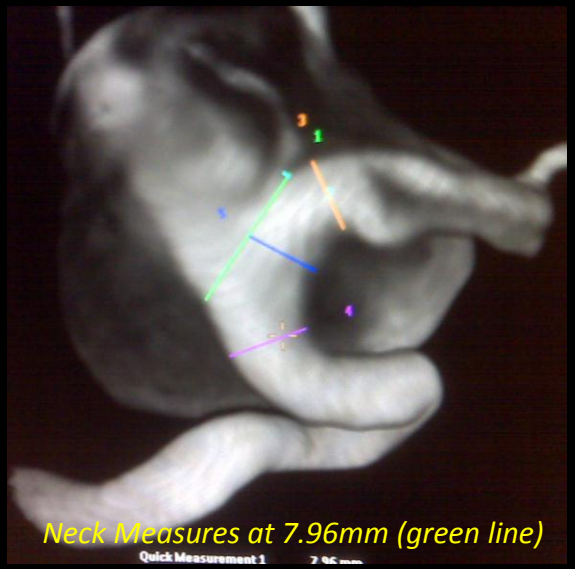
- Successful placement in 30/31 cases (96.8%)
- 2 patients with major periprocedural stroke
- Follow-up angio demonstrated complete aneurysm occlusion in 28/30 cases (93.3%)
- No significant in-stent restenosis an follow-up angio

- These results have been confirmed in both Buenos Aires and Budapest experiences with similar obliteration rates and complication profiles
- PED changes the treatment modality from thinking about packing density in the aneurysm dome to thinking about luminal reconstruction and curative treatment at the level of the aneurysm neck
- This technology is a “game-changing” development for a population of aneurysms that carry a low-curative rate with endovascular coiling alone and a significant peri-operative morbidity with surgical clipping

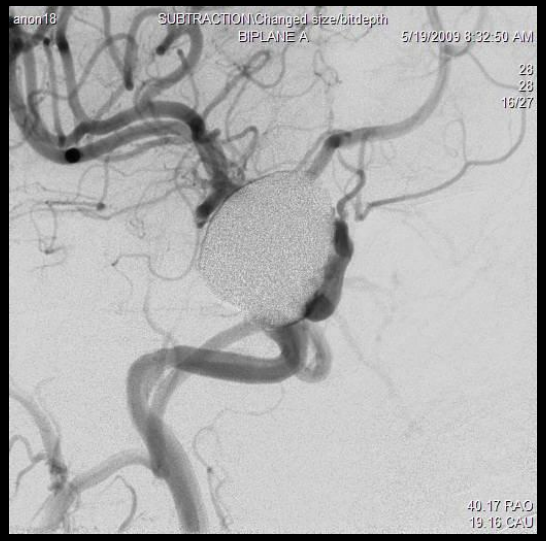
- Caveats:
  - Perforators and telescoping stents
  - Previous self-expanding stents (Neuroform, Enterprise) and risk of endoleak
  - Ruptured aneurysms given the need for dual anti-platelett adjuvant treatment
  - Bifurcation aneurysms
  - Changes in reperfusion rates in the native vasculature (TJU experience to be published

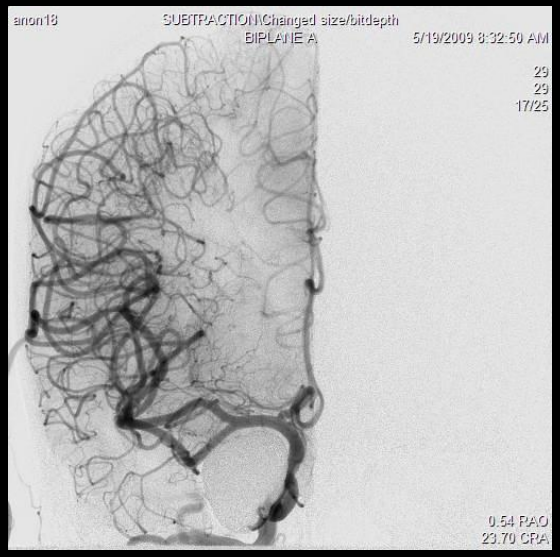
Onyx into Aneurysms

Initial presentation



Neck Measures at 7.96mm (green line)





Coil Recanalization: treatment with Onyx

Coil recanalization (66 coils 1070 cm.)

Post Onyx Injection

1.8mL Onyx Injected

Cornell Experience (7/31/2009)

- 516 aneurysms in 504 patients
  - Fusiform: 19, Saccular: 497
  - Saccular aneurysms
    - ruptured: 244
    - unruptured: 253
- Saccular aneurysms treatment: coils/stent
    - GDC alone in 204
    - Matrix alone in 121
    - GDC/Matrix 74
    - Hydrocoil in 24
    - Axium in 26
    - Neuroform/Enterprise stent in 65
- Fusiform Aneurysms:
  - mostly parent artery occlusion

Cornell Experience (7/31/2009)

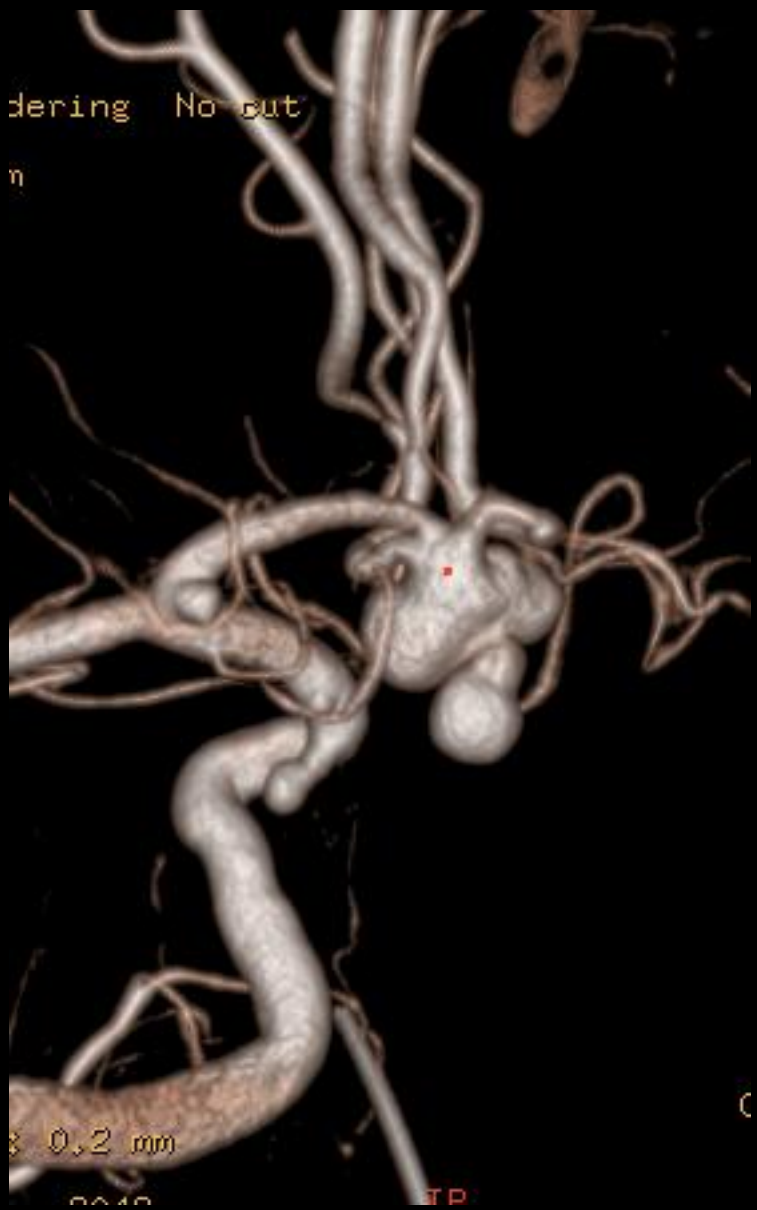
- Complication rate 8.72%
  - 41 complications:
    - 14 thromboembolic
    - 1 CN III palsy
    - 1 CN VI palsy
    - 10 groin hematomas
    - 2 dissections
    - 8 coil migration,
    - 5 hemorrhage
  - 3 deaths:
    - 2 ruptures
    - 1 migration of coils following by hemorrhage after retrieval of coils

- Retreatment rate: 27/516= 5.2%

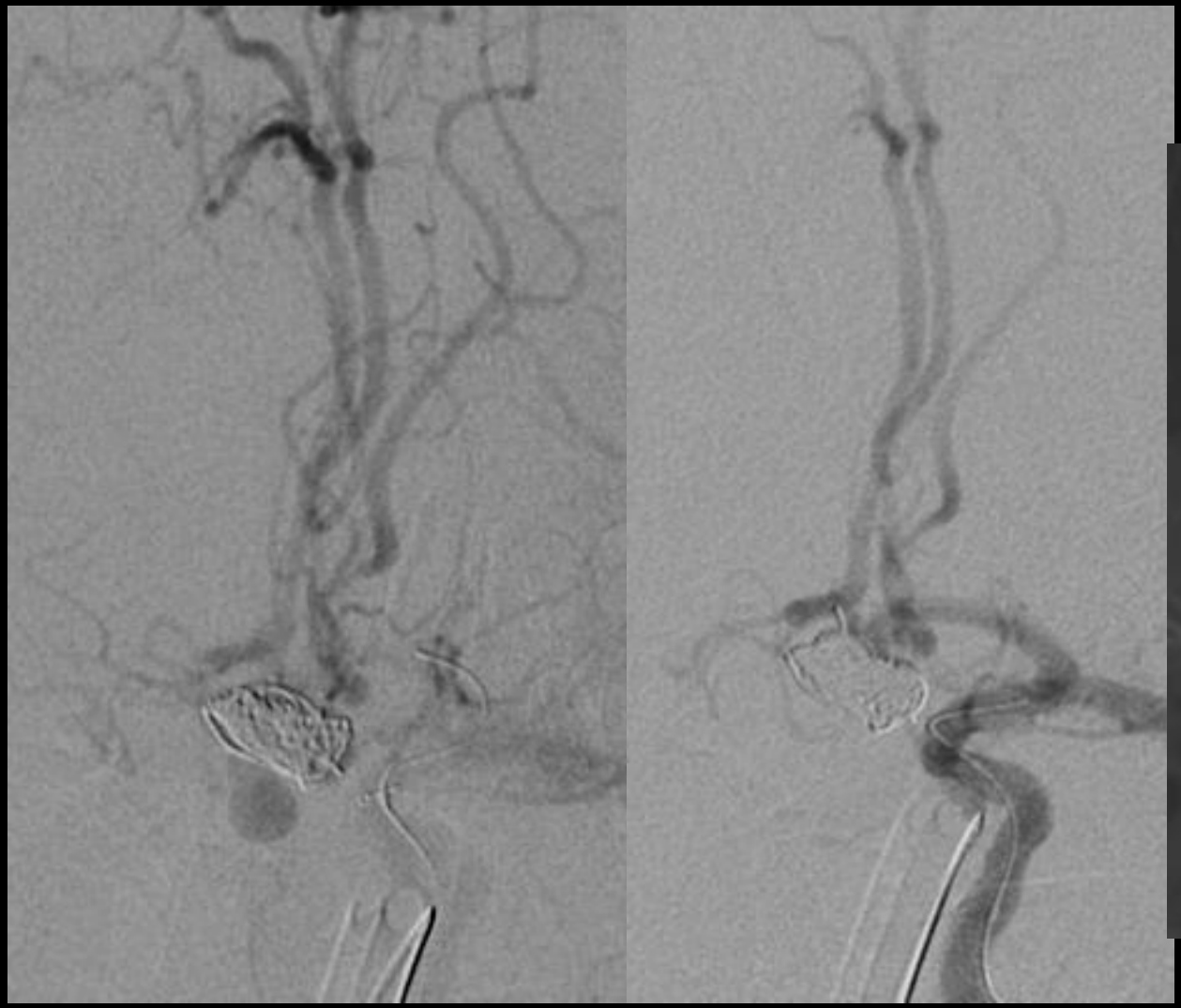
- Clinical outcome at six months:
  - Morbidity (Rankin >1) : 7 (1.3%)
  - 3 death (0.6%)

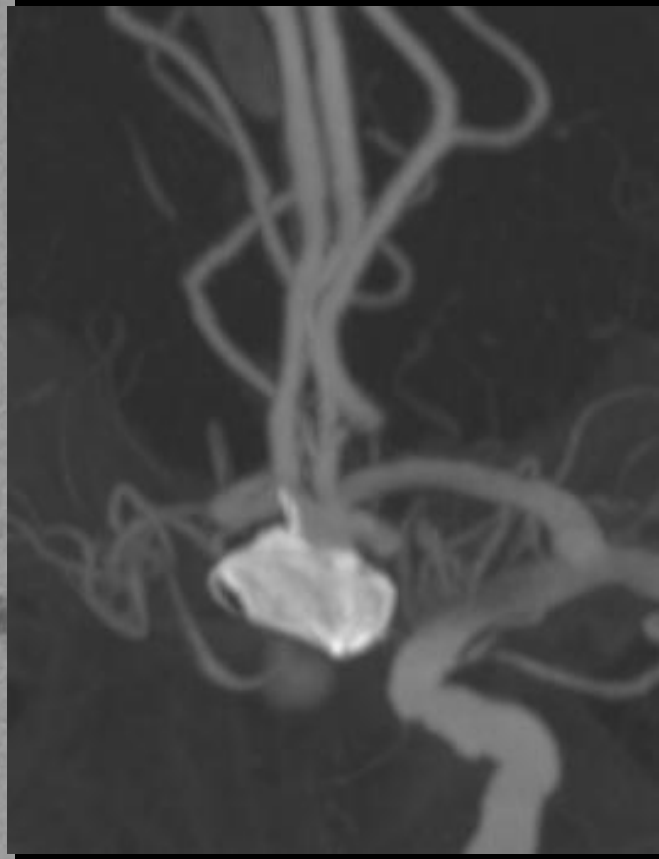
Coils


DoB: Jun 01 1949
Dec 27 2009
9:23
No cut
L
3
0
151/2
Angles
0 L 0 LAD 0 CRA
0.2 mm

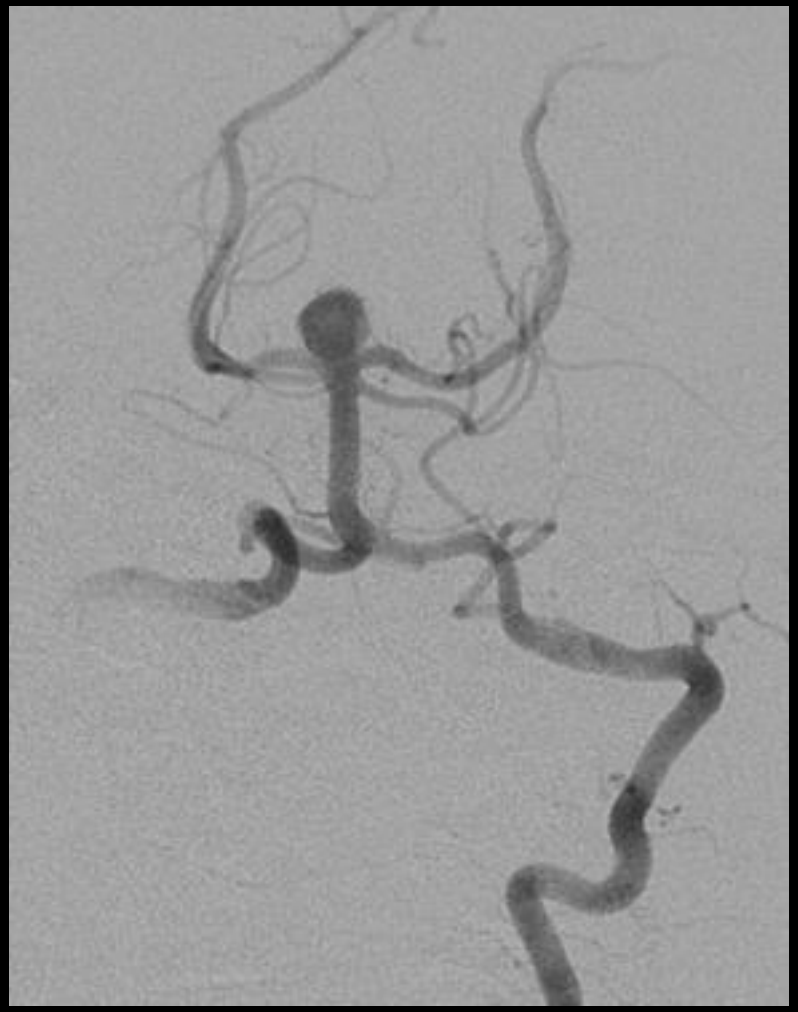

No cut
0.2 mm

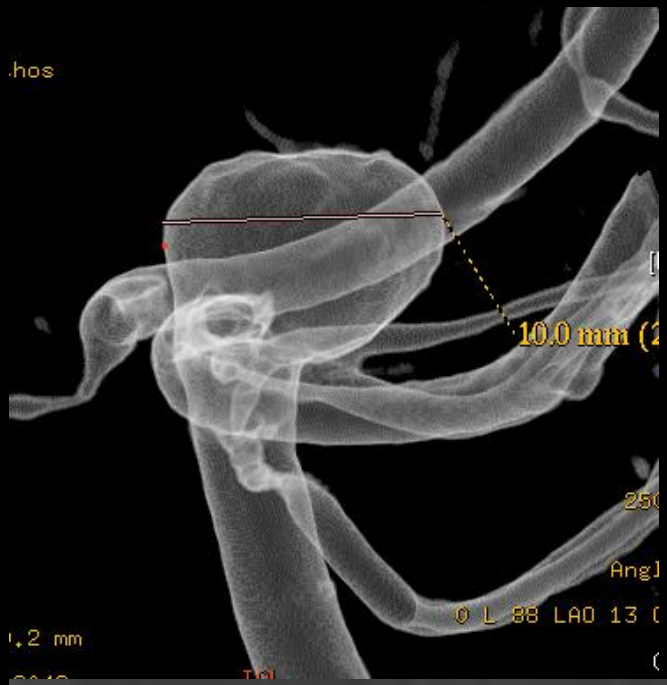
Coils





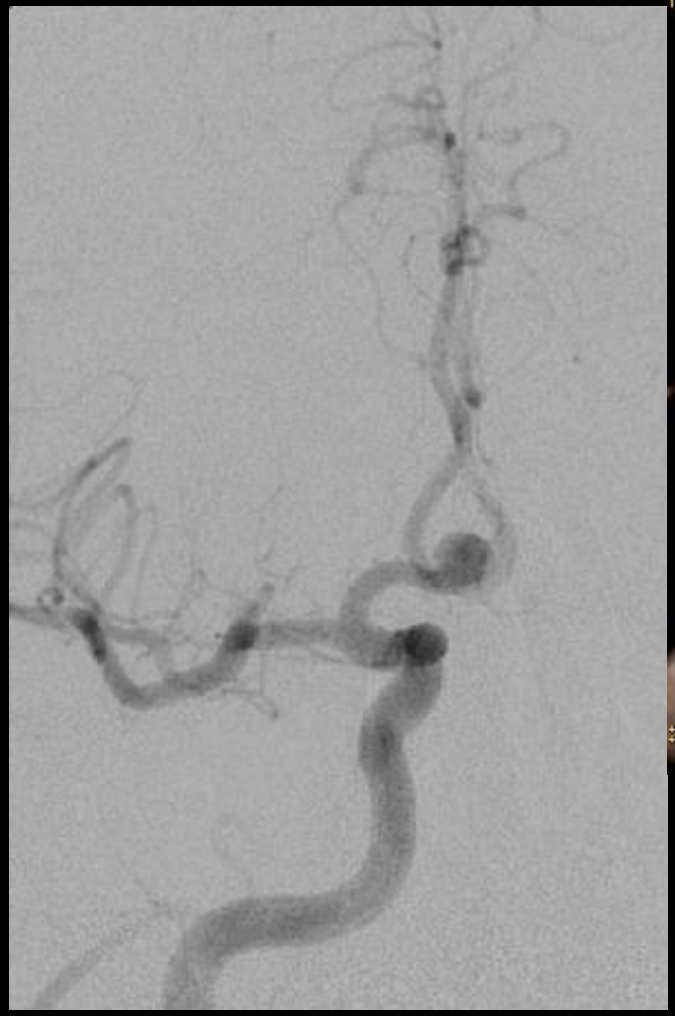
Coils/balloon





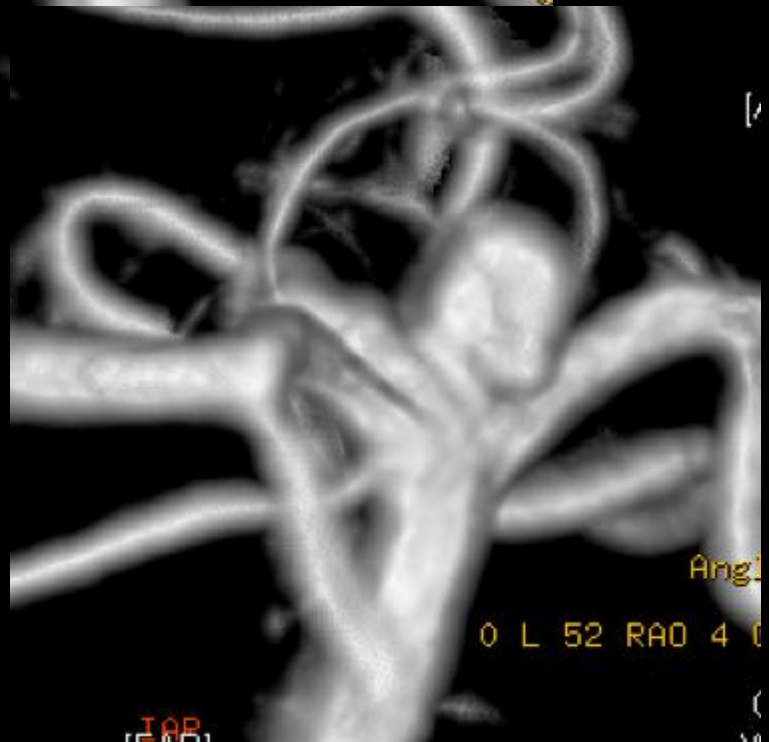
Coils/balloon

Coils/balloon

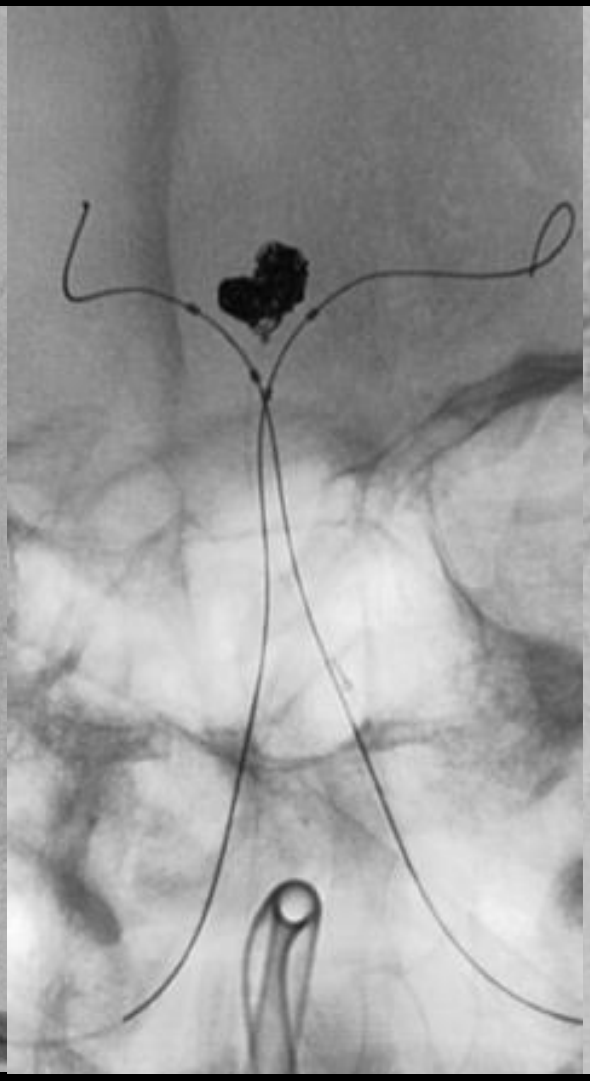


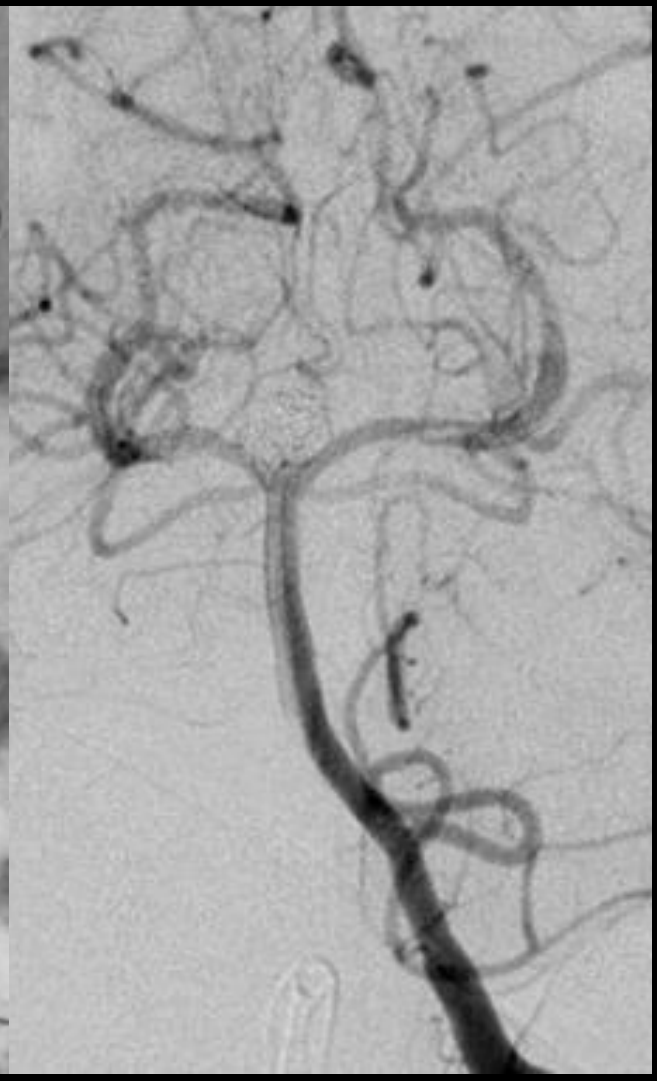
Coils/ balloon

Coils/ balloons



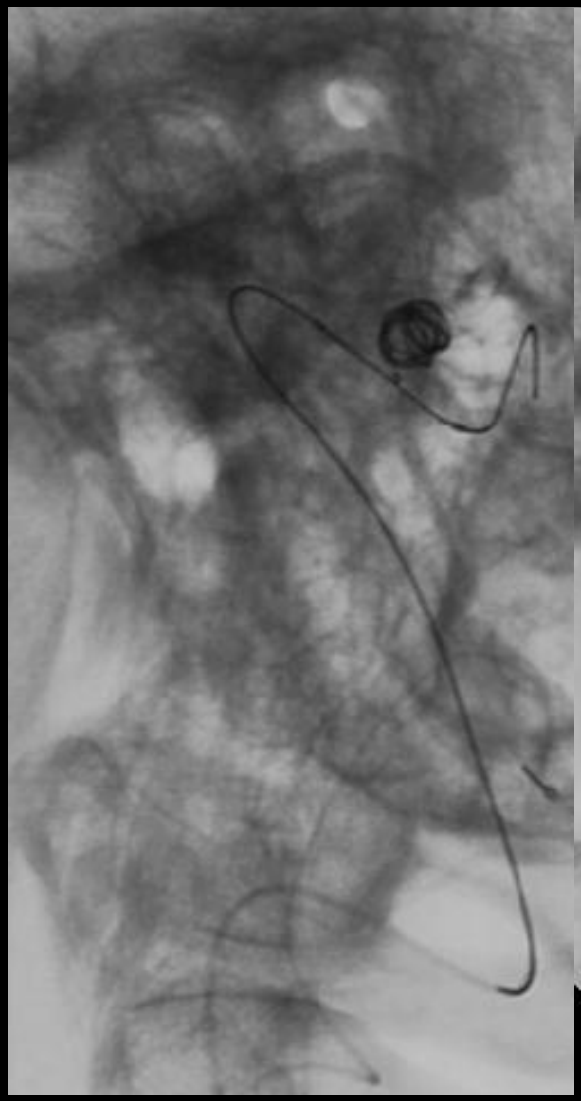
Coils/ balloons

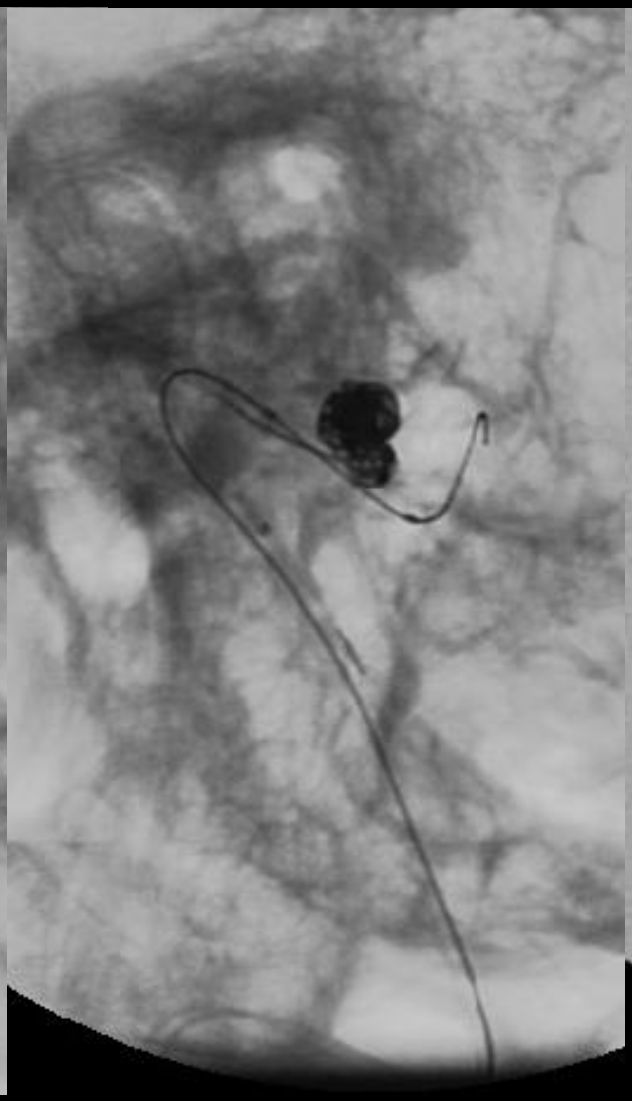




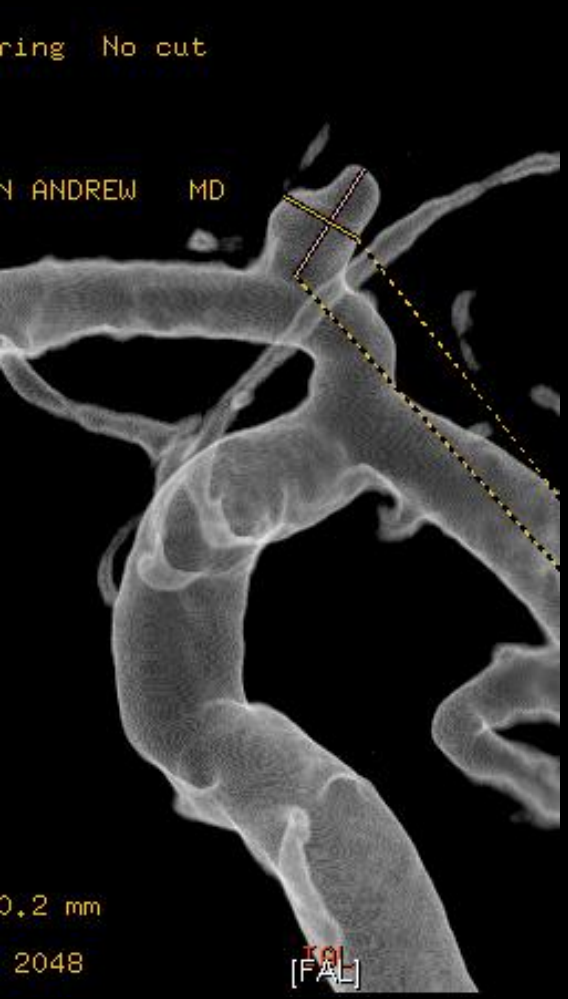
Coils/ balloon

Coils/ balloon

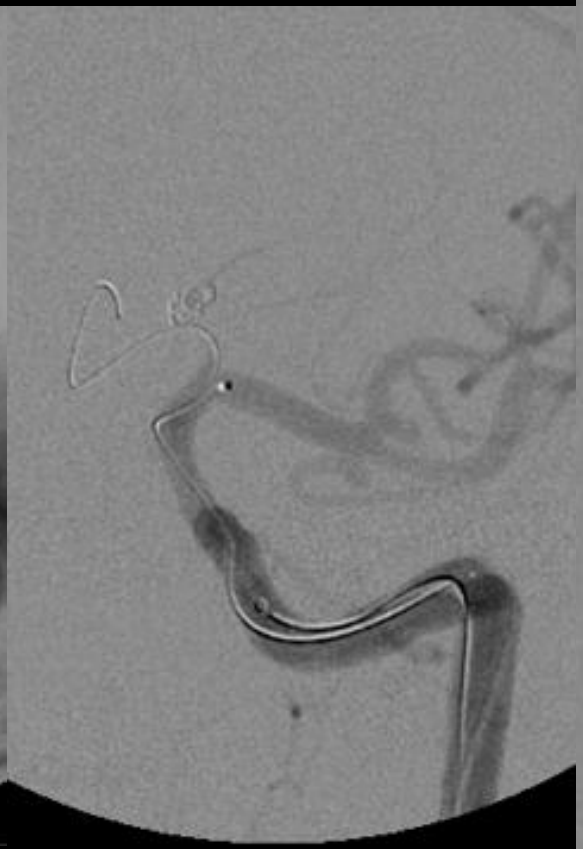


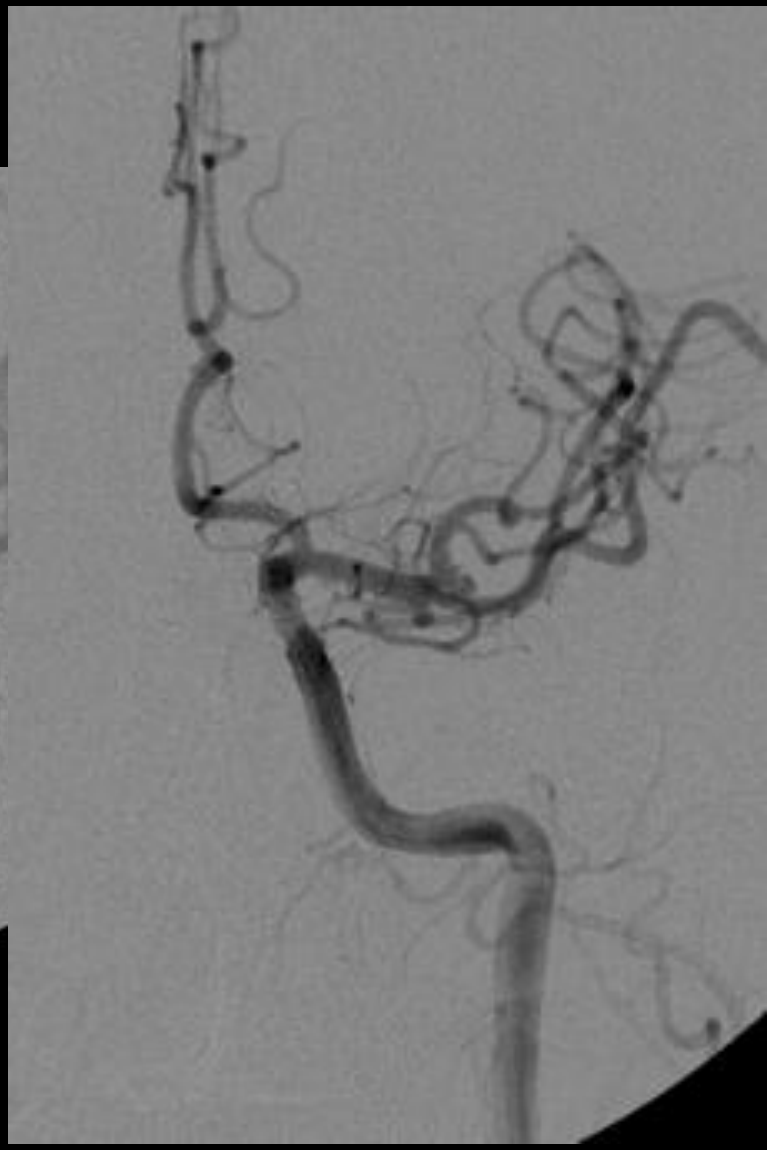


Coils/ balloon

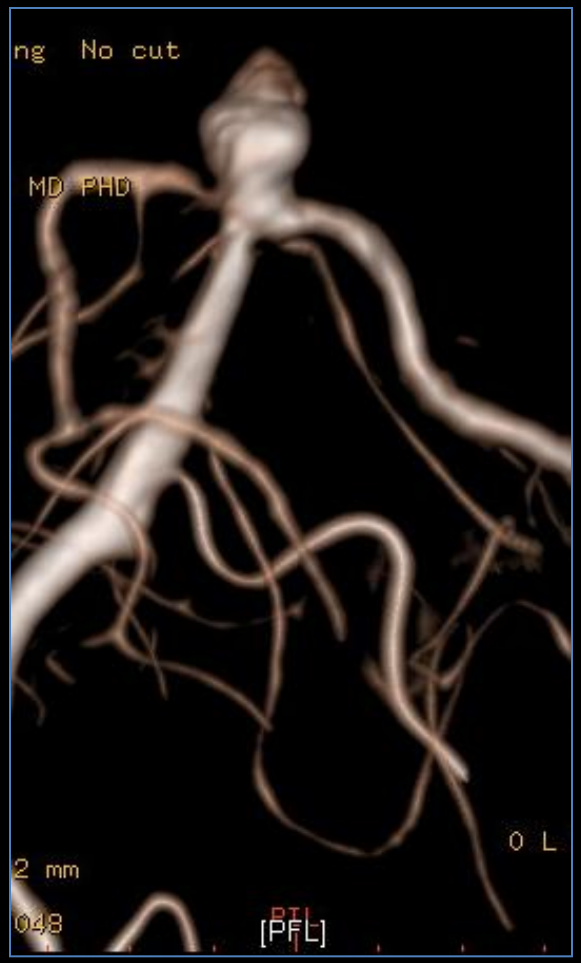


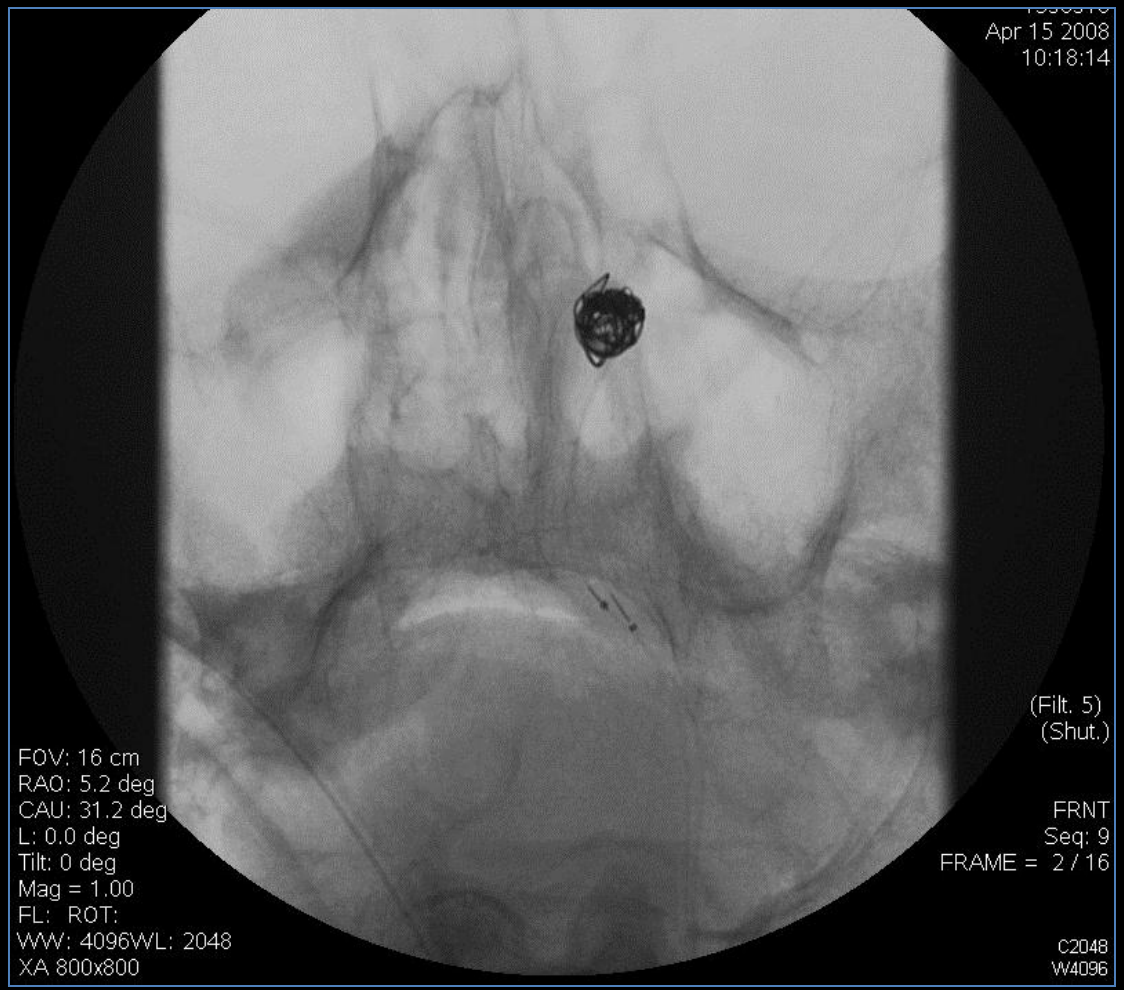
Coils/ balloon

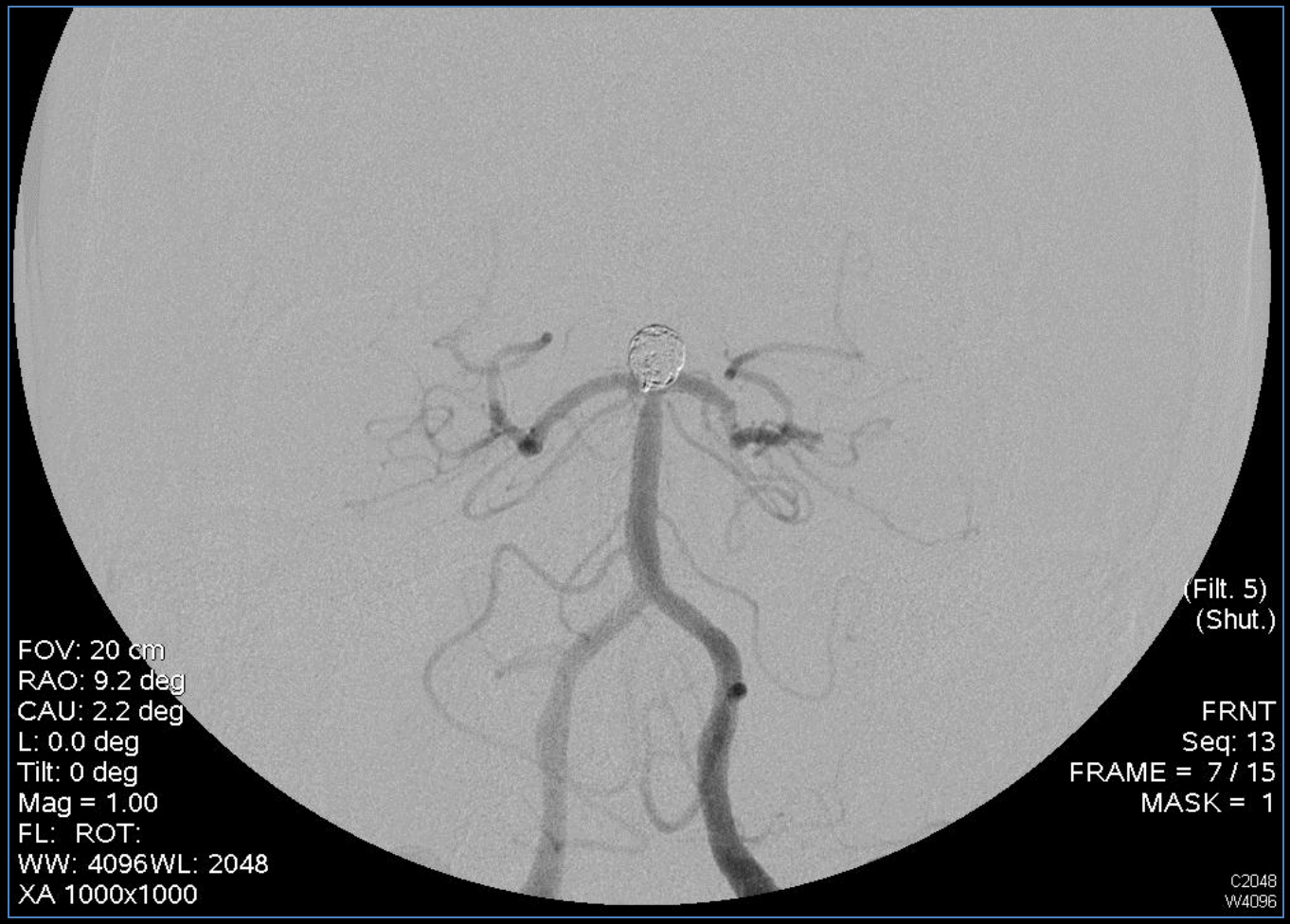




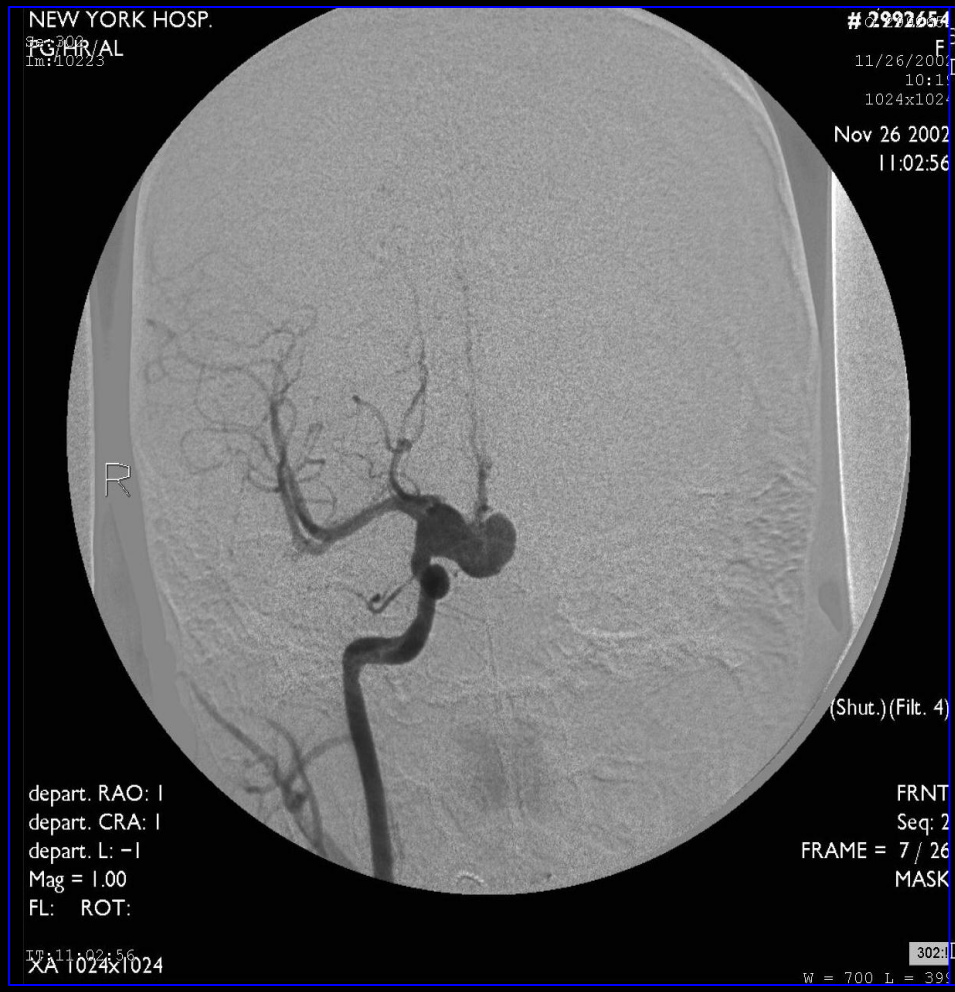
Two Catheter Technique



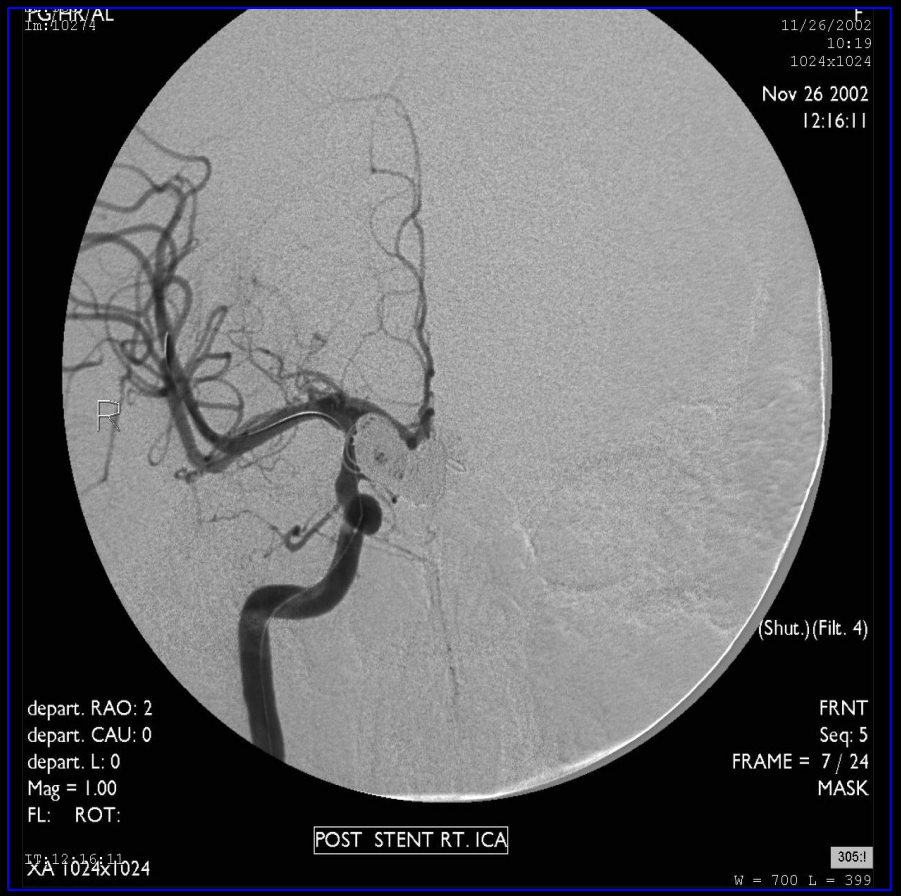


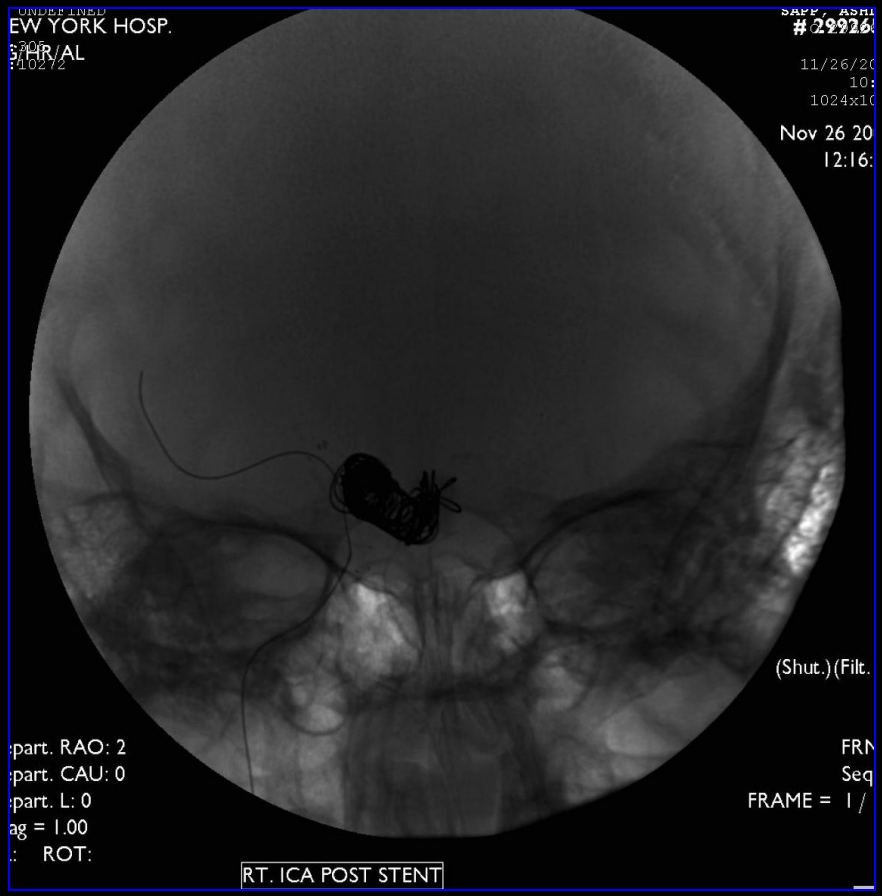

(Filt. 5)
(Shut.)
FOV: 20 cm
RAO: 9.2 deg
CAU: 2.2 deg
L: 0.0 deg
Tilt: 0 deg
Mag = 1.00
FL: ROT:
WW: 4096WL: 2048
XA 1000x1000
FRNT
Seq: 13
FRAME = 7 / 15
MASK = 1
C2048
W4096

Coiling/Stent

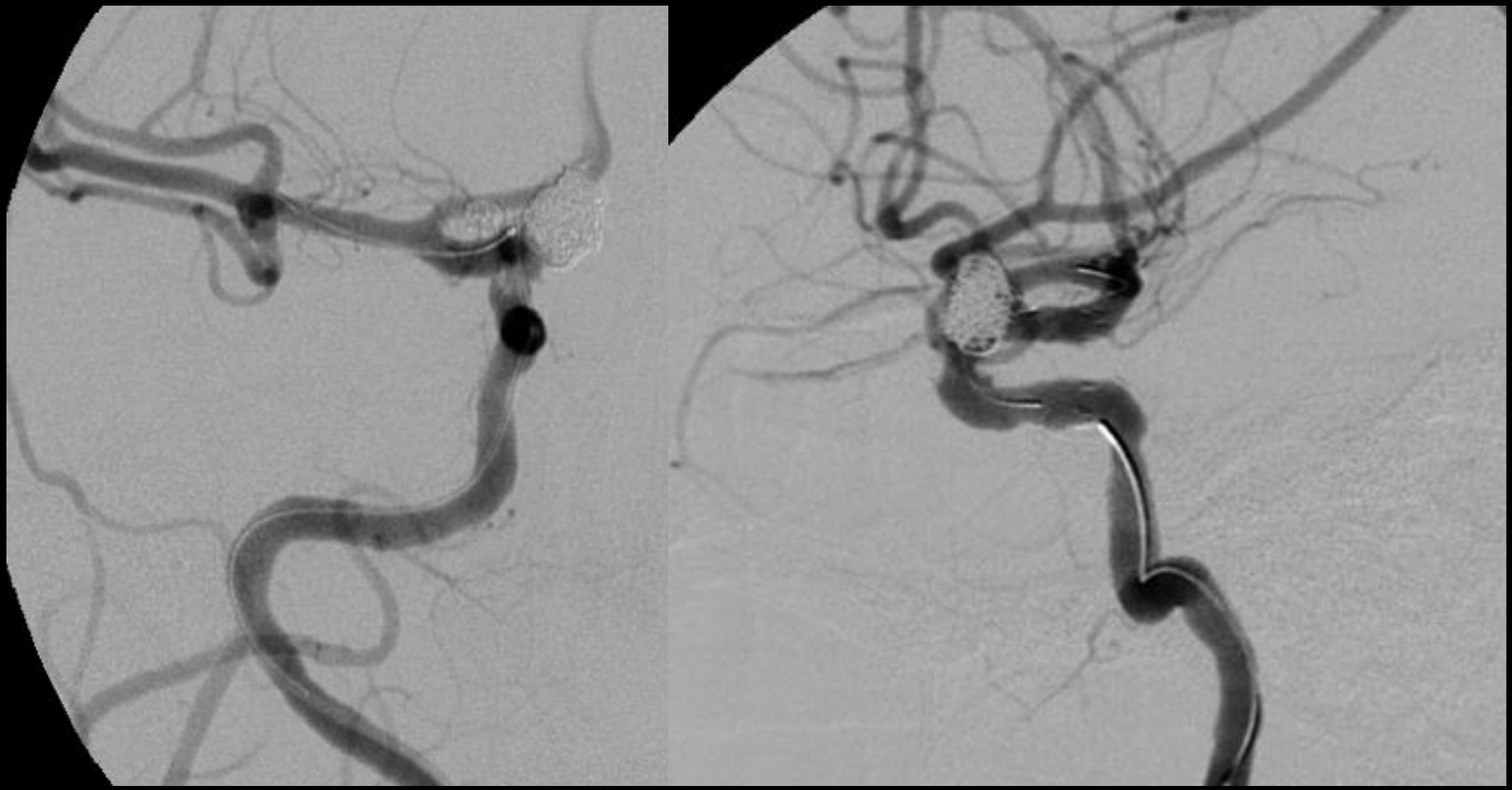


Coiling/Stent

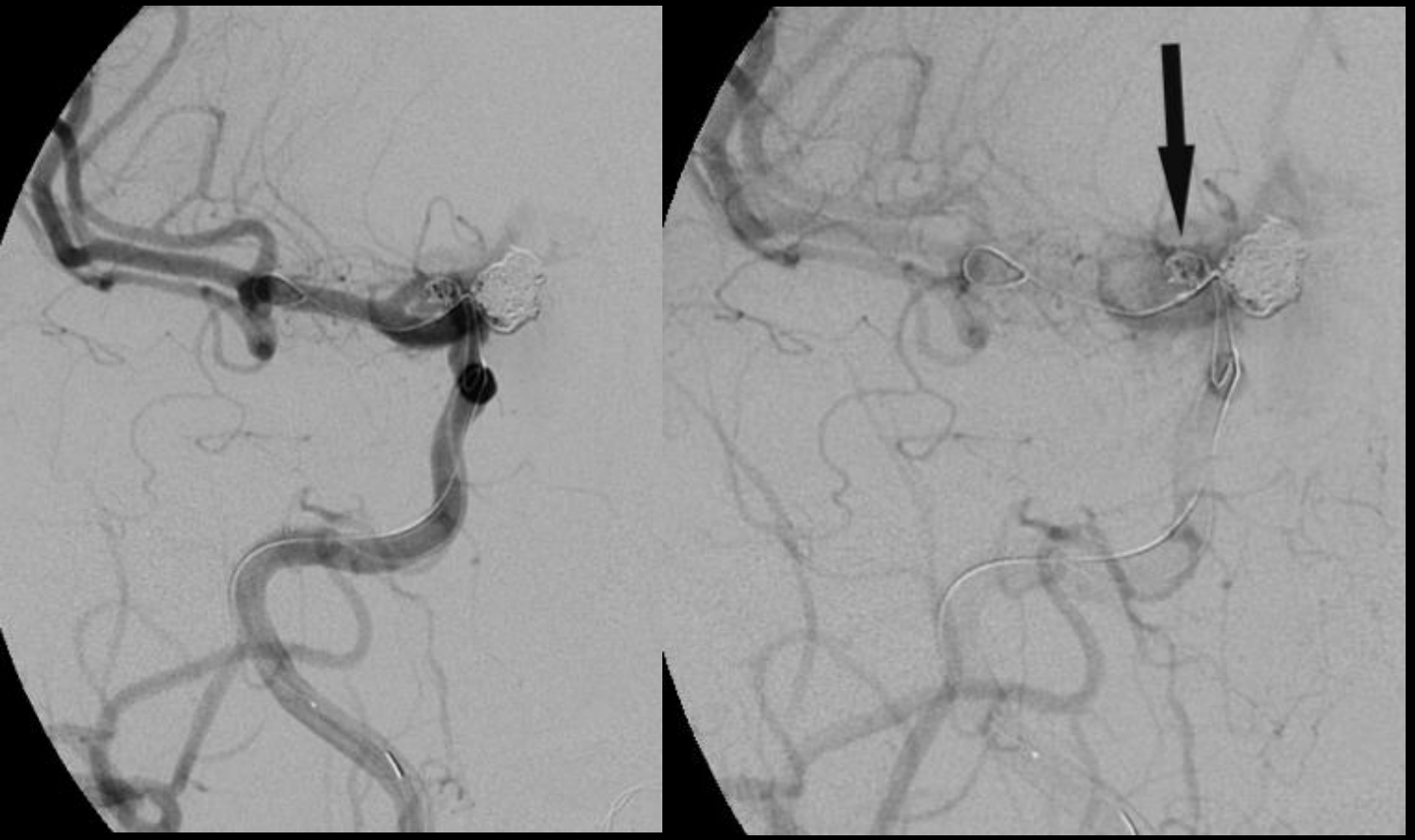




Coils/ balloon/ glue/ stent

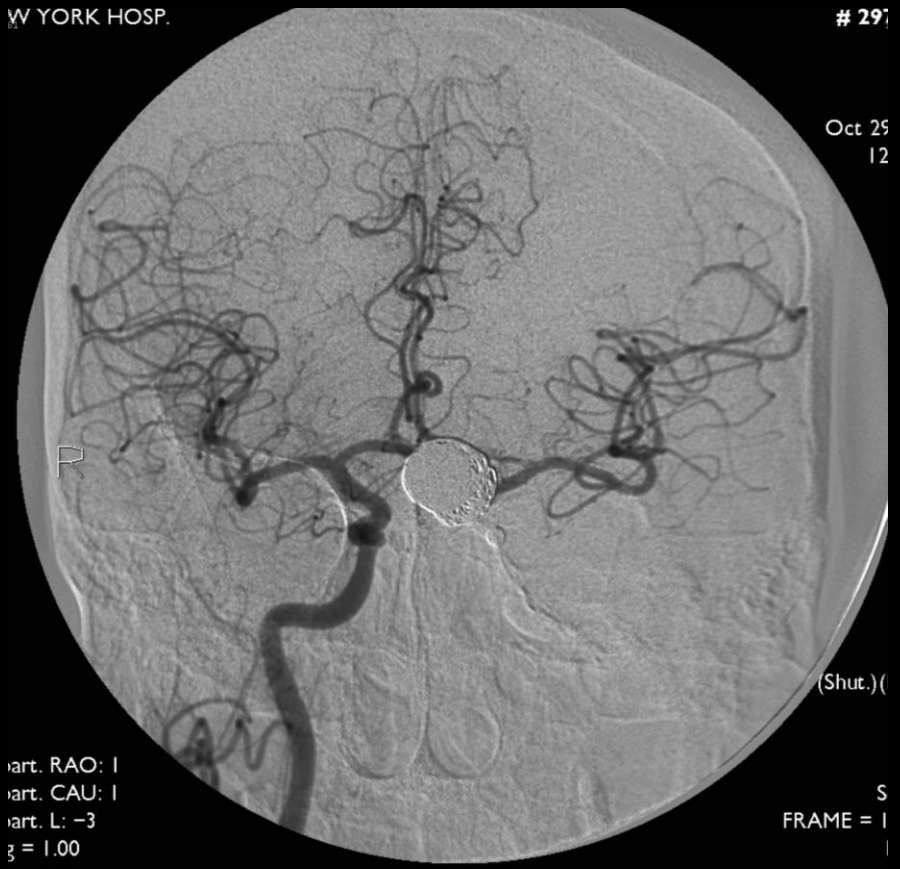


Coils/ balloon/ glue/ stent



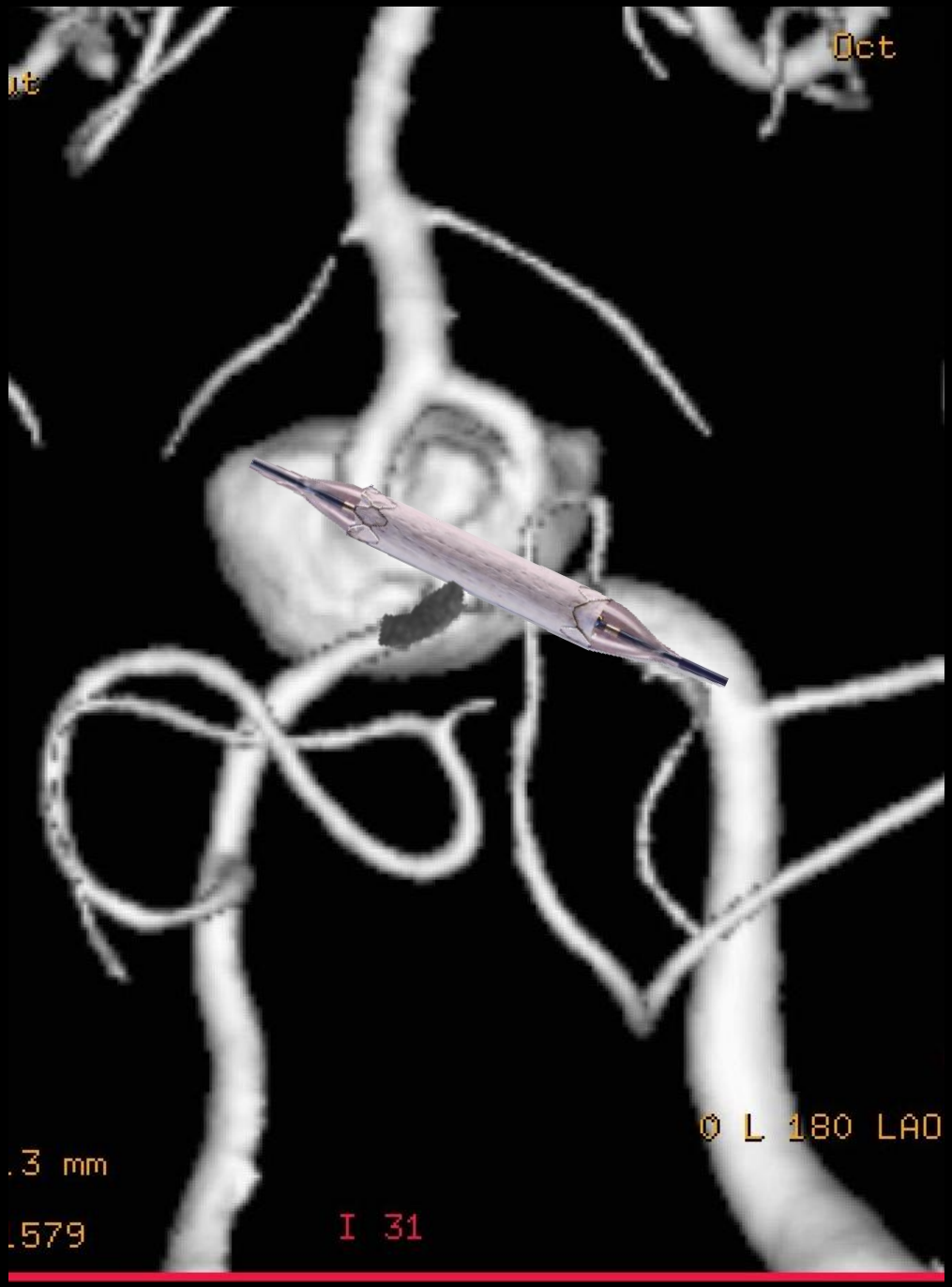
Retreatment

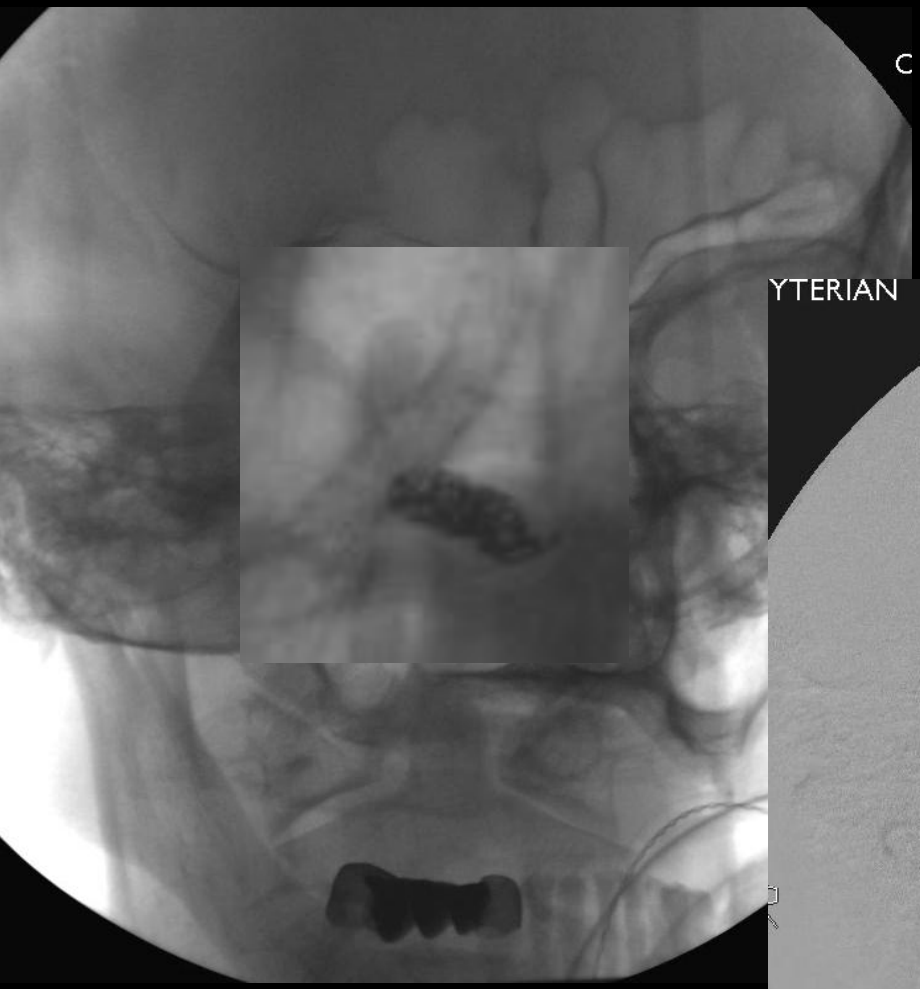
Deconstruction

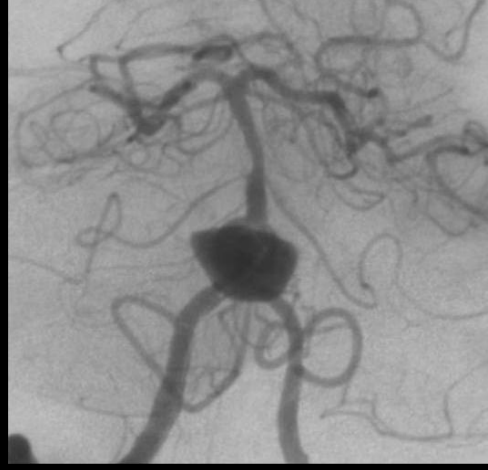


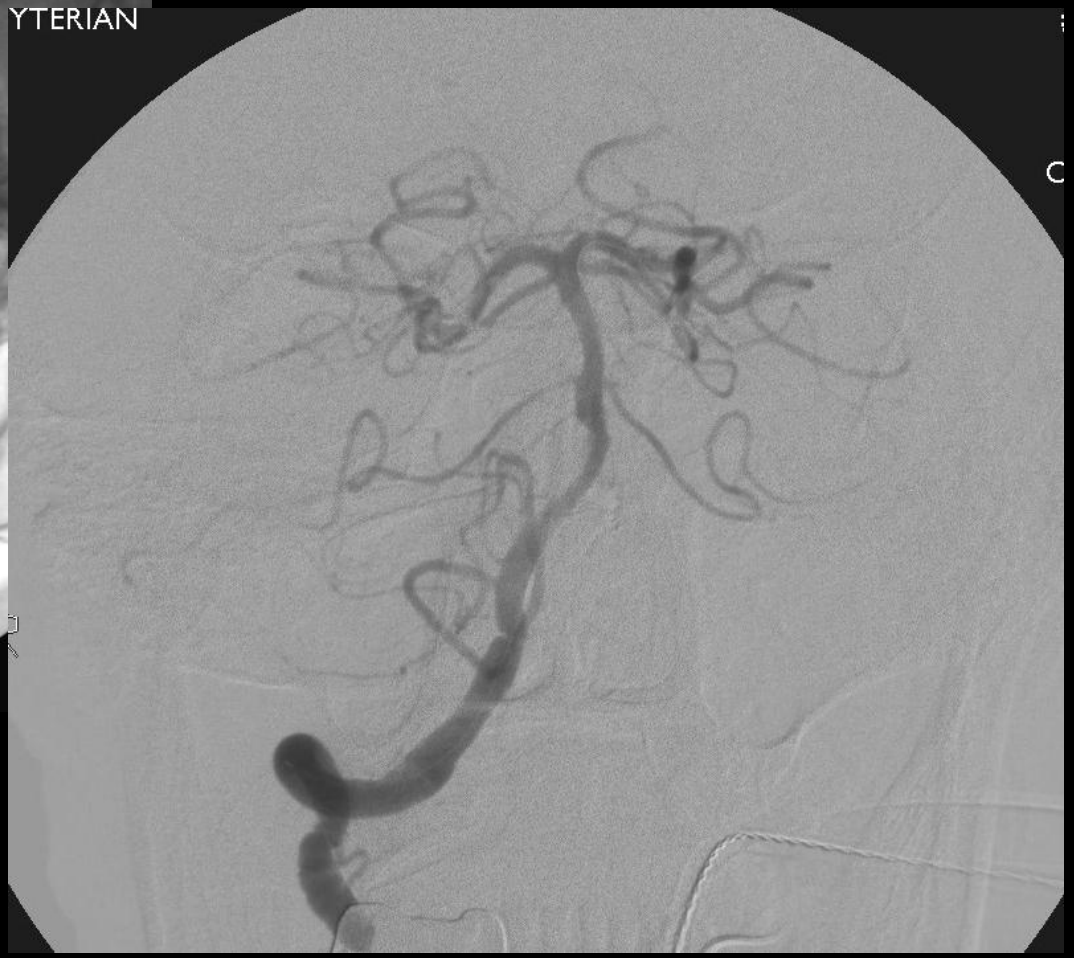
Reconstruction


TERIAN
No cut
cm
RT.
ze: 0.3 mm
L = 1579
nm
3
I 31
AN
S 34
t
3 mm
579
I 31
BUSHGJOK
? 32
Oct
0 L 180 LAO


Oct
0 L 180 LAO
.3 mm
.579
I 31






YTERIAN

Conclusions

- Multiple ways to treat unruptured aneurysms
  - Observation
  - Microsurgical
  - Endovascular
    - Coil, liquid embolic agent, stent
- Subarachnoid hemorrhage occurs with rupture
  - High morbidity and mortality
- **Clipping and endovascular therapies are adjunct treatments to aneurysms, not competing ones**
- Tertiary care centers with 24-hour OR, angio, NSICU, neuroanesthesia offer the best outcomes to patients