Treatment of Complex Intracranial Aneurysms: Clips, Coils, Bypass, and Stents

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Definitions

- Ruptured Aneurysms
- Unruptured Aneurysms
- Simple Aneurysms = ≤ 1cm Size

  and….Dome/ Neck Ratio ≤ 1.5
- Complex Aneurysms = >1 cm. size

  Dome/ Neck Ratio > 1.5

  Fusiform Aneurysms

  Branches arising from Sac

  Atherosclerotic/calcified/thrombosed/coiled sac

  Blister /Dissecting / Mycotic Aneurysms

Recommendations Based on

- UW Experience with More than 1300 Aneurysms 2005 - 2012
- Outcomes Analysis of Our Own Patients
- ISAT Trial and Follow Up (some flaws)
- Brat Trial (some flaws)
- Innovations Taking Place in Aneurysm Management, including Personal Surgical Innovations

Ruptured Aneurysms

- Simple Aneurysms

  Age ≥ 50 years, H&H > 3 = Coiling ± Balloon Assistance

  Age < 50 years, H&H ≤ 3 = Clipping

- Complex Aneurysms

  Dome/Neck Ratio ≥ 2, Age ≥ 50 years= Coiling

  All Others = Clip Reconstruction, or Bypass with Trapping

Unruptured Aneurysms

- Consider Natural History, Patient's preference, and Patient's age in Deciding Treatment
- Simple Aneurysms: Coiling, and Clipping are Both Options
- Complex Aneurysms:

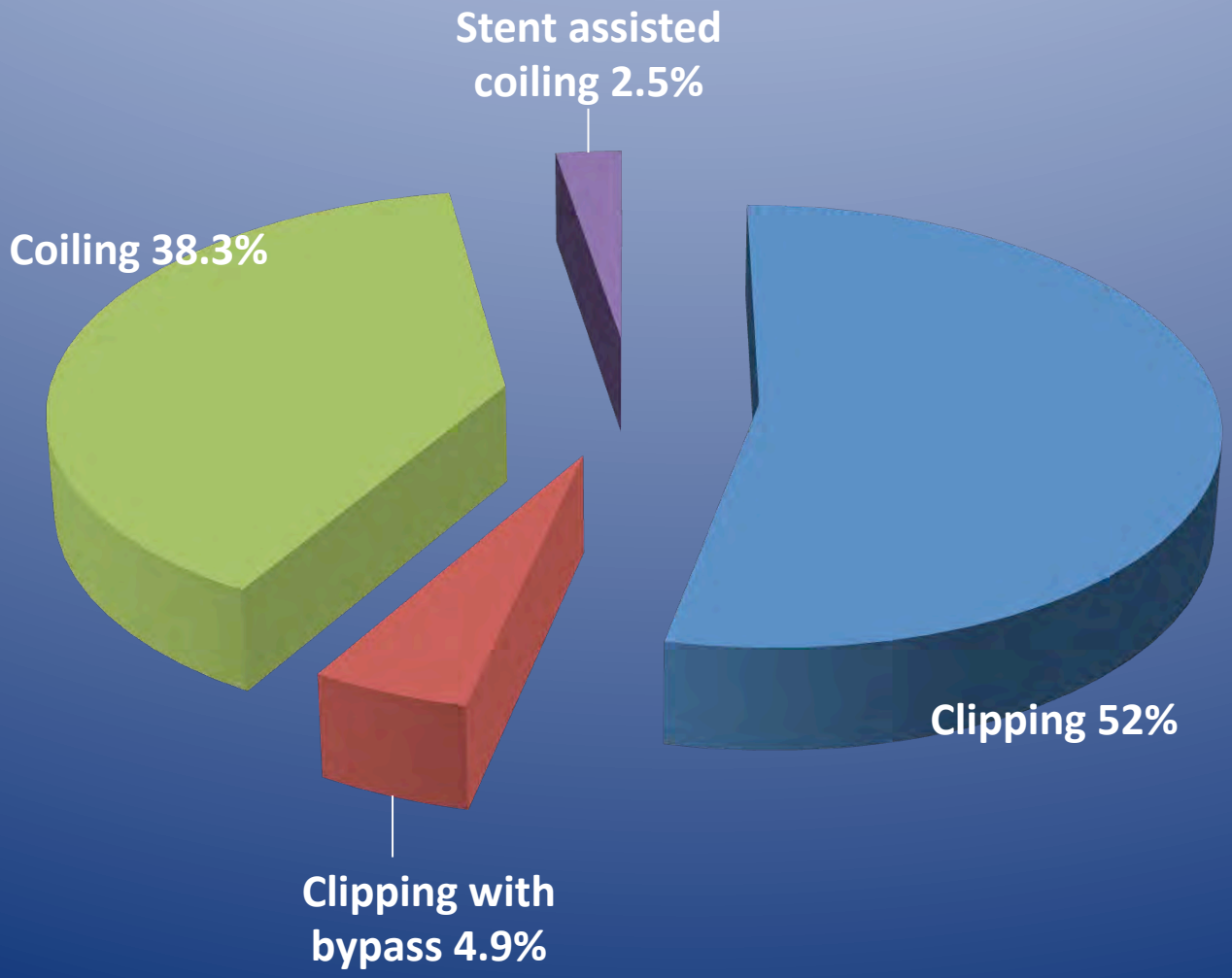
  Cavernous, Paraclinoid, Ophthalmic = Pipeline Stent, unless Patient prefers Microsurgery

  ACOM = Clip Reconstruction ± A3/A3 Bypass

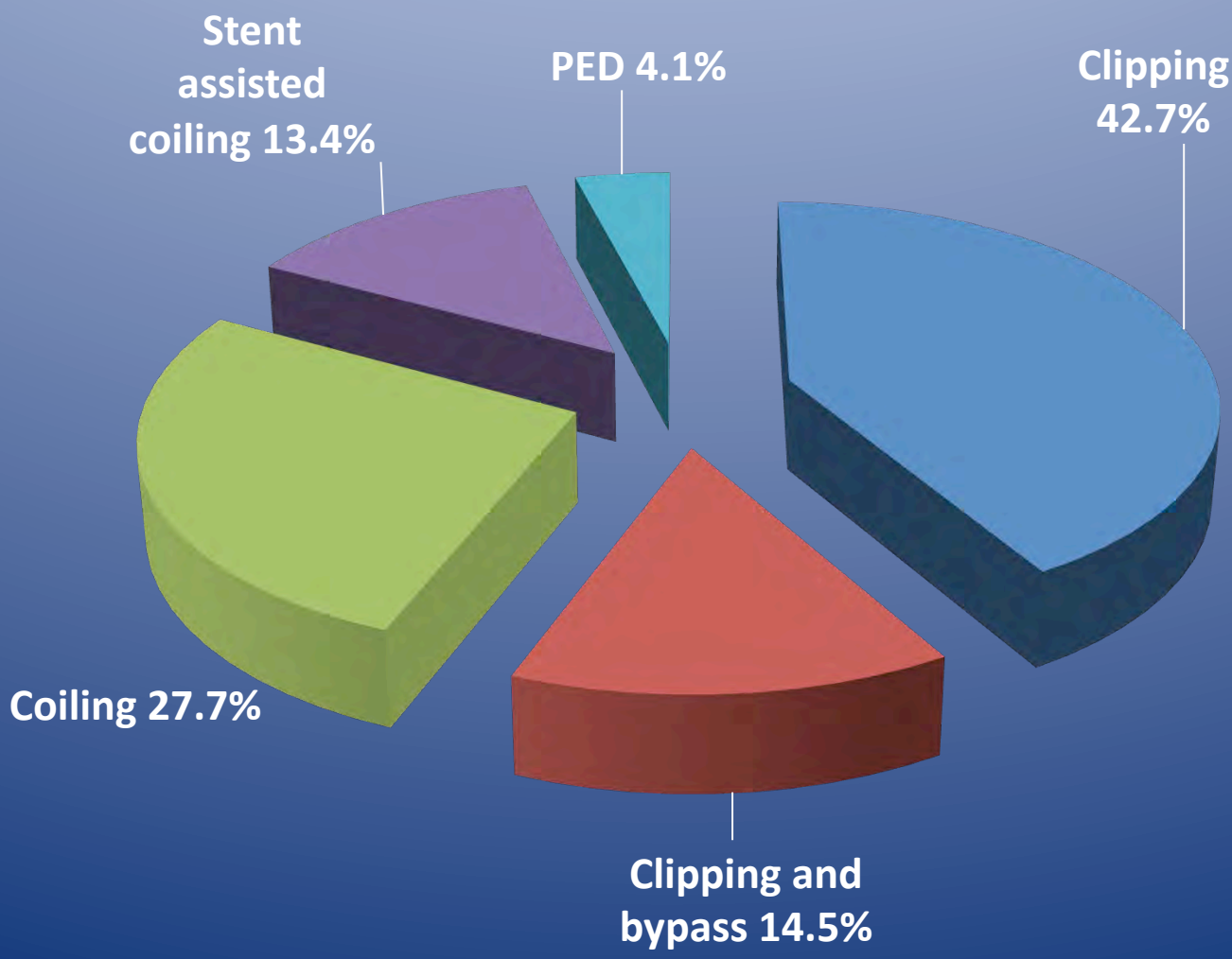
Complex Unruptured Aneurysms

- ICA distal to Pcom = Clip Reconstruction, Bypass, Pipeline Stent, Stent + coils all Possible
- MCA Aneurysms = Clip Reconstruction, Bypass
- BA Tip Aneurysms = Stent Assisted Coiling, Clip Reconstruction, Bypass to PCA + BA Occlusion
- Mid Basilar Aneurysms = Bypass +Trapping, stent + coiling, ? Pipeline Stent?
- Vertebral, and PICA Aneurysms = Clip Reconstruction, Bypass + Clipping, ?Pipeline Stent

Ruptured Aneurysms Treated at HMC 2005 – 5/2012 (N= 840)

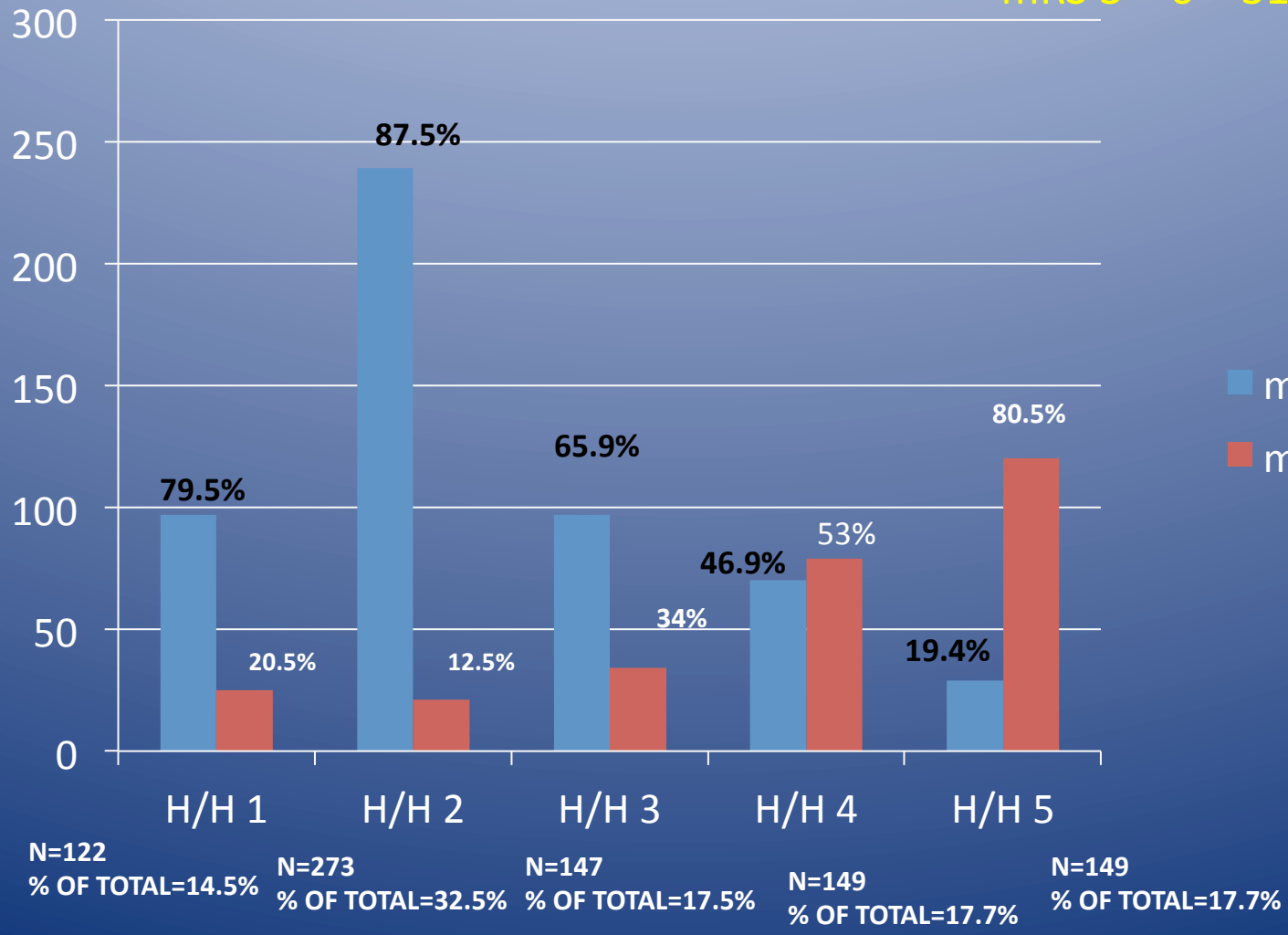


Unruptured Aneurysms Treated at UW – HMC 2005 to 5/2012 (N =454)

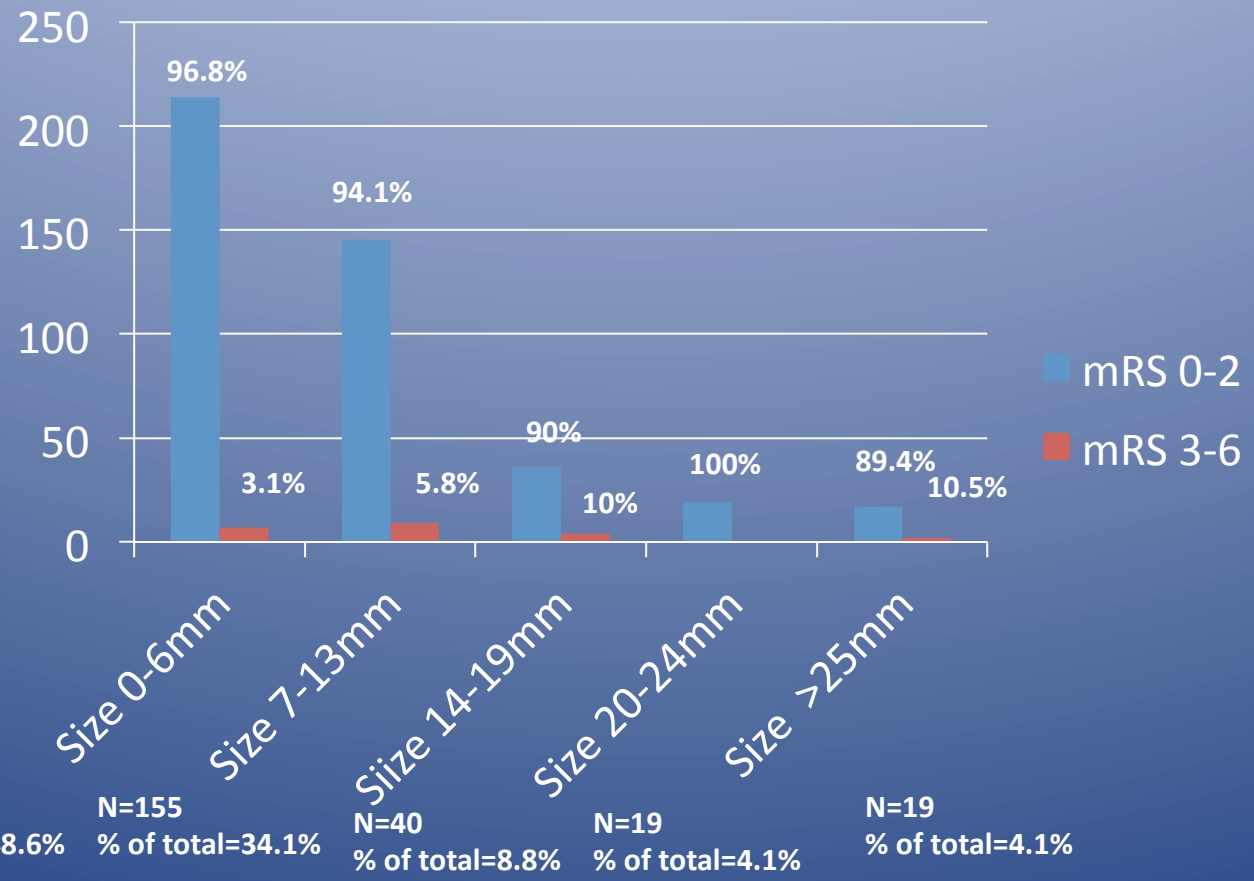


Outcome of ruptured aneurysms based on admission Hunt And Hess grade: Total =840

All Patients: mRS 0 - 2 = 528 (62.8%)
mRS 3 – 6 = 312 (37.1%)



Outcome of Unruptured aneurysms in Relation to size Total patients = 454



Outcome of All Patients at 3 months: mRS 0 - 2 = 429 (94.4%)

mRS 3 – 6 = 27 (5.5%)

No definite Trends noted; Further analysis is needed

Methods of Treating Complex Aneurysms

- Clip Reconstruction
- Bypass with Proximal Occlusion/ Trapping
- Balloon Assisted Coiling
- High Porosity Stent and Coils
- Flow Diversion Stent (+ coils in some cases)

Microsurgical Clip Reconstruction

- Often requires temporary clipping or trapping for ± 15 minutes
- Burst Suppression, Monitoring, and Induced Hypertension (for Unruptured Aneurysms) during Temporary Occlusion
- Aneurysm Neck Calcification, Severe Atherosclerotic Changes, and Excessive Thrombosis May preclude such Clipping
- Preparations must be made for bypass in some cases
- Intraoperative angiography and/or ICG Angio + Doppler is mandatory to check the flow thro all branches
- Intraoperative MEP monitoring may also be used to assist in decisions
- When in doubt, do a bypass procedure

Clip Reconstruction

- Temporary Proximal Occlusion or Trapping
- Careful Dissection of all branches
- Opening of Aneurysm and removal of atheroma, thrombus, etc. may be needed
- Clipping often involves: Fragmentation technique, Tandem Clipping, Encircling Clips, Booster Clips, Nub Clips
- Some part of the neck may need to be left behind in order to preserve a branch or the parent vessel
- In some patients, delayed thrombosis of the arteries may occur
- Aspirin 325 mg. should be administered preoperatively, if Bypass is a possibility

Clip Reconstruction Techniques

- Fragmentation: Aneurysm Neck and Sac are fragmented into different segments
- Tandem Clipping: Addition of Clips in a tandem manner to provide additional closure of the aneurysm, or to preserve arteries
- Encircling Clips: A New Arterial Shape is Created; Or a stronger closing force at the tip of the Aneurysm
- Booster Clips: Providing Additional Closing Force, to eliminate leak thro the Clip into the sac
- Surgeon's Intraoperative Imagination is important

Pros and Cons of Clip Reconstruction

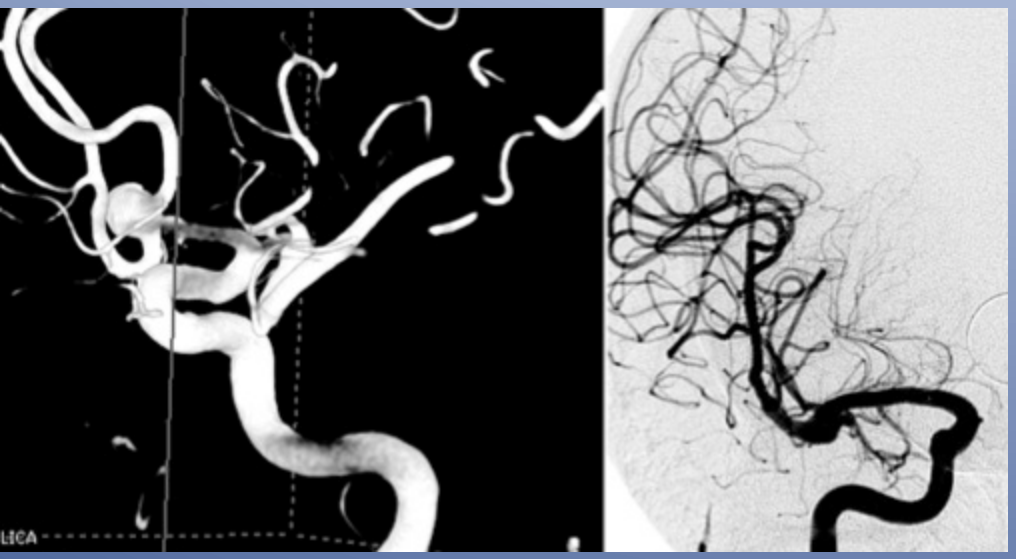
- Pro: Shorter time of temporary Occlusion

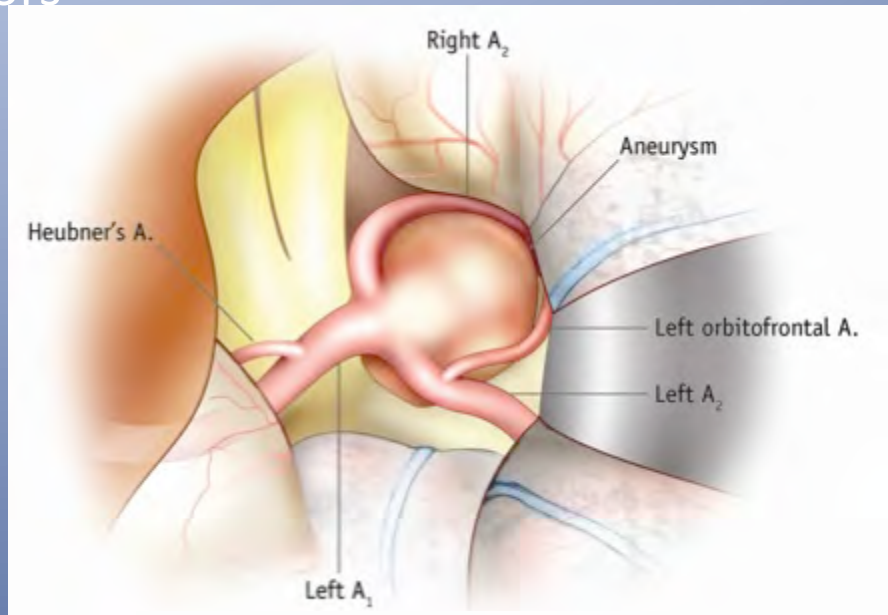
  Less Complicated than Bypass
- Con: Aneurysm May Recur, making the second operation more complex

  Branch may clot in a delayed fashion

  Stenosis of Branch, resulting in Ischemia

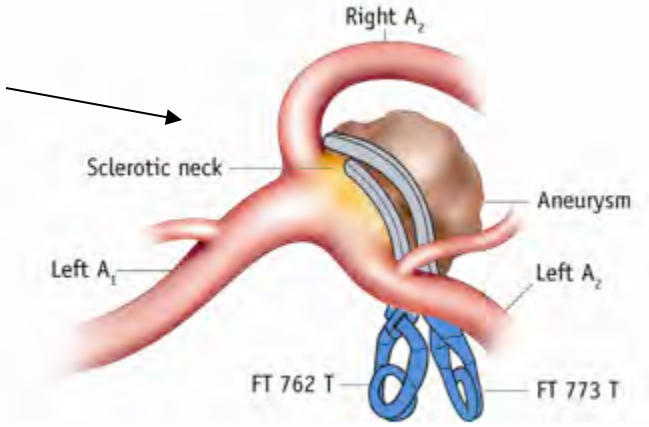
63 F with Unruptured ACOM aneurysm
Atherosclerotic neck, Endoscopy was used to preserve hypothalamic perforators



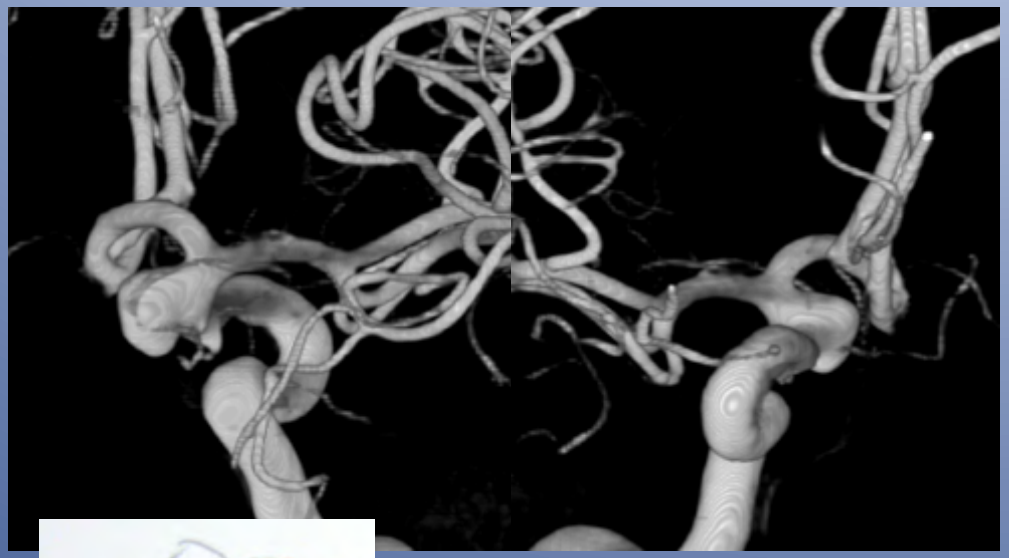


Leaving a portion of neck to save the branch

Patient:
Transient Arm Weakness
Complete recovery

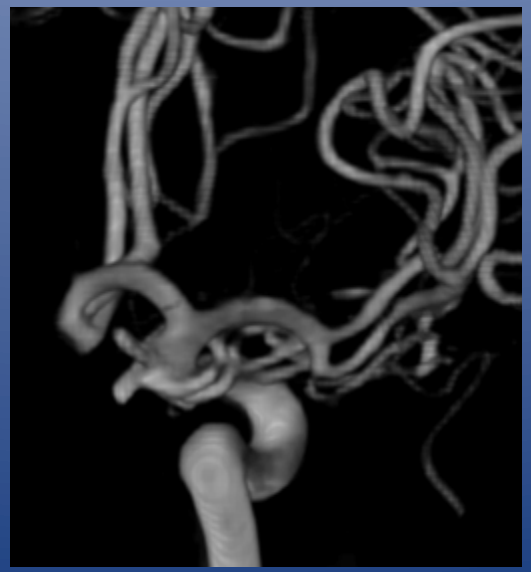


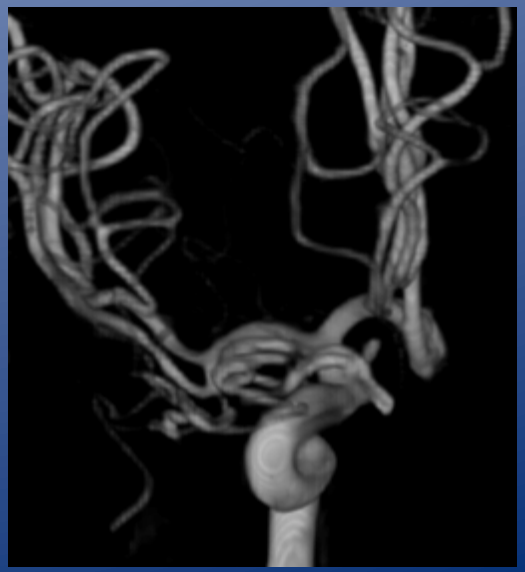
63/F, Unruptured Superior Hypophyseal ICA Aneurysm 8x9 mm, neck 6 mm H3061717



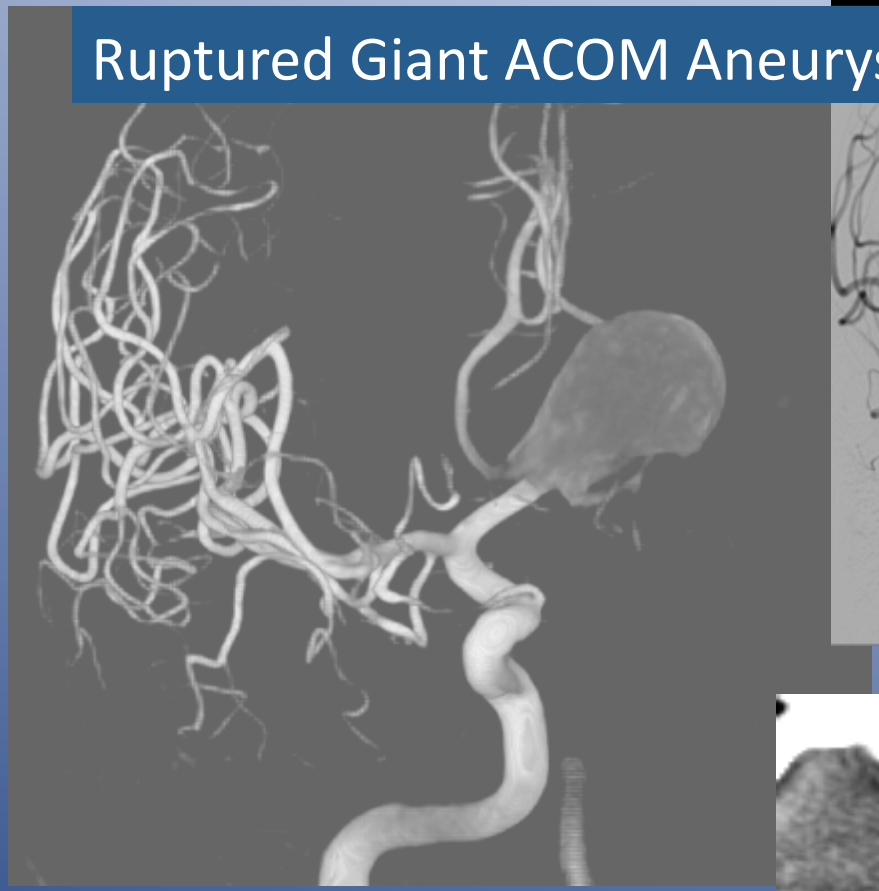
Preparation for Bypass with
SVG Exposure,
Cervical ICA Exposure
Not Used

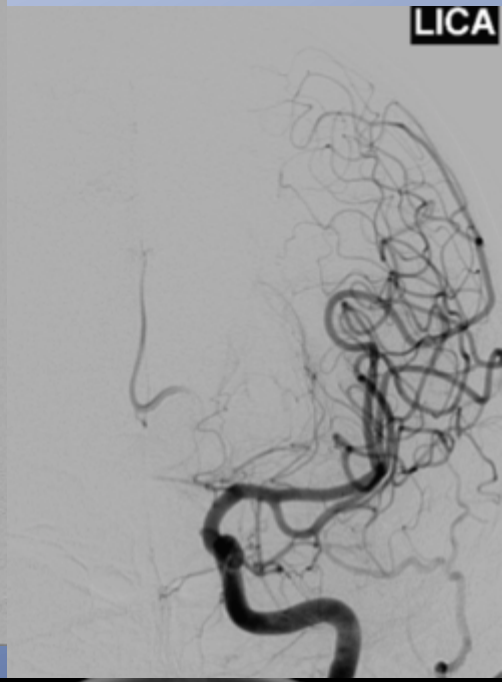
Interlocking Fenestrated Clips
to Reform the Artery

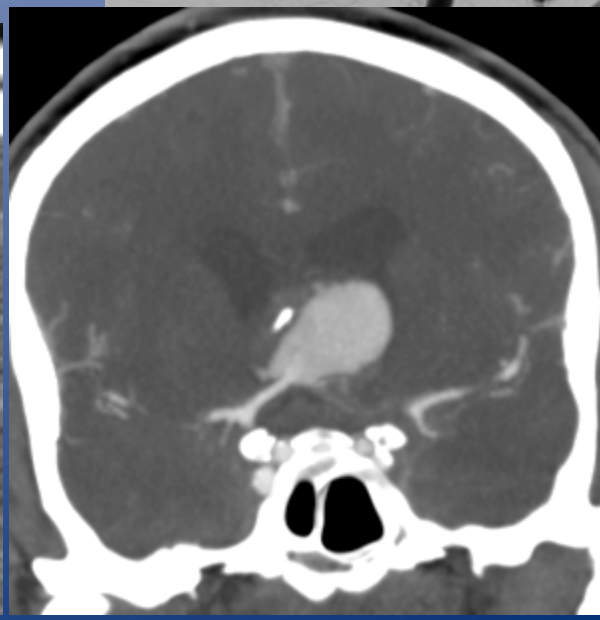




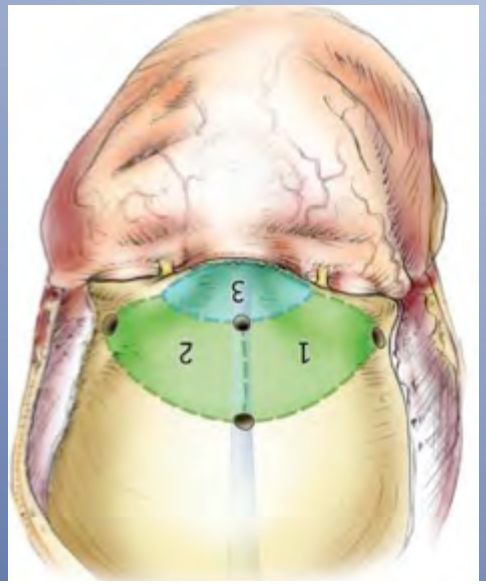
Ruptured Giant ACOM Aneurysm



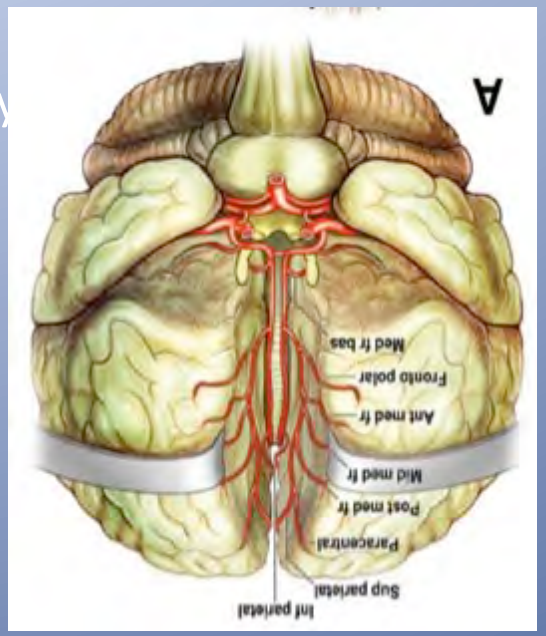


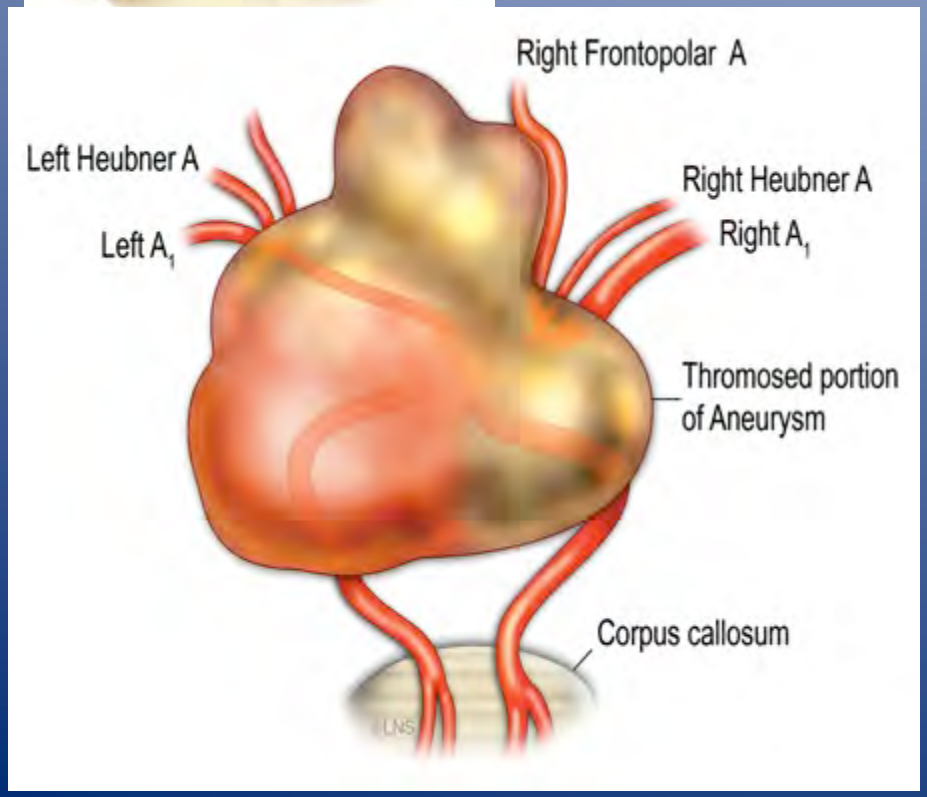


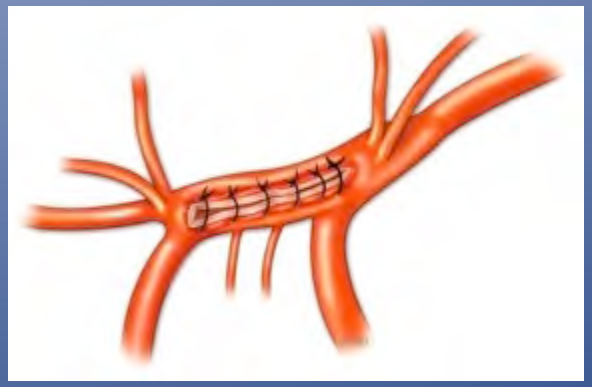
2.8 cm Giant Aneurysm
Partially Calcified
Patient H/H 4, Fisher 3

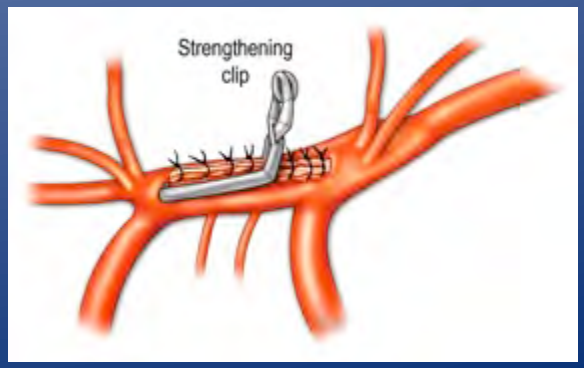


Bifrontal Craniotomy & Orbitotomy
Interhemispheric Approach
Temporary Trapping
Aneurysm Excision
Aneurysmorraphy, & Clipping



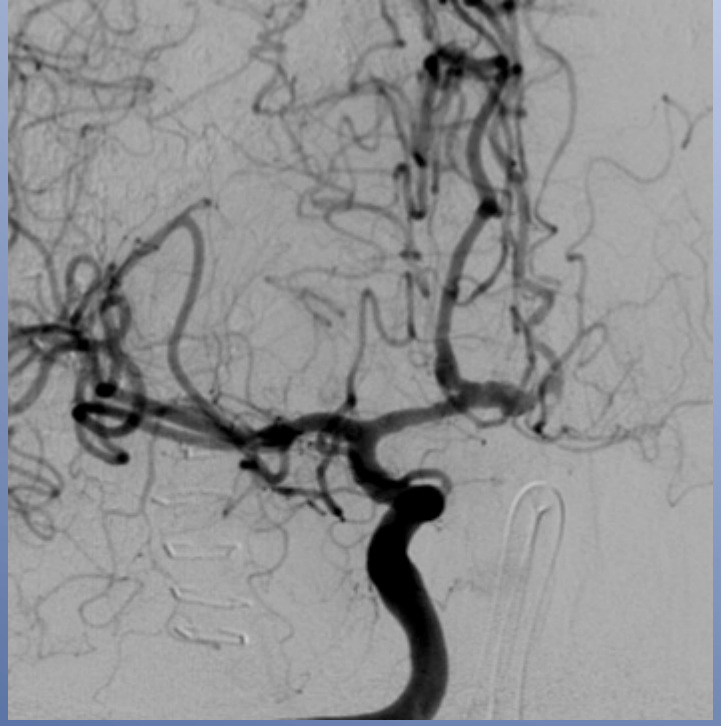






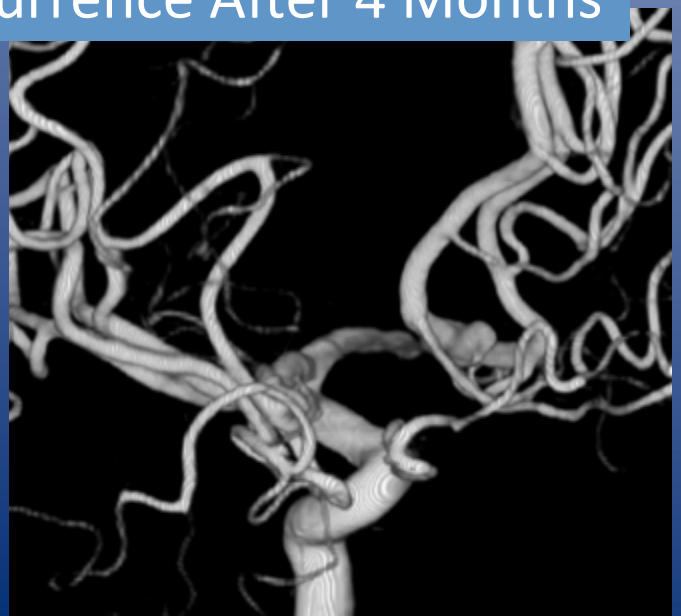
Video 1:

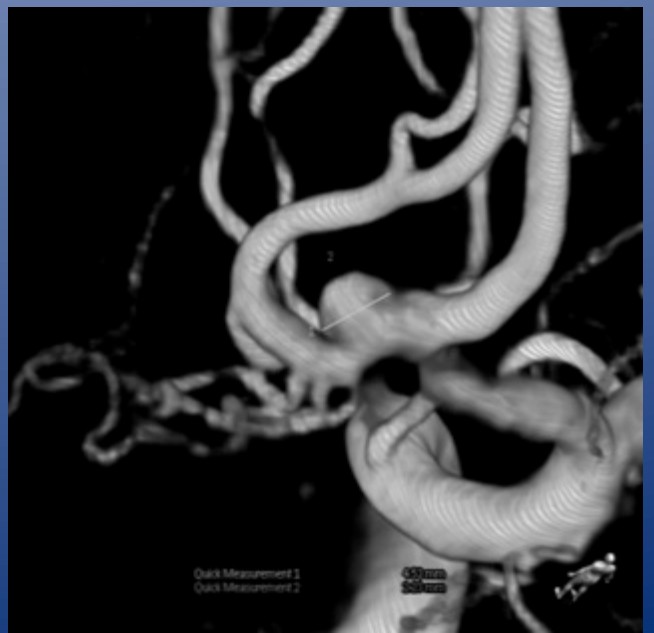

Right Frontotemporal and Bifrontal craniotomy
Orbital osteotomy, Resection and clipping
of Giant ACOM-Aneurysm

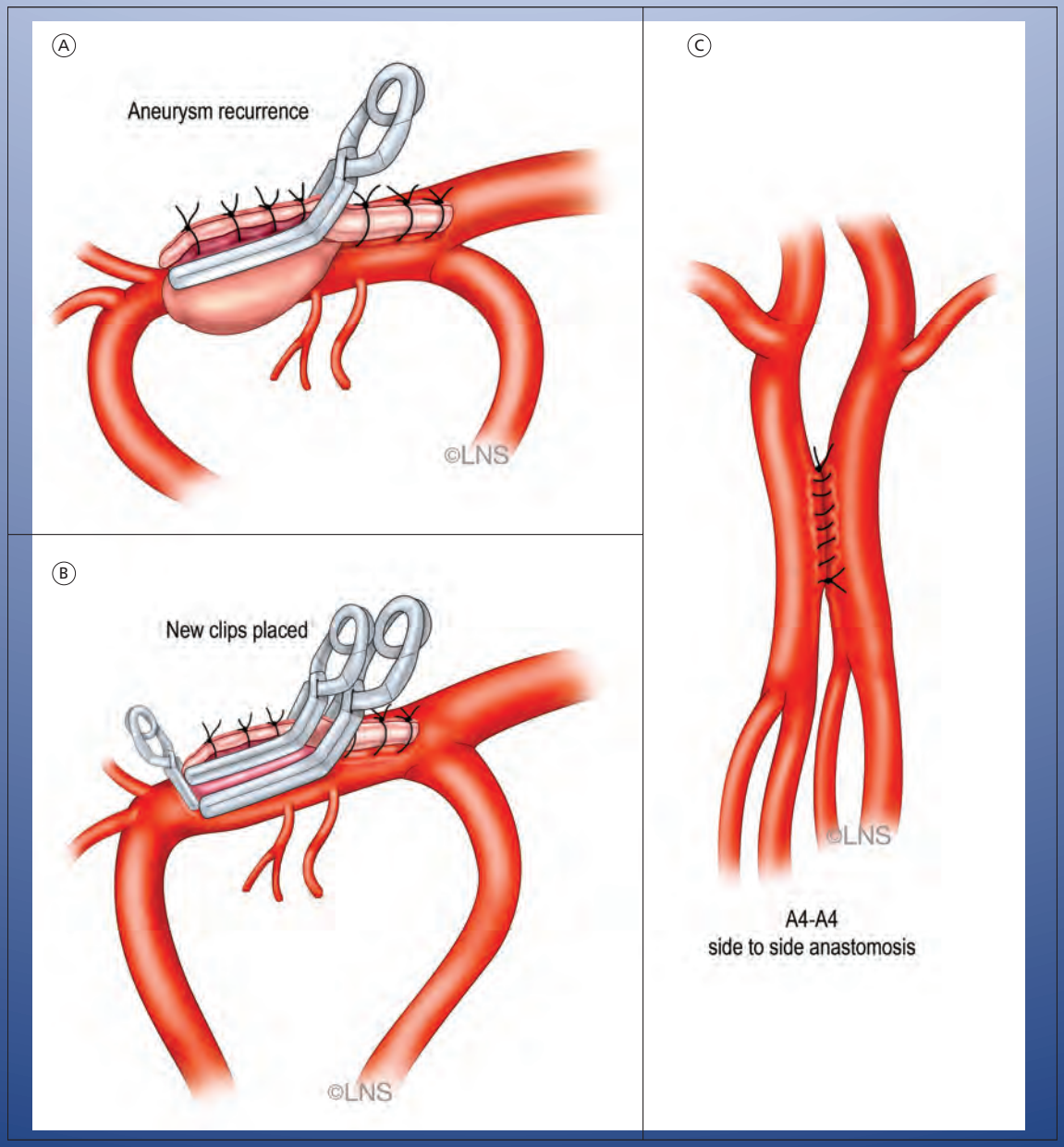


Postoperative Angiograms

Recurrence After 4 Months







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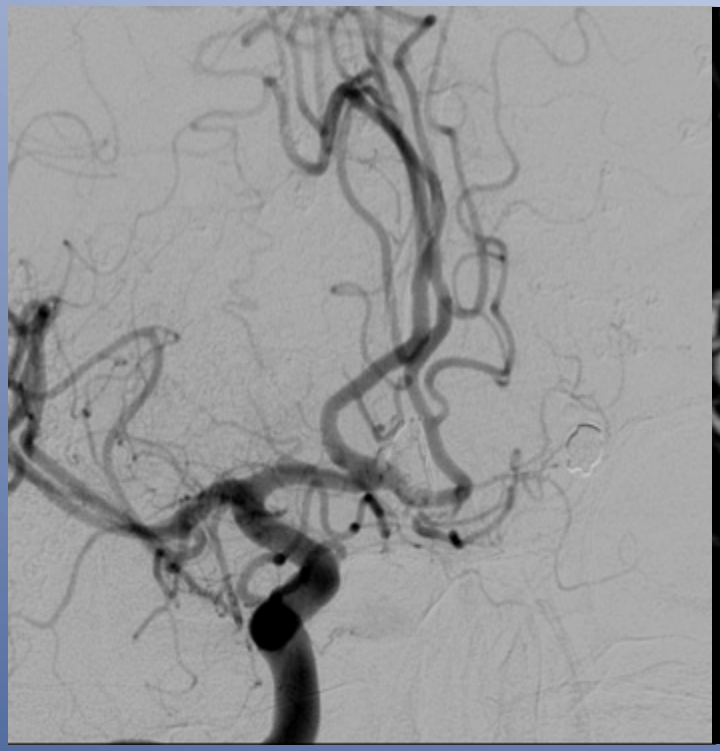
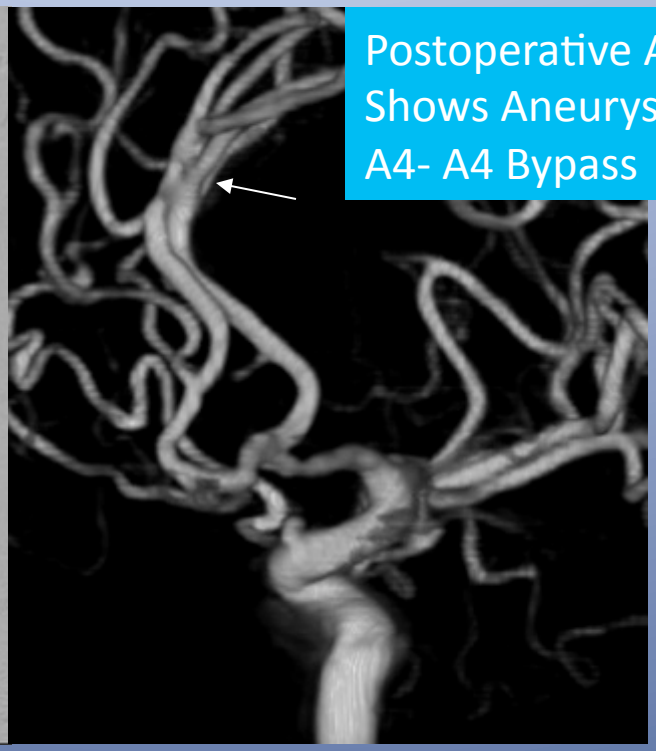
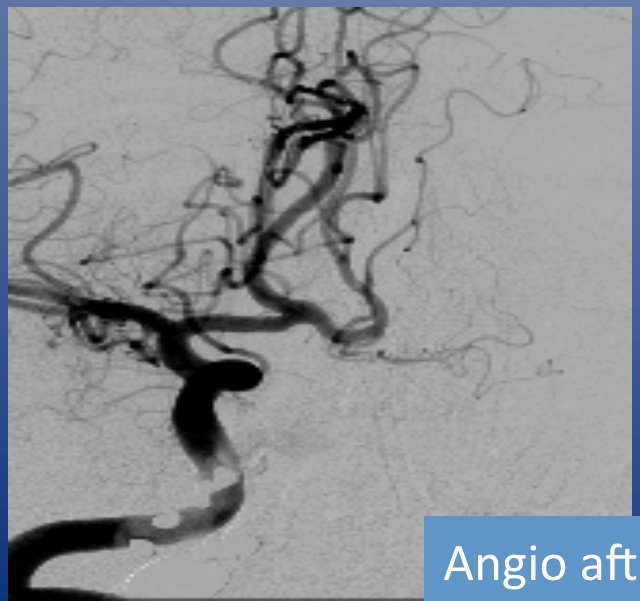
Re explored; Aneurysm Clipped, A4 to A4 Bypass





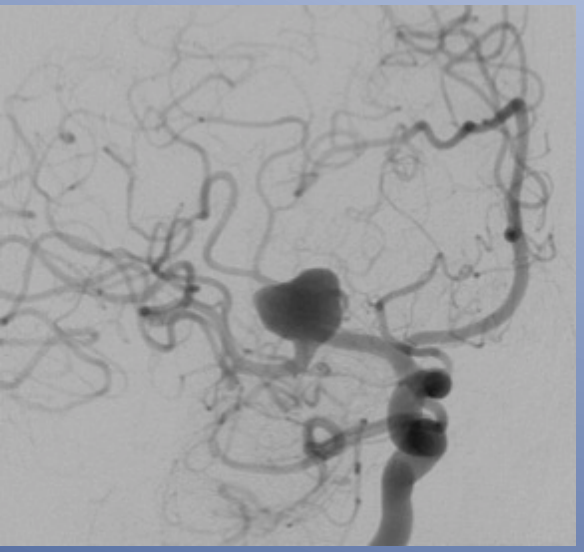
Postoperative Angiogram 11/30/2011
Shows Aneurysm Clipped
A4- A4 Bypass

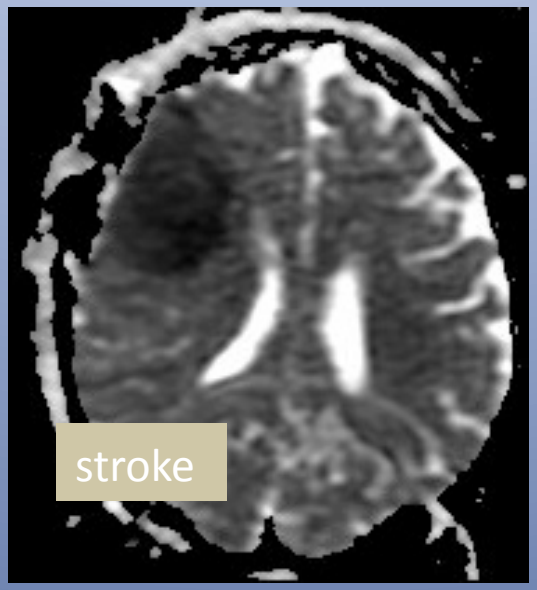
Complete Recovery
No new deficits

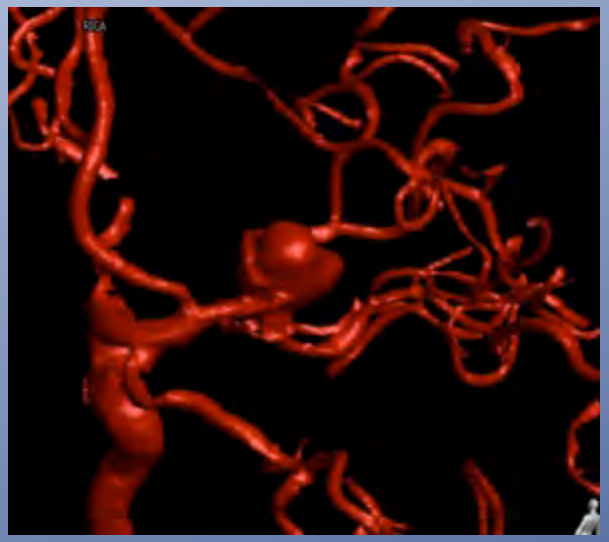


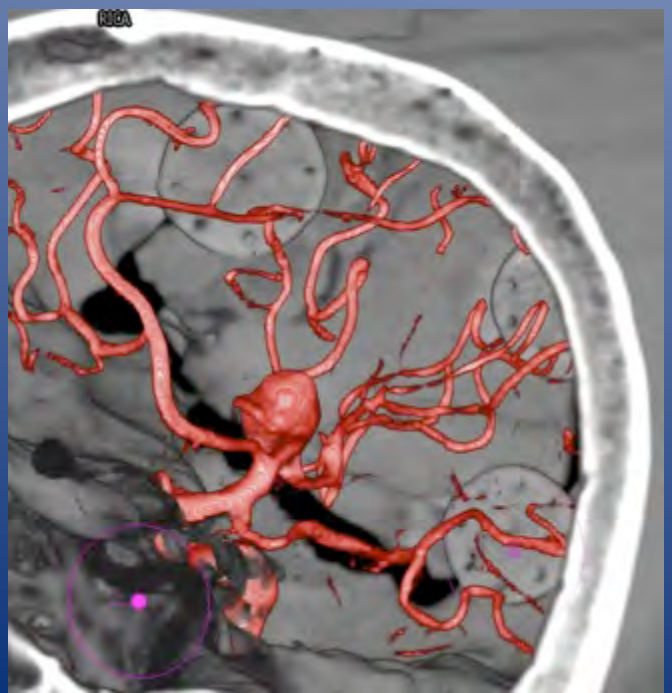
Angio after 1 year; No Recurrence

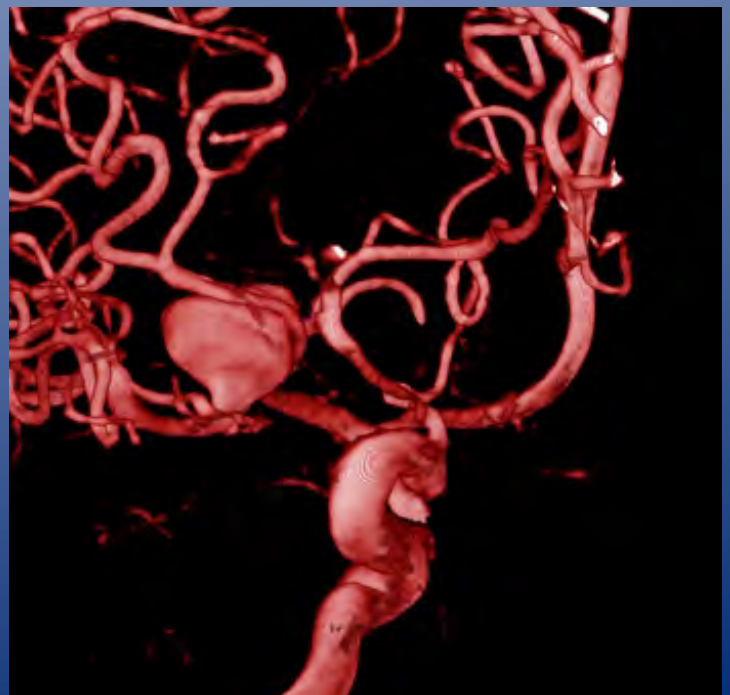
59/f, Sentinel Bleed, Explored and Wrapped, Transferred for further Treatment





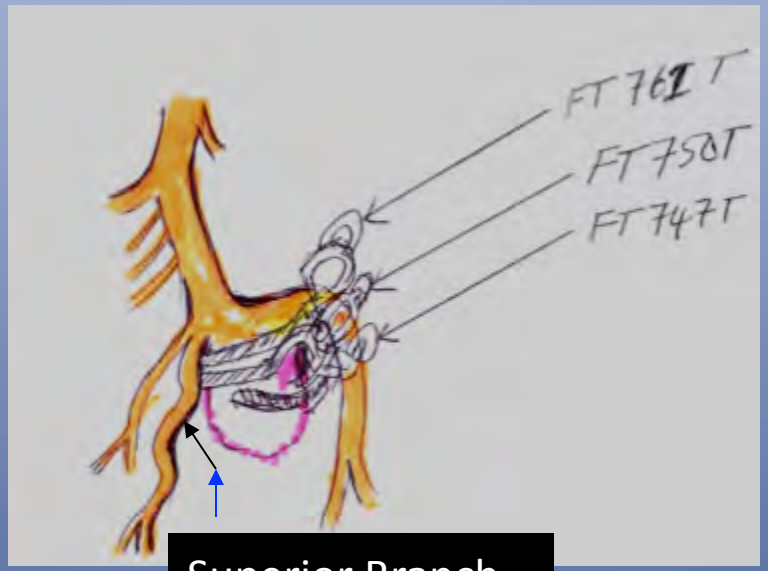


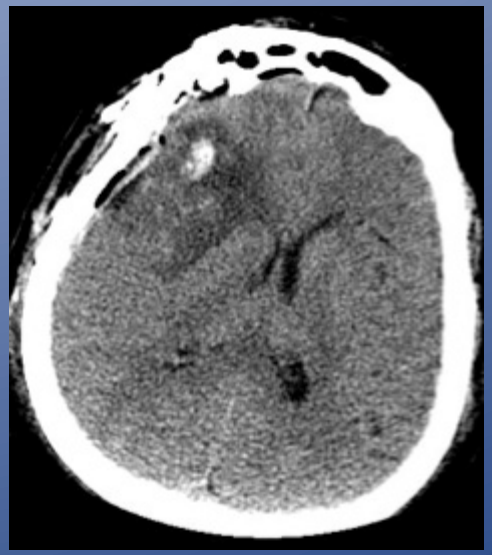




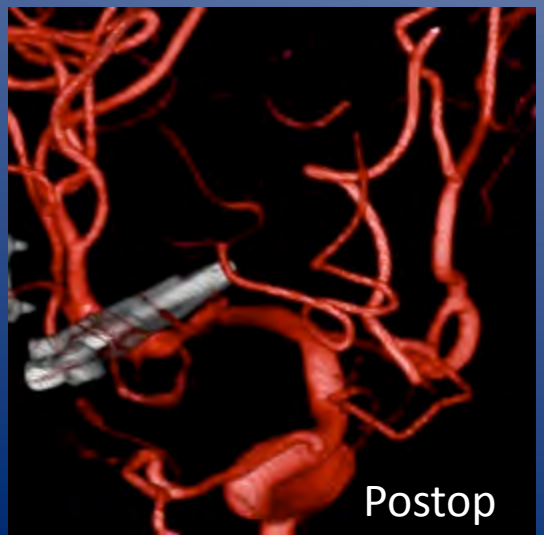
FT – Orbital Approach, RAG Prepared, Clip Reconstruction, Concern About Middle M2 Branch, Side to Side Anastamosis Not Done

Superior Branch Occluded on Postoperative Angiogram Despite Good Flow on ICG Angio



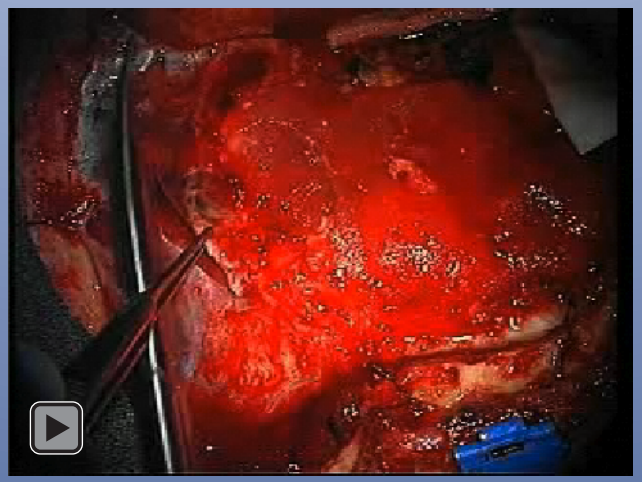


Superior Branch



Patient recovered Independent, but Memory Problems mRS 2

Video 2:



Brain Bypasses For Aneurysms

- Replacement of a Branch or Parent Artery when it cannot be Preserved
- To completely Eliminate the Aneurysm
- To Prevent a Postoperative Stroke
- To Prevent Long Term Complications of Parent Vessel Occlusion :
  - Increased Stroke incidence
  - Increased Incidence of Flow Related Aneurysms
  - Reduced Cerebrovascular Reserve

Bypass with Occlusion vs. Only Occlusion for Major Vessels

- Bypass versus Occlusion?

  Universal (all occluded vessels) vs. Selective (based on flow measurement after test occlusion) Approaches – I prefer the universal approach

Ref : Sekhar LN, Patel SJ: Permanent occlusion of the internal carotid artery during skull - base and vascular surgery: is it really safe, an editorial. *The American Journal of Otology* 14 (5):421 - 22, 1993.

- In Cases of Unplanned Arterial Occlusion, the safest choice is to Revascularize, even if there is no change in monitoring parameters

Bypasses and Reconstruction For Aneurysms

- Replacement of :1)Parent vessel
  2)Branch vessel
  3)Both Parent and Branch, or 2 Branches

- Types of Bypass : a) Local Bypass
  Side to side Anastomosis
  Interposition Graft
  Direct resuture
  Patch Graft

  b) Extra Intracranial Bypass

  Low Flow (STA-MCA, OC-PICA, OC-SCA)

  High Flow (RAG, SVG)

What Type of Bypass?

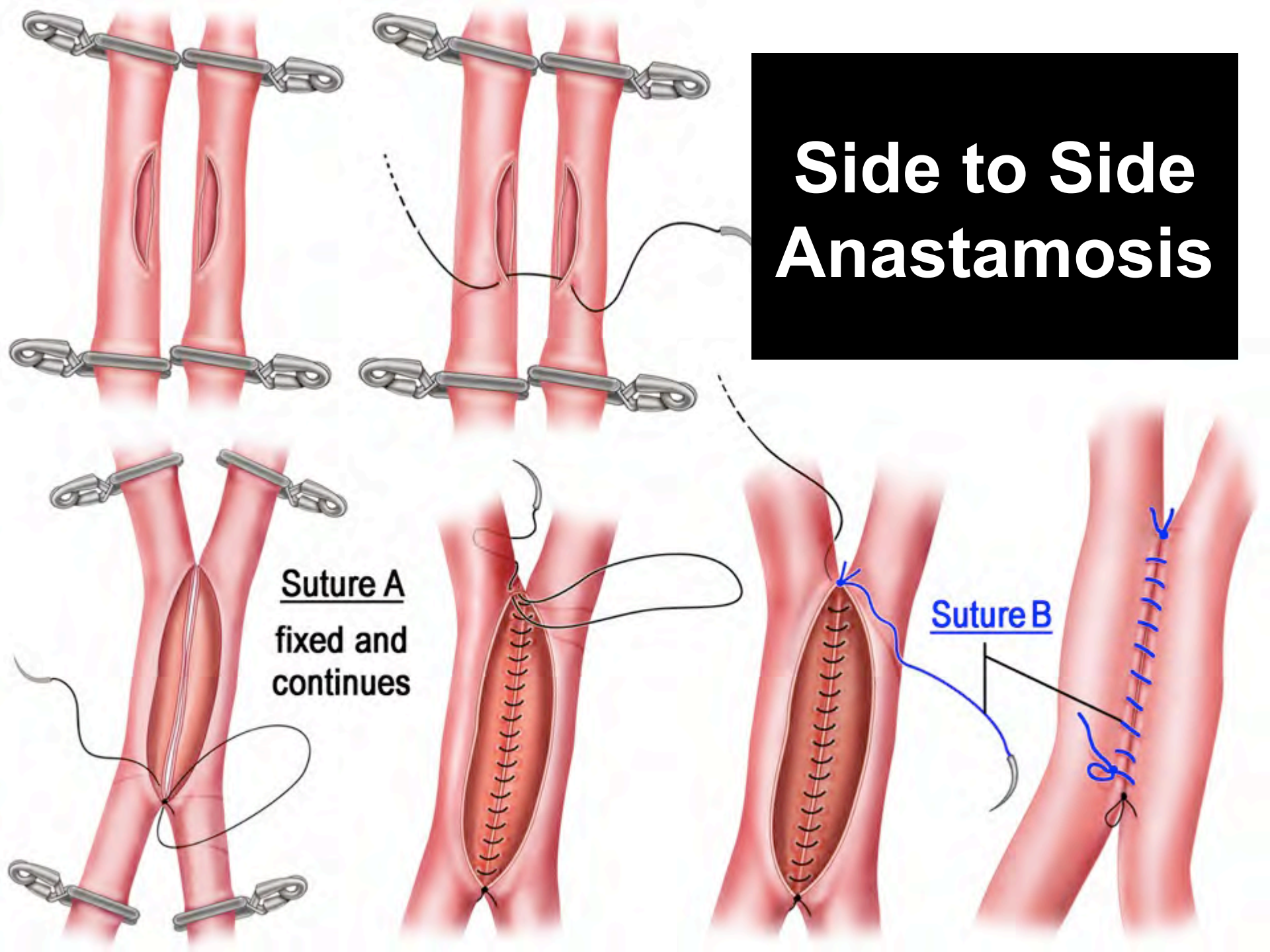
- If a "Local bypass" is adequate, it is preferred to an EC –IC Bypass, but the price of failure is higher (two vessels at risk)…..
- Collateral Circulation: Poor collaterals require a High Flow Bypass
  Charbel makes decisions based on preoperative NOVA, and Intraoperative Doppler Flow Measurements
- Size of the Vessel : the vessel implanted should be the same size to about twice larger size
- Availability of Donor Vessel: Radial Artery, Saphenous Vein,
  large STA, etc.
- An unplanned arterial occlusion is better managed by an in situ bypass, when it is possible

Anesthesia and Brain Protection During Bypass Procedures

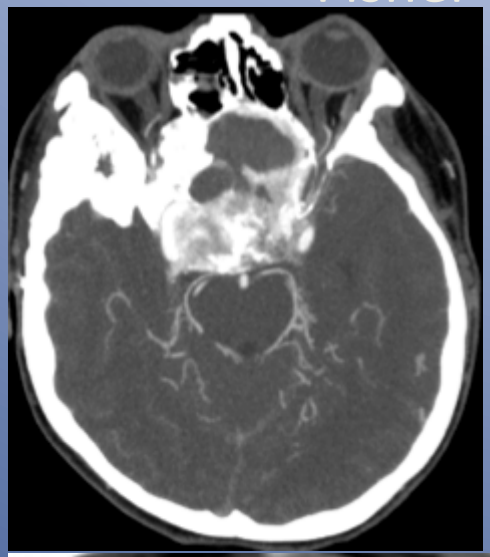
- Anesthesia for Bypass Procedures Requires a Higher Level of Skill than Standard Neurosurgical Anesthesia
- Balanced Total Intravenous Anesthesia
- Monitoring of SEPs, MEPs, and EEG
- During temporary occlusion, BP raised 20% for unruptured aneurysms, kept normal for ruptured aneurysms
- Propofol induced “burst suppression”
- If MEP or SEP changes during temporary occlusion, Raise BP further, or Release temporary clip for a short time (if possible)
- Preoperative and Postoperative ASA 325 mg p.o
- During Bypass, Heparin 2500 units, ACT >250

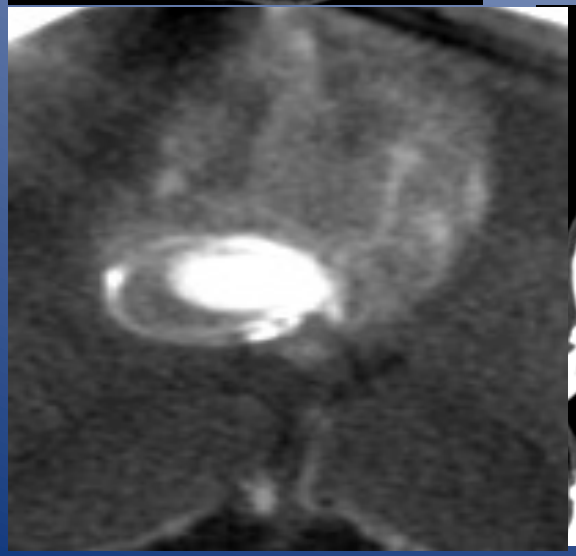
Local Bypasses

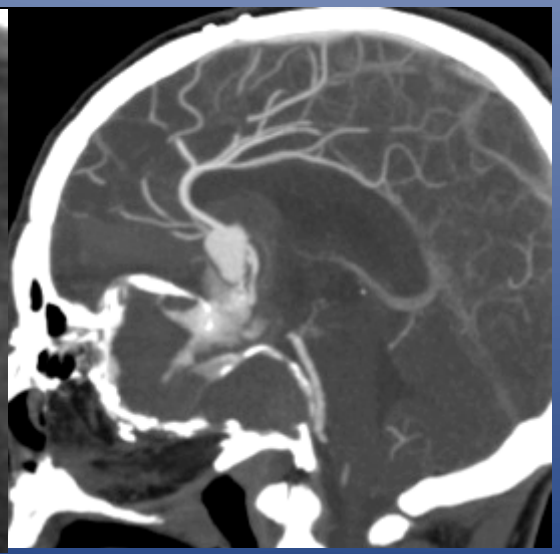
Side to Side Anastamosis



26/F, Prior Fibrous Dysplasia Operation, SAH, Rebleed, HH3, Fisher 4, Giant A2 Aneurysm H3079358

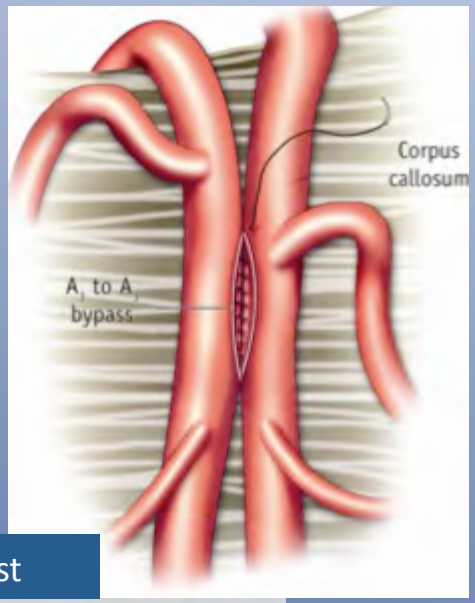






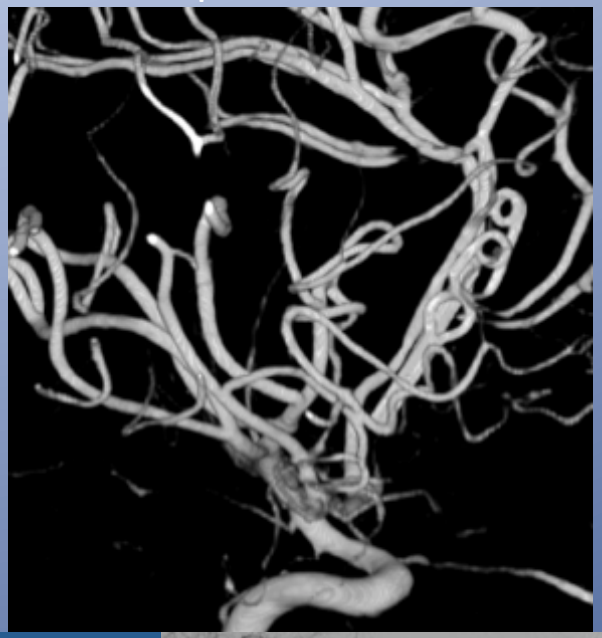
Aneurysm almost Fusiform, Clip Reconstruction failed

Interhemispheric & Pterional Approach



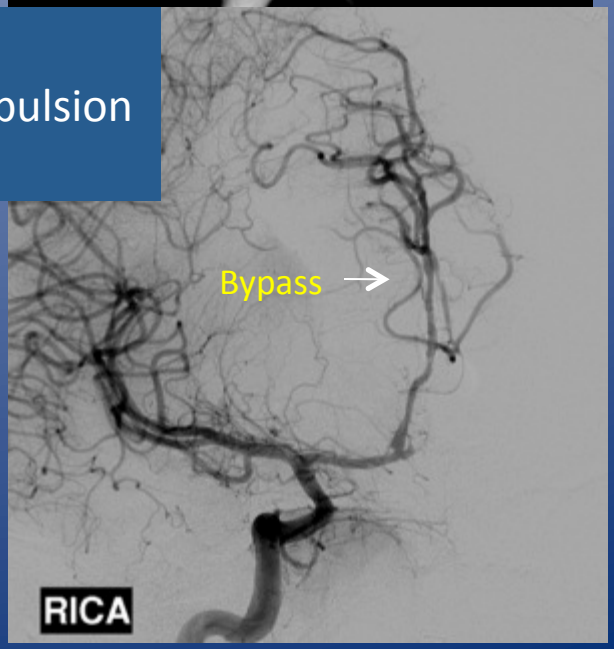
A3 to A3 Bypass First

Postoperative

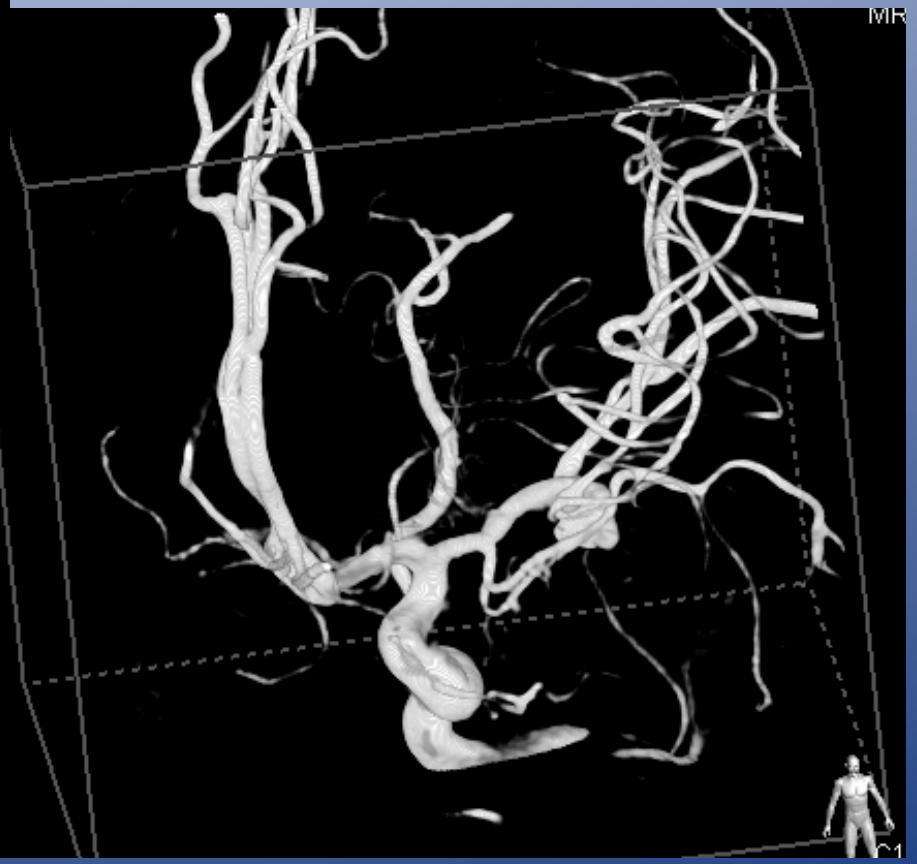


Intraoperative Rupture

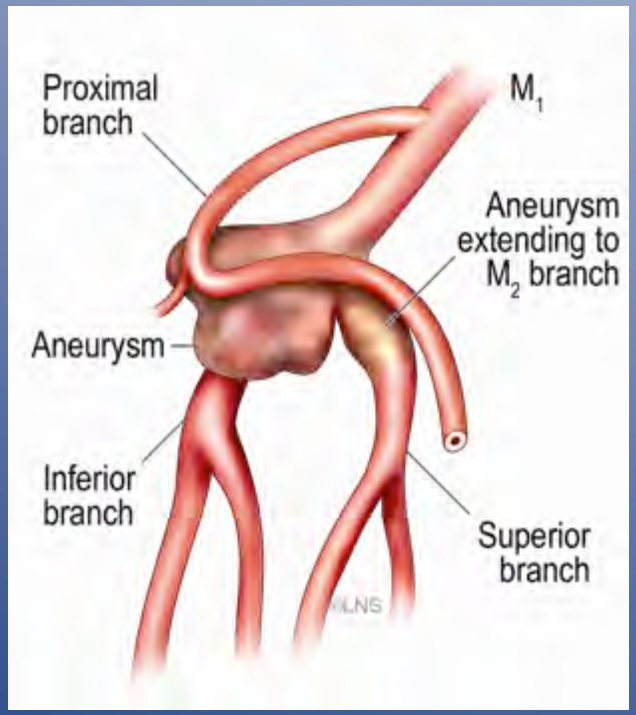
Good Recovery after
Intra aortic Balloon Counterpulsion
for Vasospasm Treatment

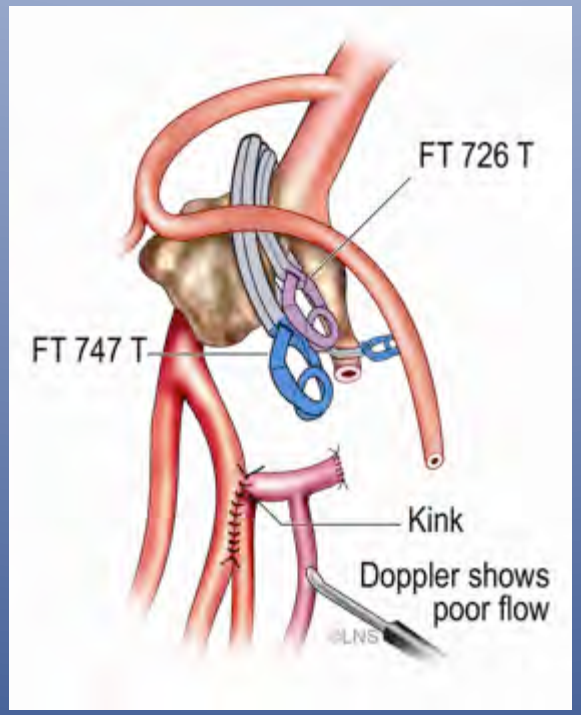


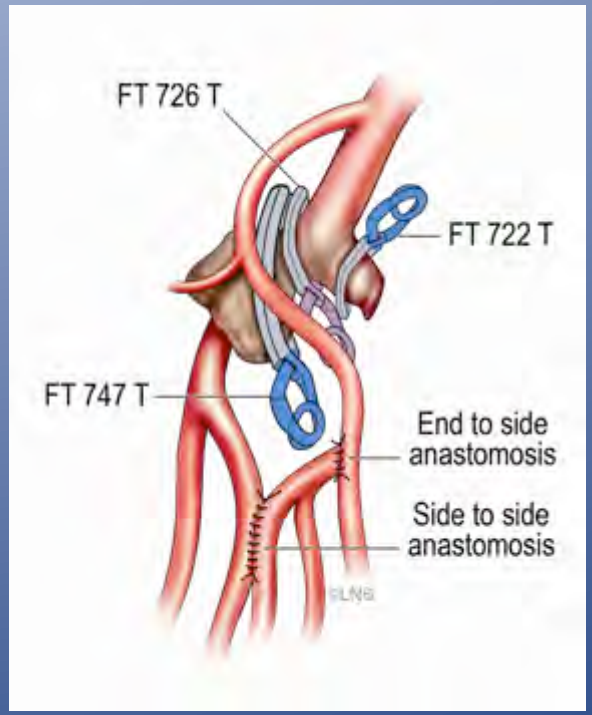
39/Woman, SAH H/H 3
? Drug Use
Possible Rebleed



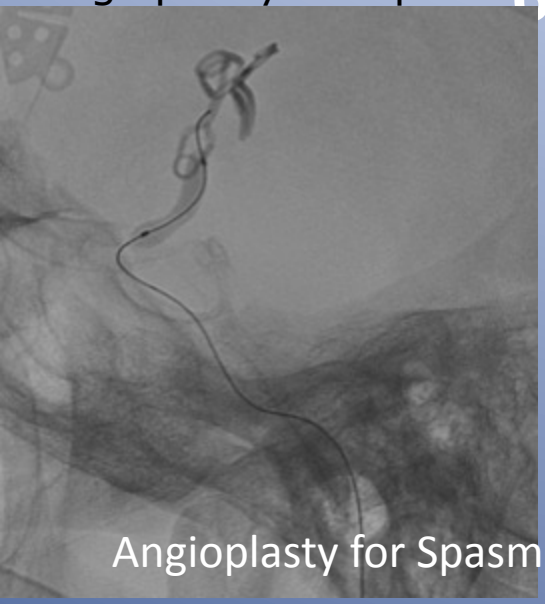
Microsurgical clipping; MCA M2 branch end to side anastomosis
Anastomosis caused kinking, and micro Doppler flows were inadequate;
So, an additional reimplant was done from M1 to anterior temporal branch



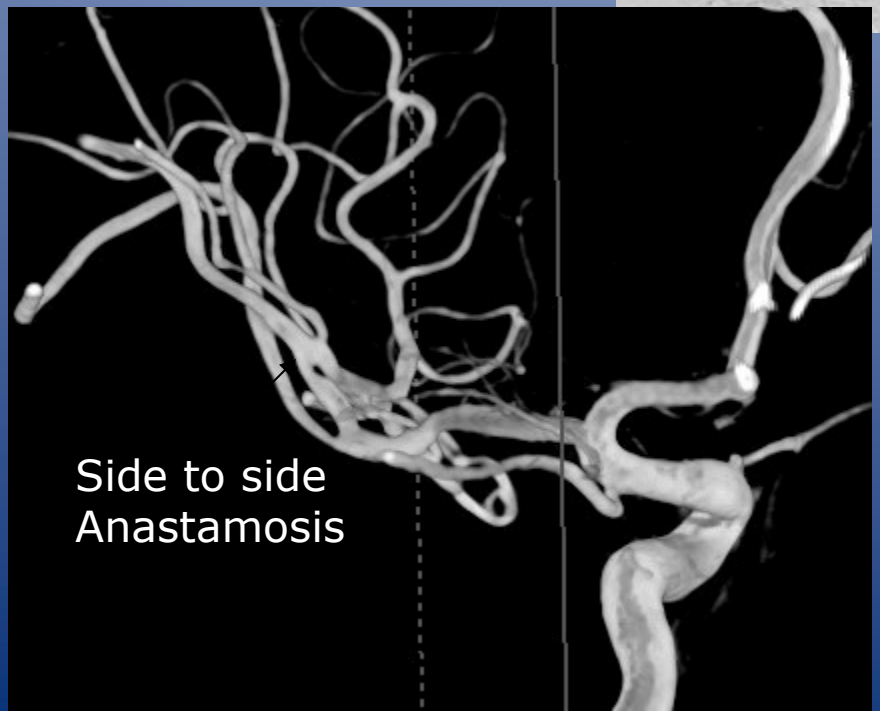




Postoperative Course-
Angioplasty for spasm M1

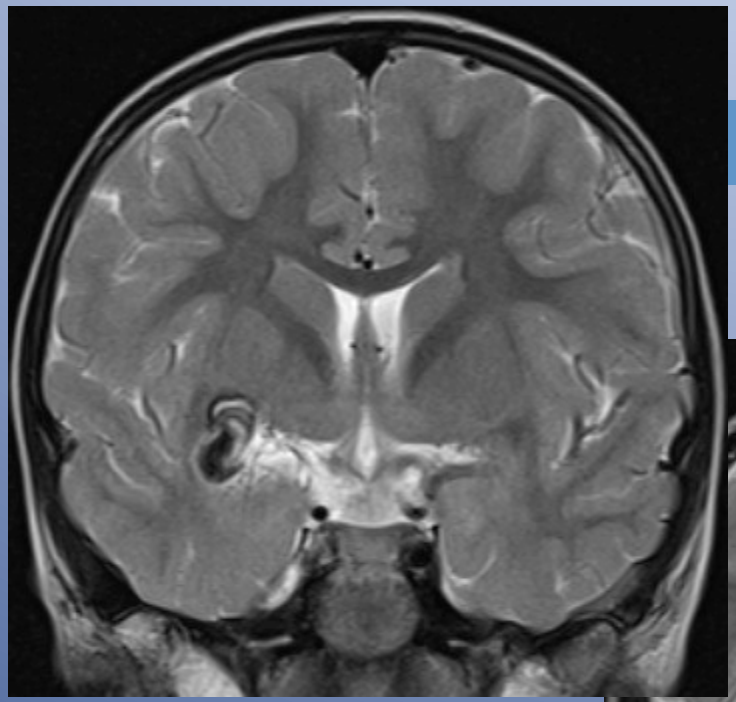


3 month Follow Up: Completely recovered, mRS

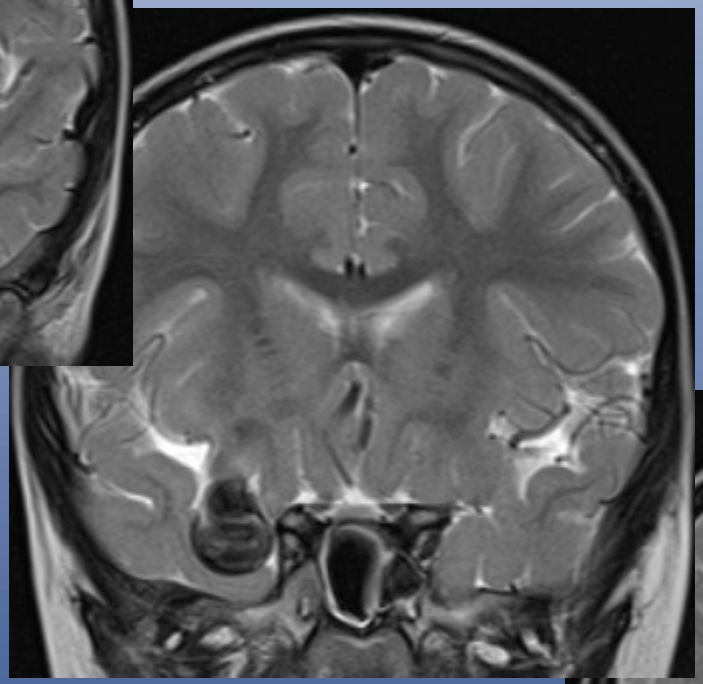


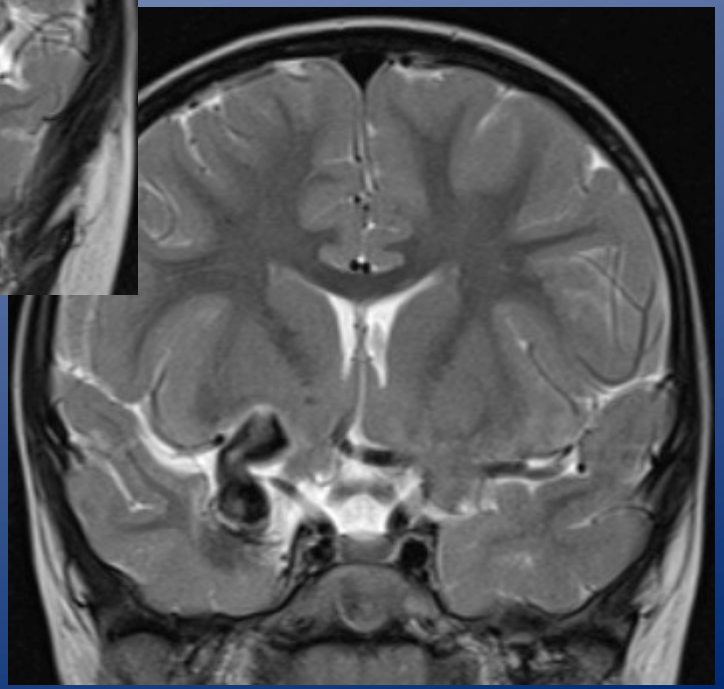
Interposition Graft Technique

- A variety of vessels may be used- (e.g.) STA, Superior thyroid or lingual A. , Radial A., Saphenous Vein etc.
- Interposition is done when the gap is more than 1 cm and the vessels cannot be approximated without tension
- Interposed graft should be slightly longer than the gap
- End to end Anastamosis, with fish mouthing of one side

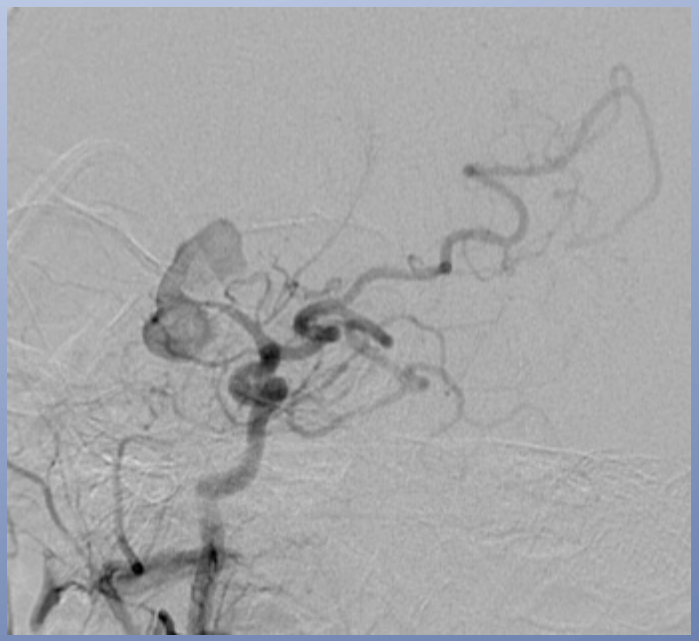


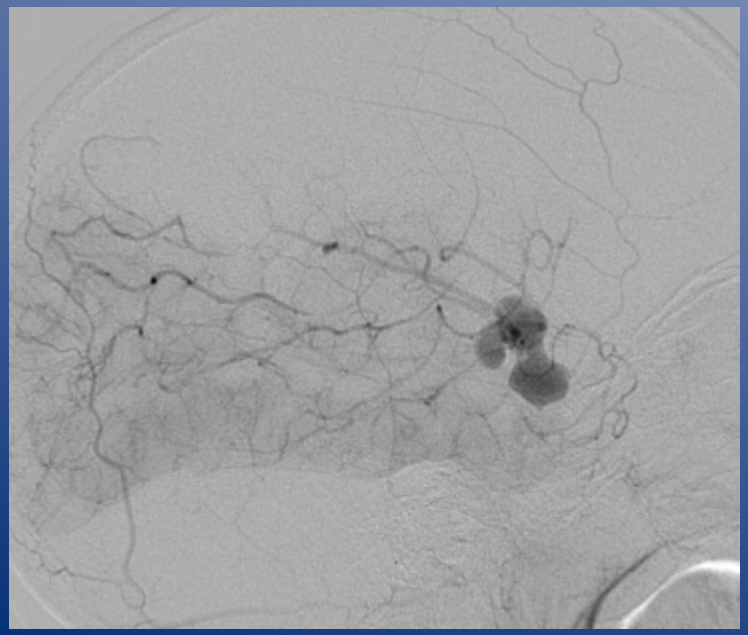
4 yr/ Girl, with Episodes of Severe Headaches x 2

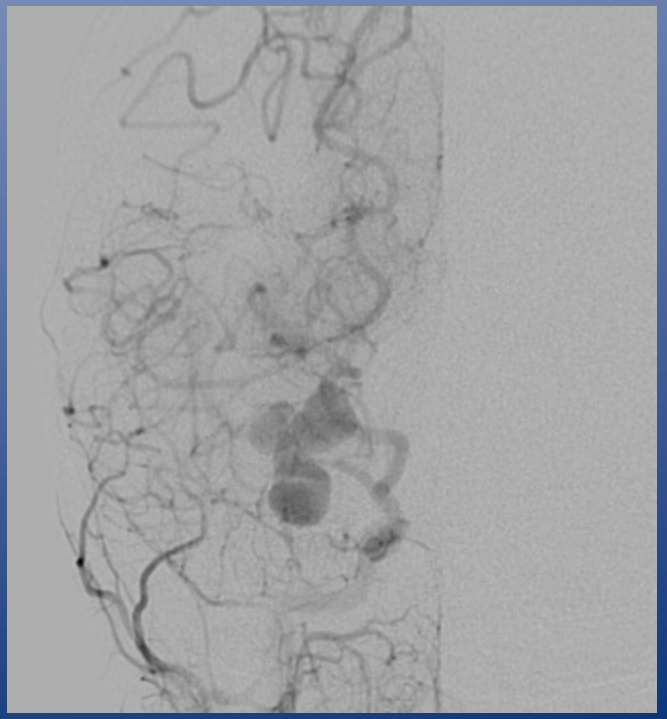


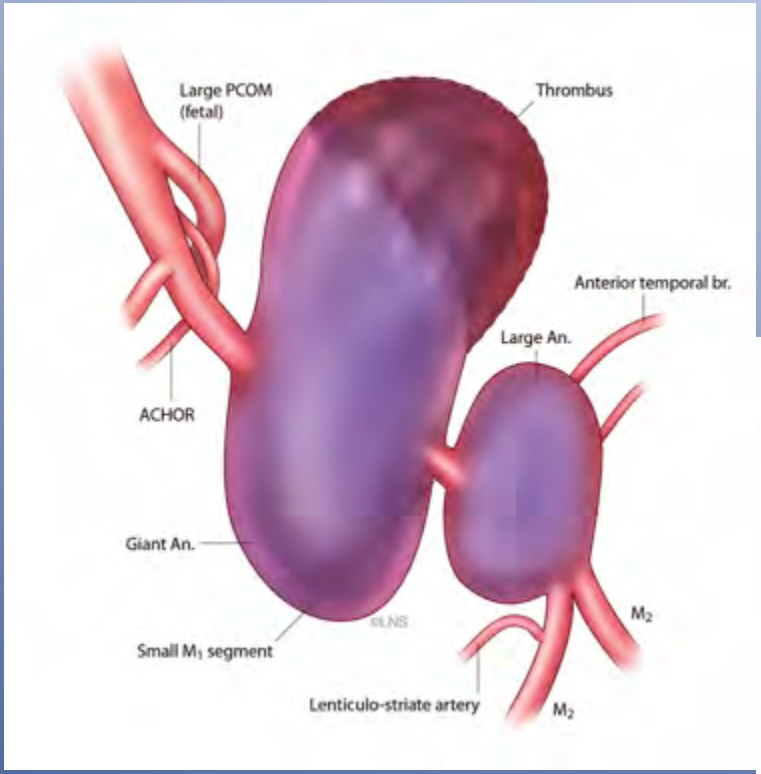


Large and Giant M1 Aneurysms
Sentinel Bleeds

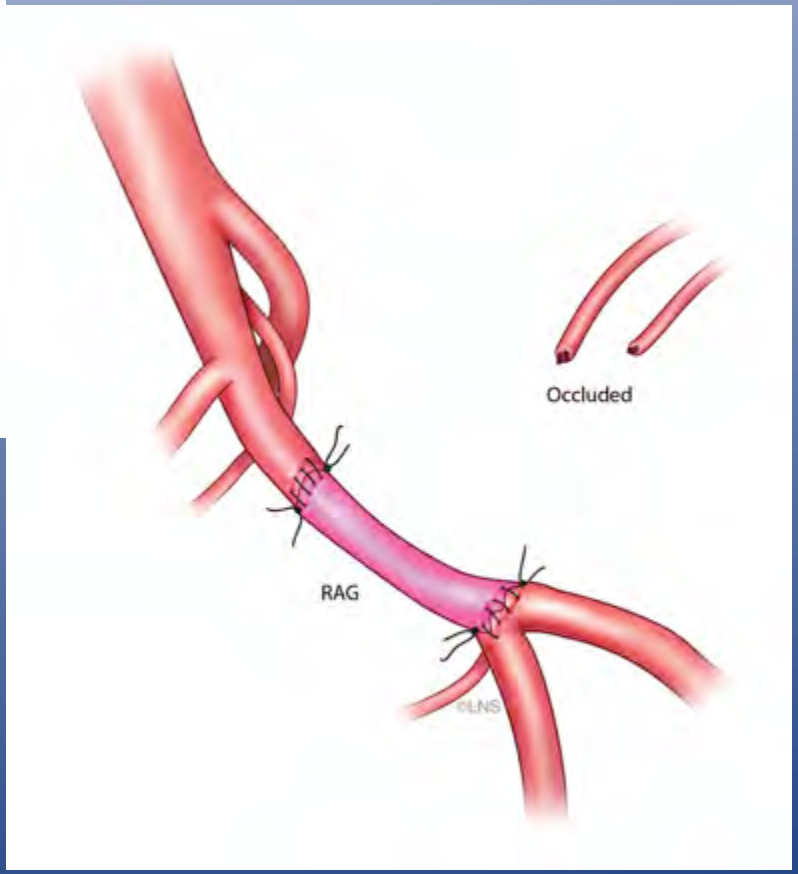




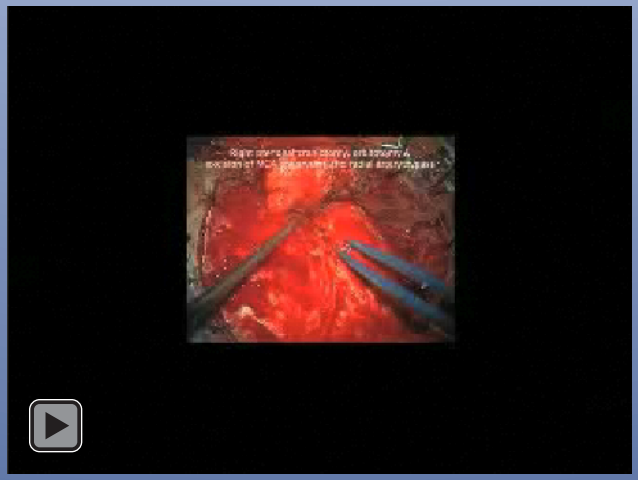


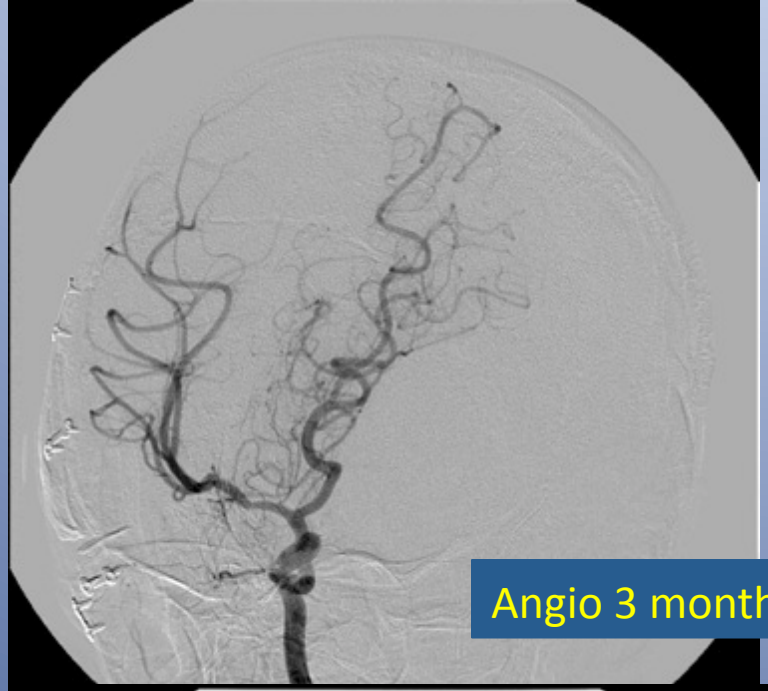


Frontotemporal Craniotomy
Orbitotomy
Aneurysms Resected
RAG Interposition Graft
Radial Artery repaired with SVG



Video 3:





Angio 3 months

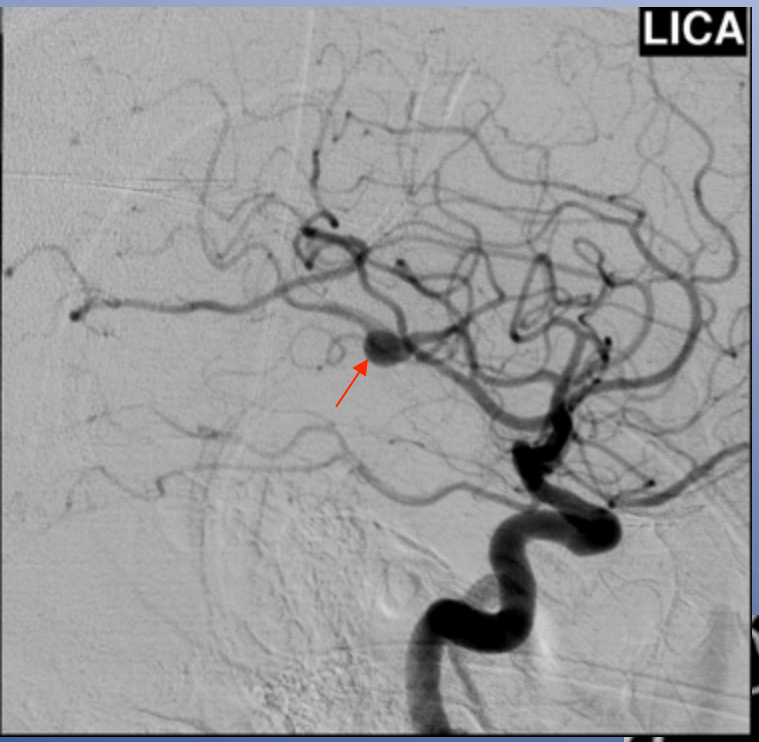
6 months Postoperative

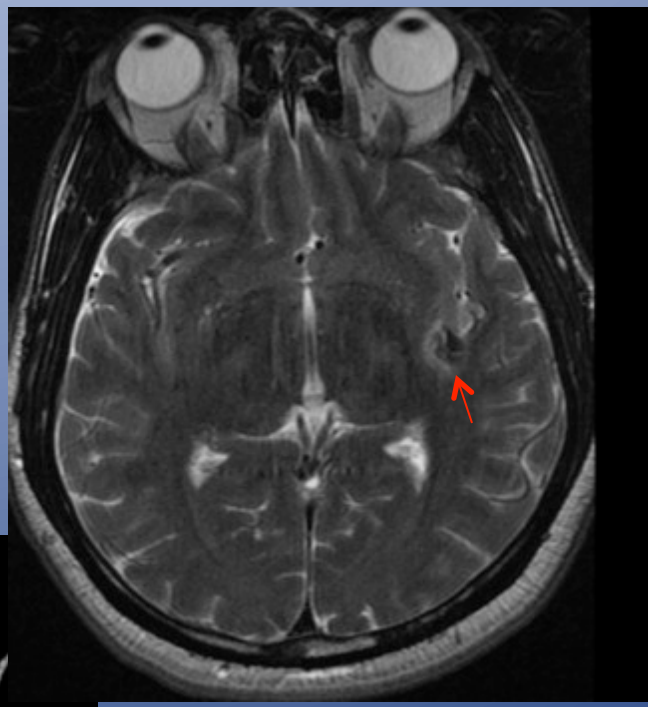
STA- MCA Bypass

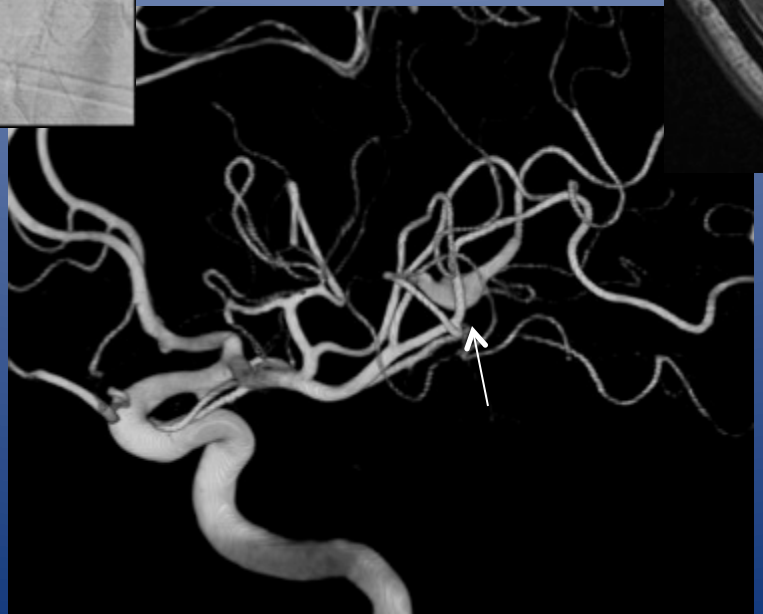
- Useful, particularly for M3, M4 aneurysms
- A large STA to MCA bypass can replace the ICA, if other collateral are present
- The STA is dissected thro a regular craniotomy incision, which allows the harvesting of both frontal and parietal branches , if needed
- It is anastomosed to the largest MCA vessel possible (usually M3 or M2 branch)
- Caution: Bypass may not be adequate to prevent a stroke

  Spasm of the artery or compression due to brain swelling may have devastating consequences

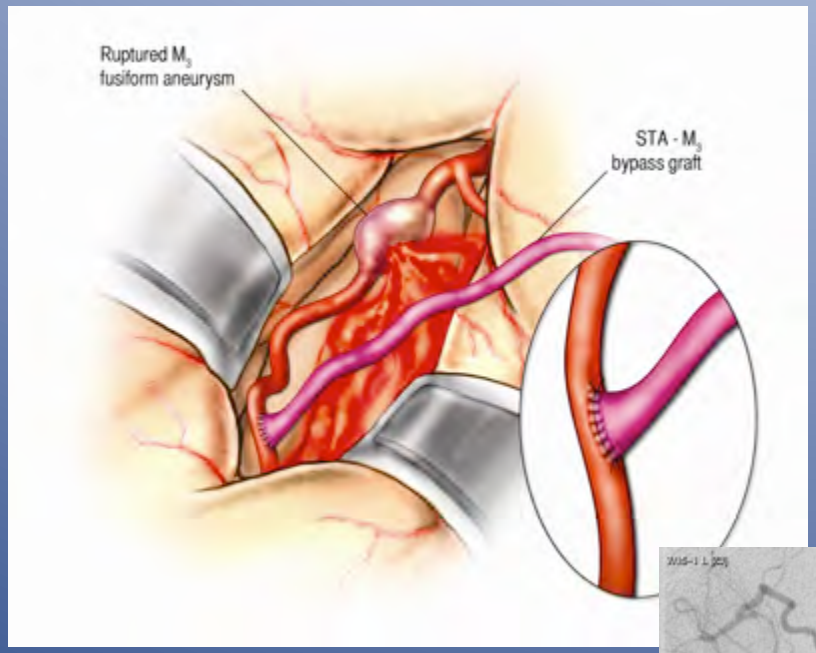
37 yo male presented with severe head ache and seizures due to SAH- ruptured aneurysm

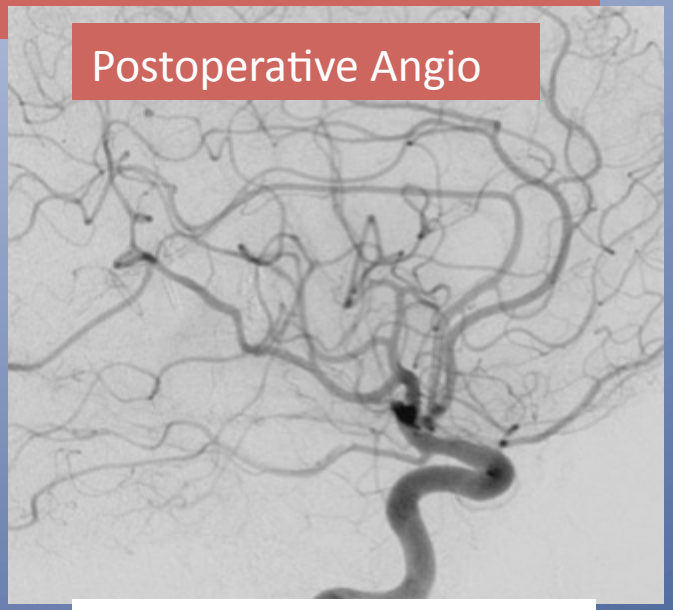


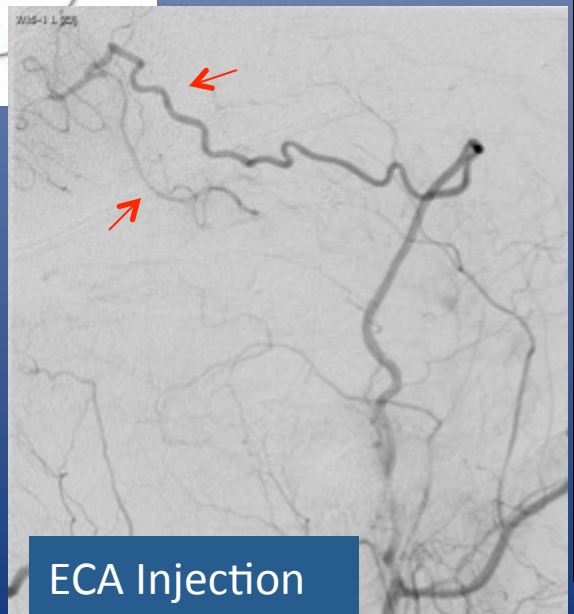




STA to M4 Bypass and Aneurysm Resection

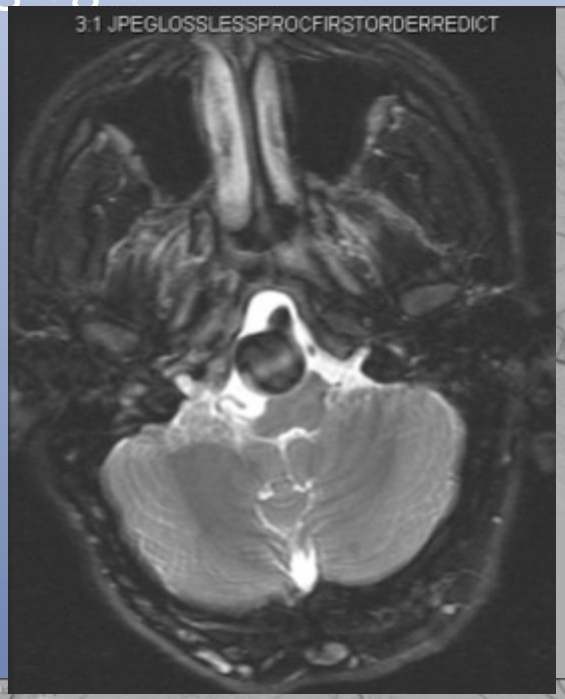


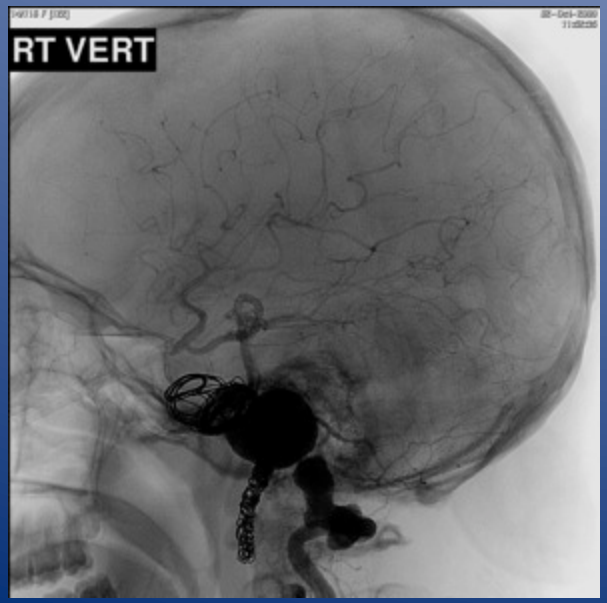


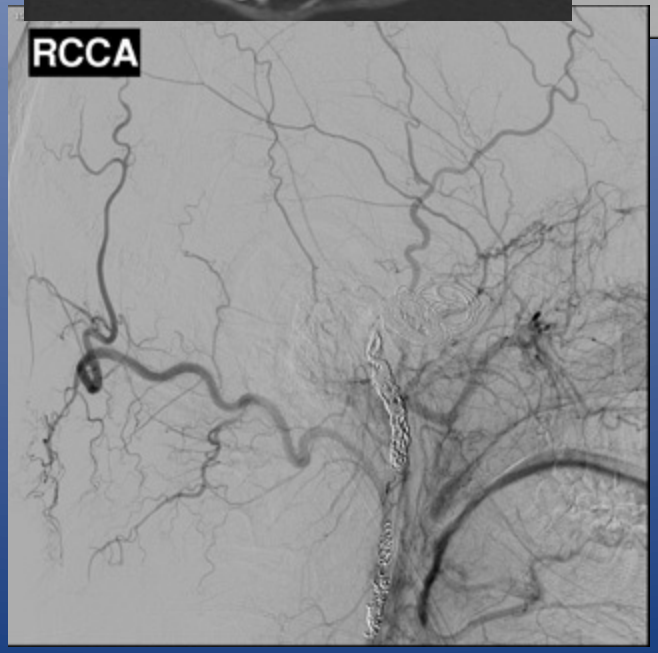


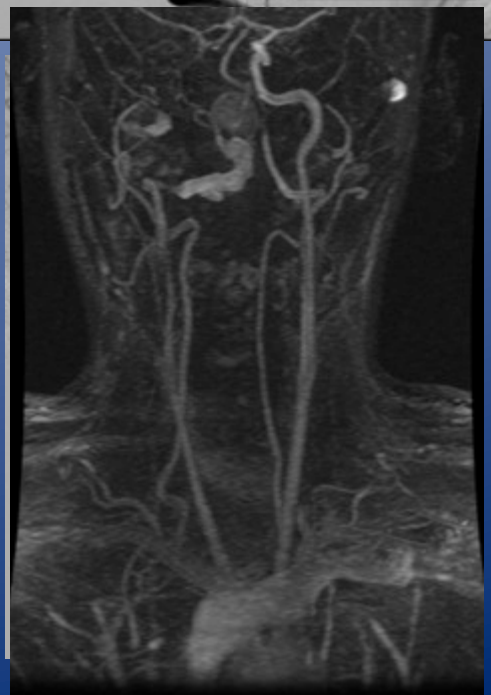
21 yr old patient presented for evaluation of fusiform aneurysm of vertebral artery. Had previously coil obliterated dissecting ICA aneurysm 9 years ago

Pre operative MRI AND Angiograms

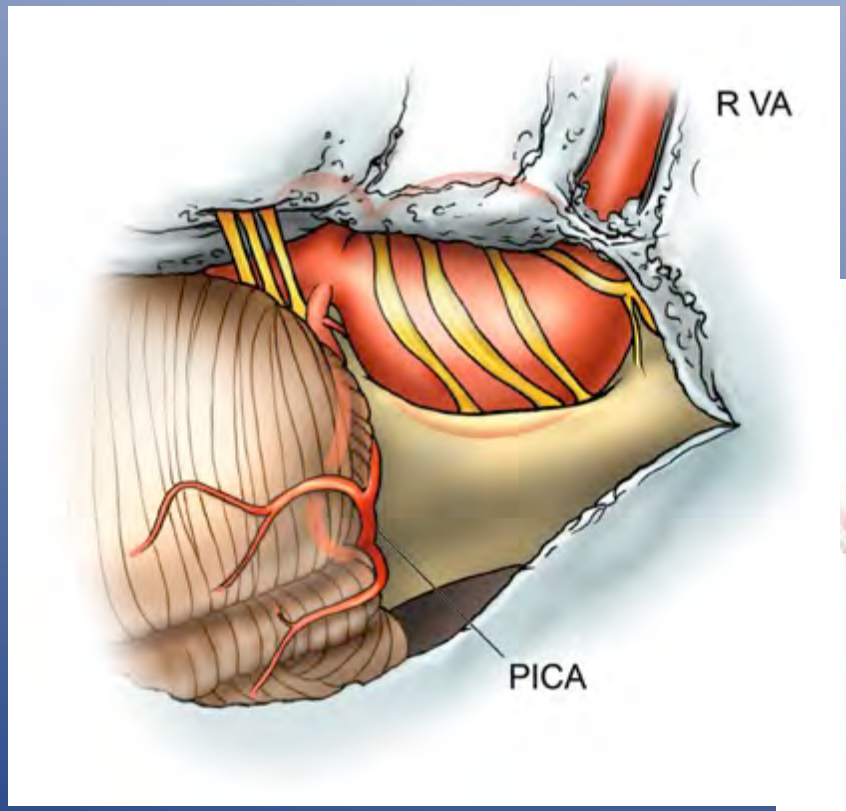


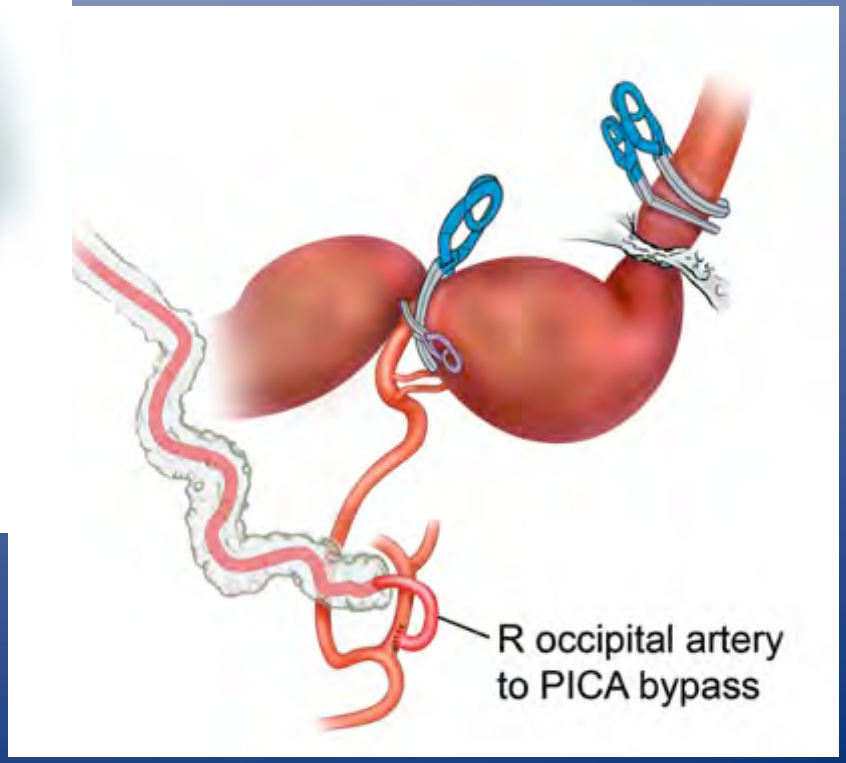






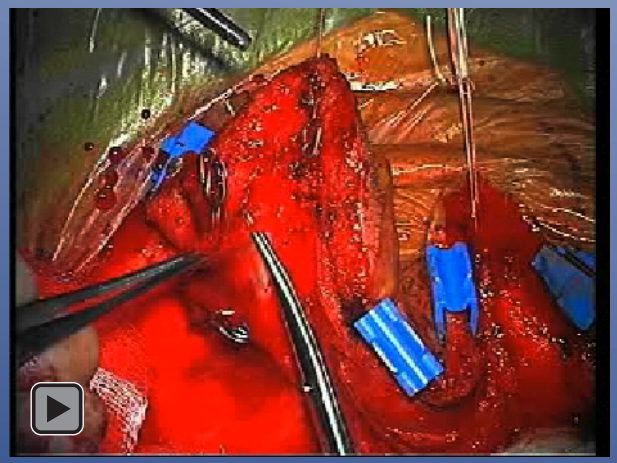
Far lateral approach, OC-PICA anastomosis Proximal Occlusion, and Clipping of Aneurysm



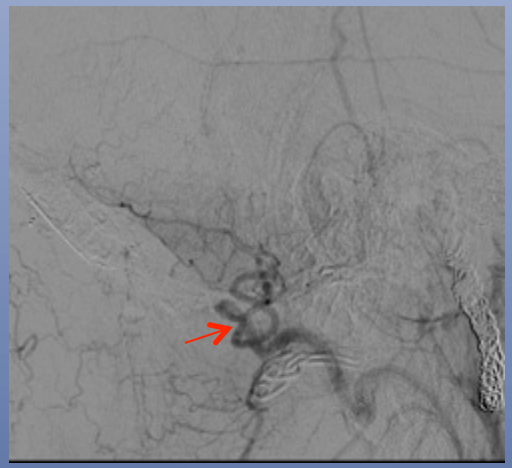


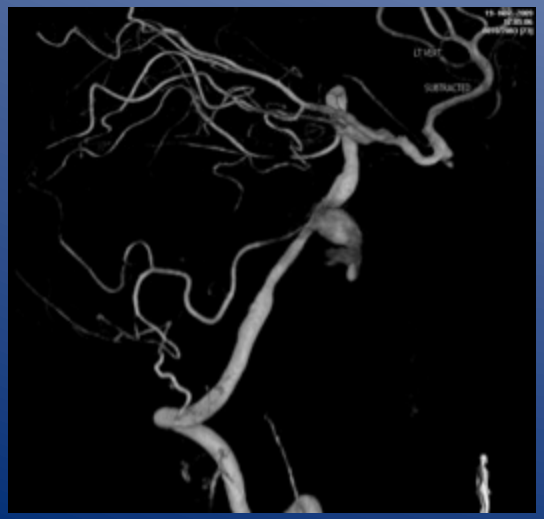
Far lateral approach with OC- PICA anastomosis

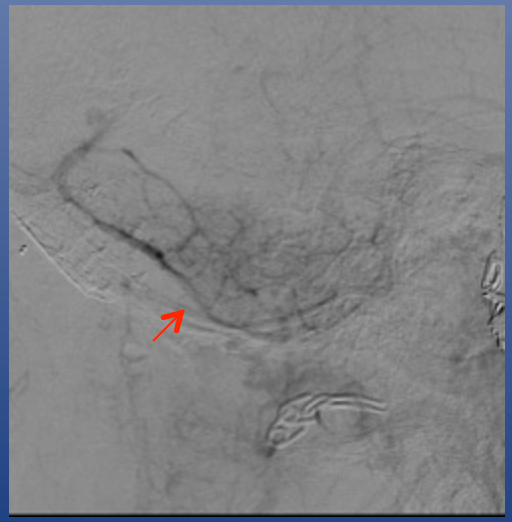
Video 4:



Post Operative 1







Second Operation

ECA to R MCA Radial Artery Graft

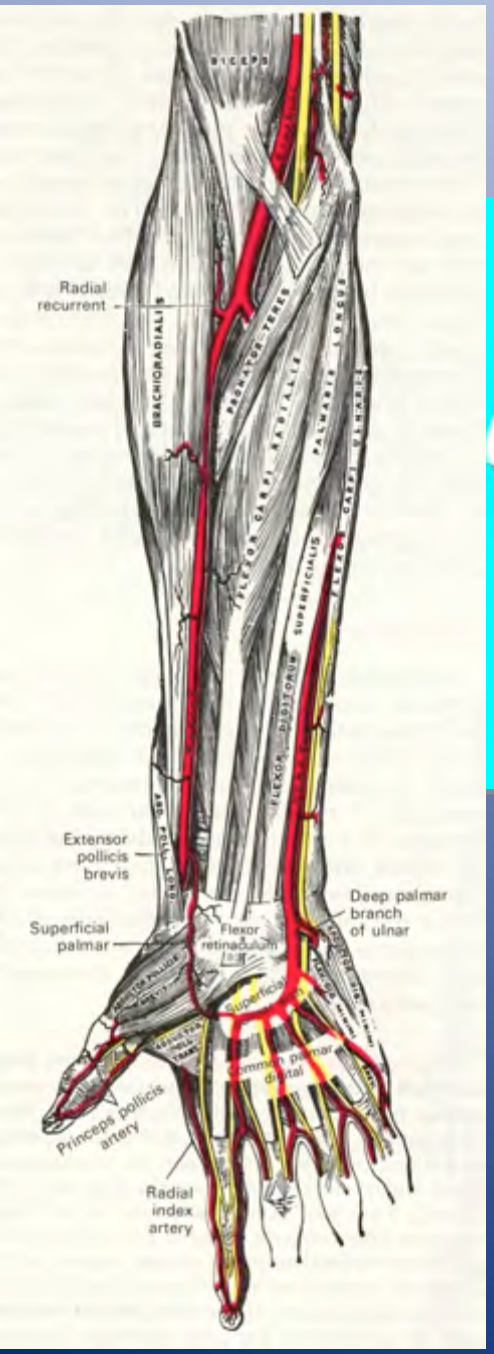
High Flow Bypasses

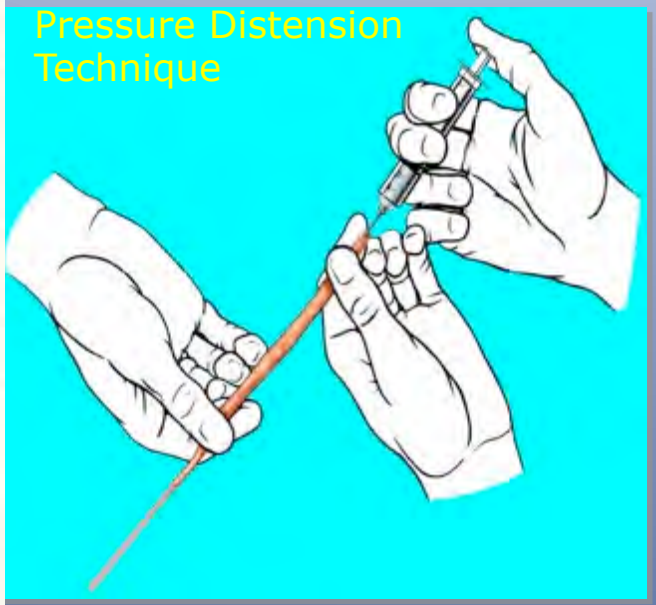
- Are Generally Preferred for the replacement of large Arteries
- Particularly Important if Collateral Circulation is Poor
- A “Temporary Bypass using the RAG” may be useful when prolonged temporary occlusion is planned
- A Higher Level of technical Skill is needed
- “An operation with a 1000 steps”, all of which need to be executed properly
- Preference of Vessels: Radial Artery > Saphenous Vein > Anterior Tibial Artery

Radial Artery or Saphenous Vein?

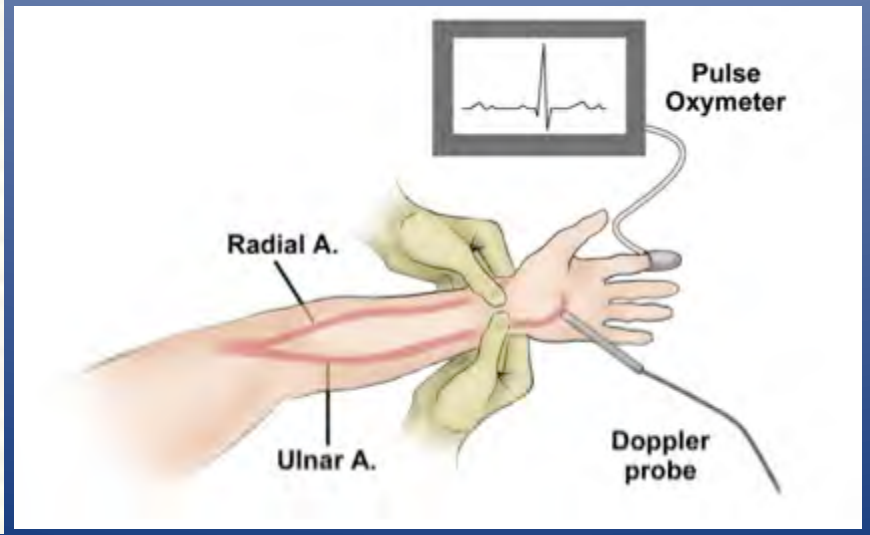
- Preoperative Duplex Scanning
- I prefer RA with at least . 20 cm diameter
- I prefer SVG with at least .25 cm diameter, usually >.3 cm over a 20 cm length
- Since the vein is used without reversal, the inferior diameter is important, upper leg to mid thigh usually has a uniform diameter
- Useful to mark the course of vein on the leg and thigh by Ultrasound Exam

Radial Artery Graft



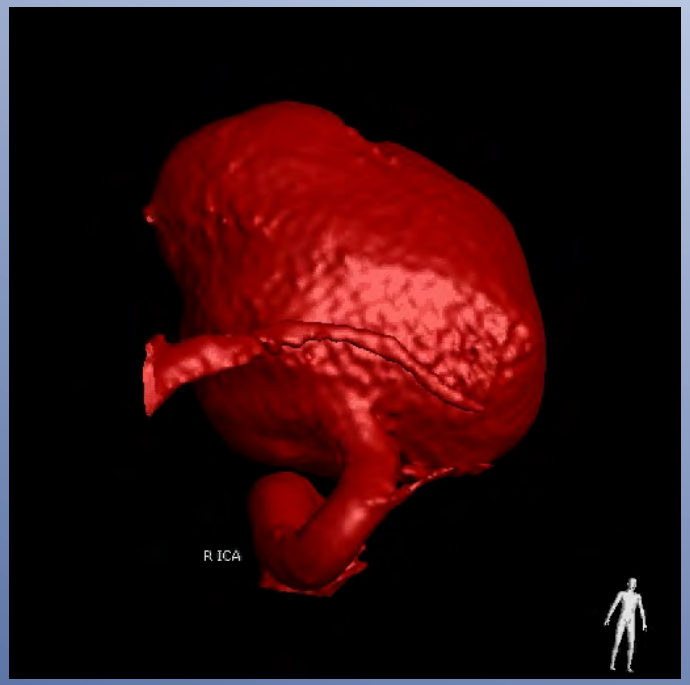


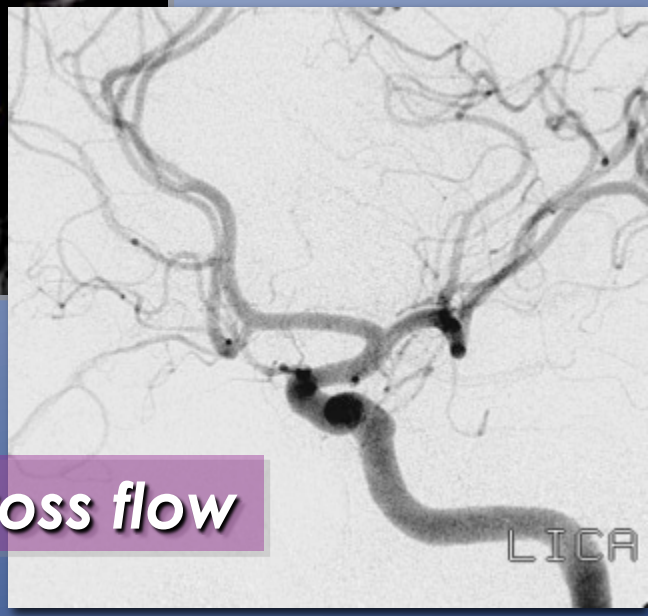
Video 5:



SVG Exposure

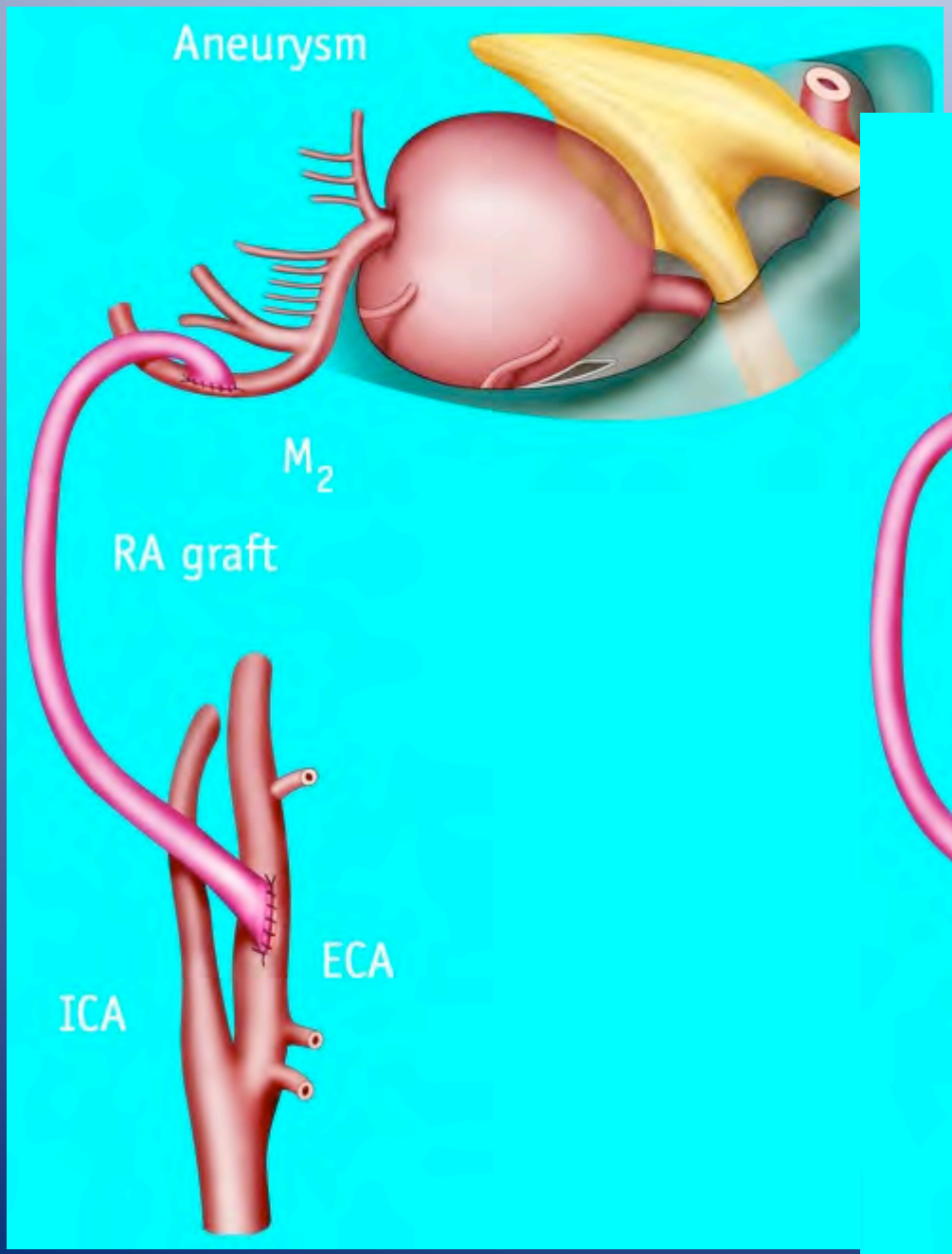
- Vein may be very superficial inferiorly, and can be easily damaged
- Branches are ligated or clipped, slightly away from the main vein
- Left in situ until the extraction
- Endoscopic Extraction May be Used, recent results indicate higher occlusion rates





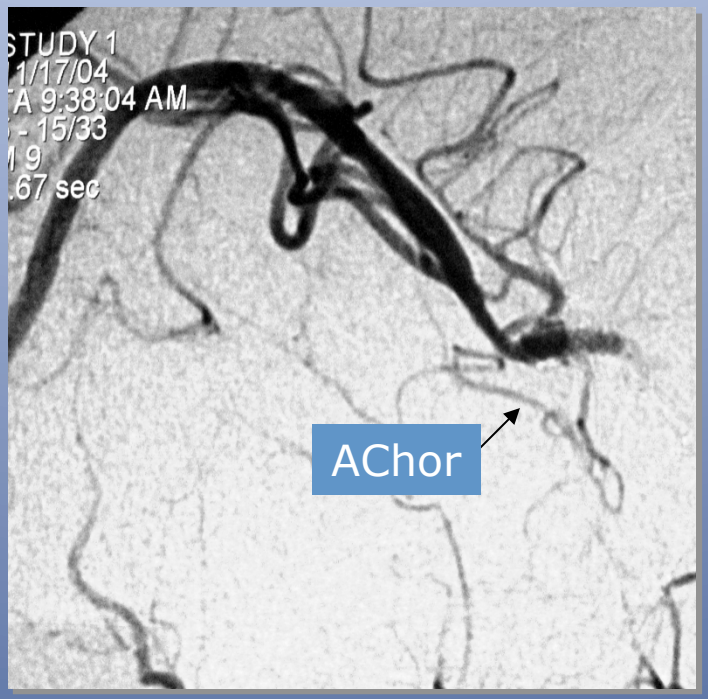
Poor cross flow

- 45 yr old Doctor
  - first noted visual problem in 2 weeks earlier
  - MRI led to angiogram
- Exam: Severe Headache
  - Left Hemianopsia

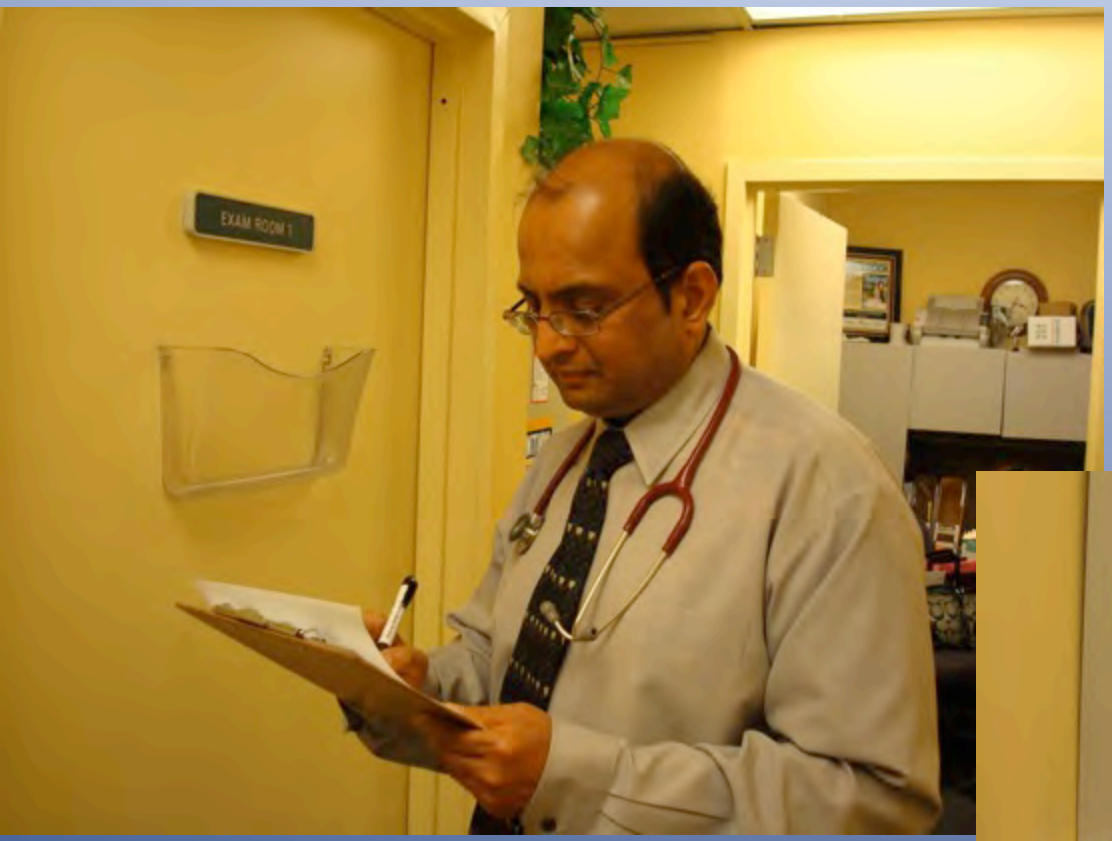


Preservation of ACHOR
By clip reconstruction

Showing the Graft and Anterior Choroidal Artery

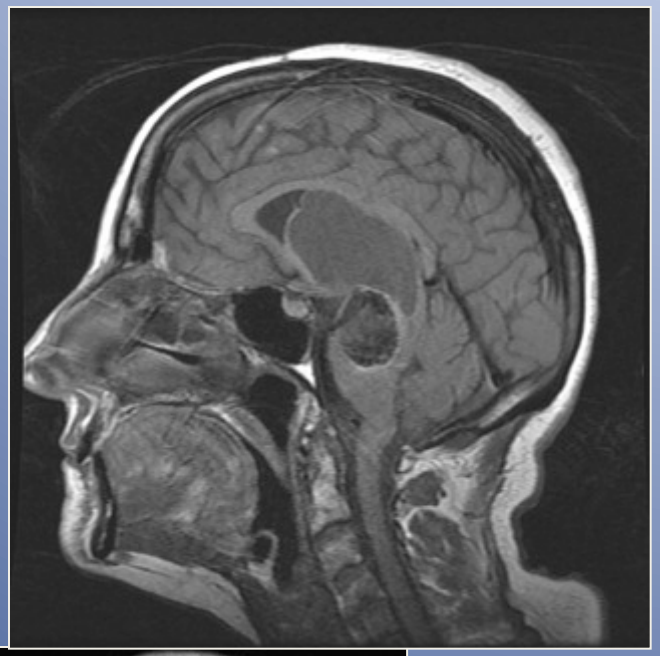


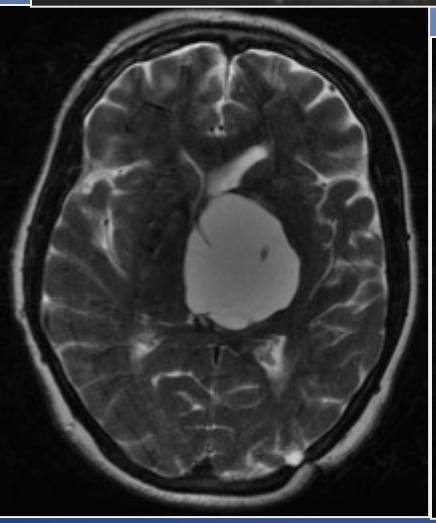
Small caudate stroke
Transient Weakness for 3 days
Returned to work after 6 Weeks

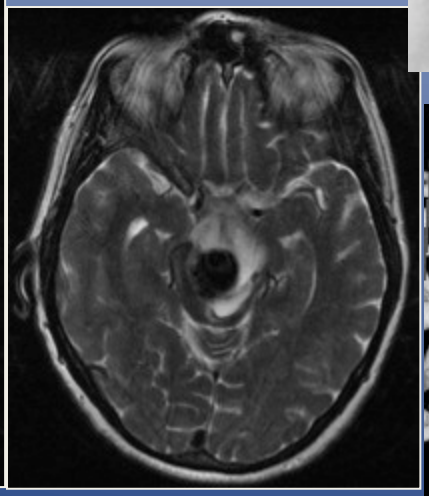


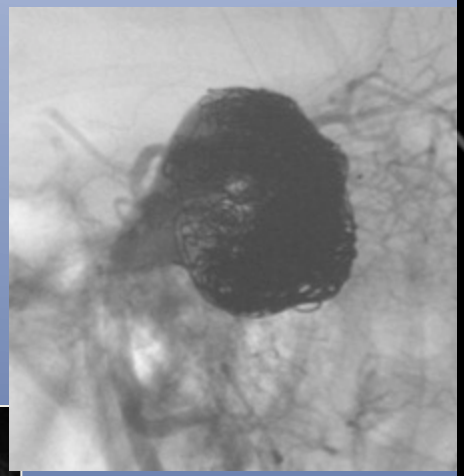
After 10 Years

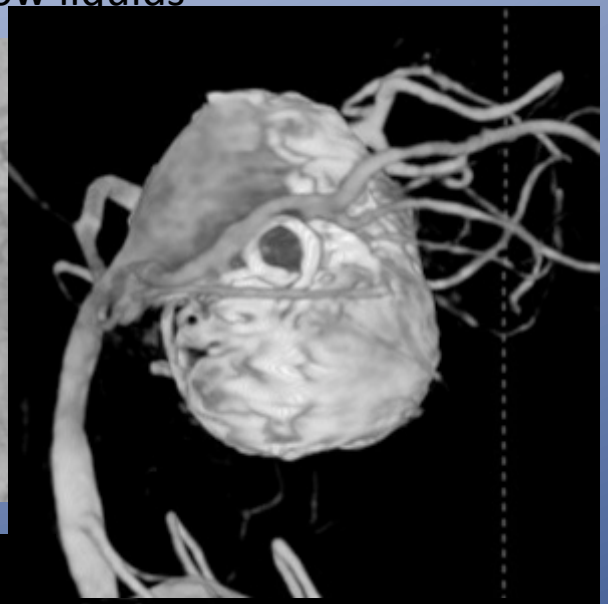
62 year old woman; Giant BA Tip Aneurysm; Unruptured
Coiled 2002, 2003,2004, 2005
Progressively worse
In a wheel chair, Quadriparesis, Dementia, Aphasia
Gastrostomy, can only swallow liquids

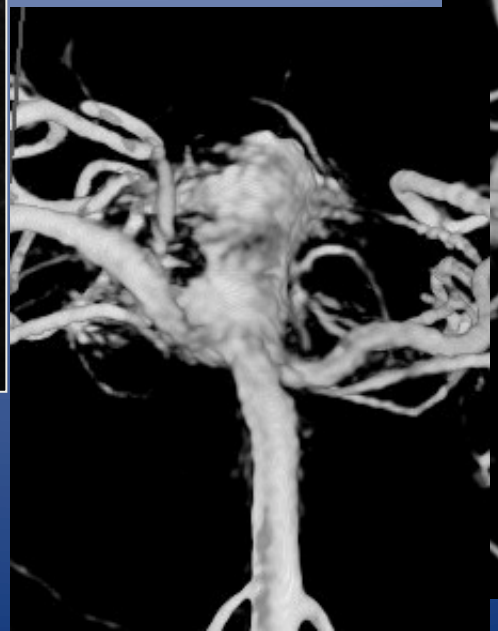


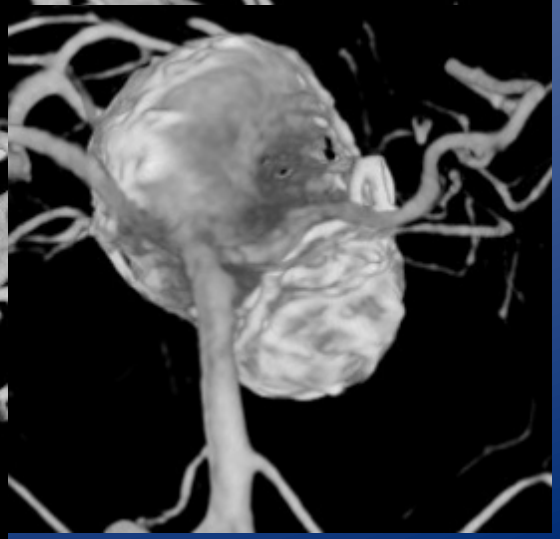










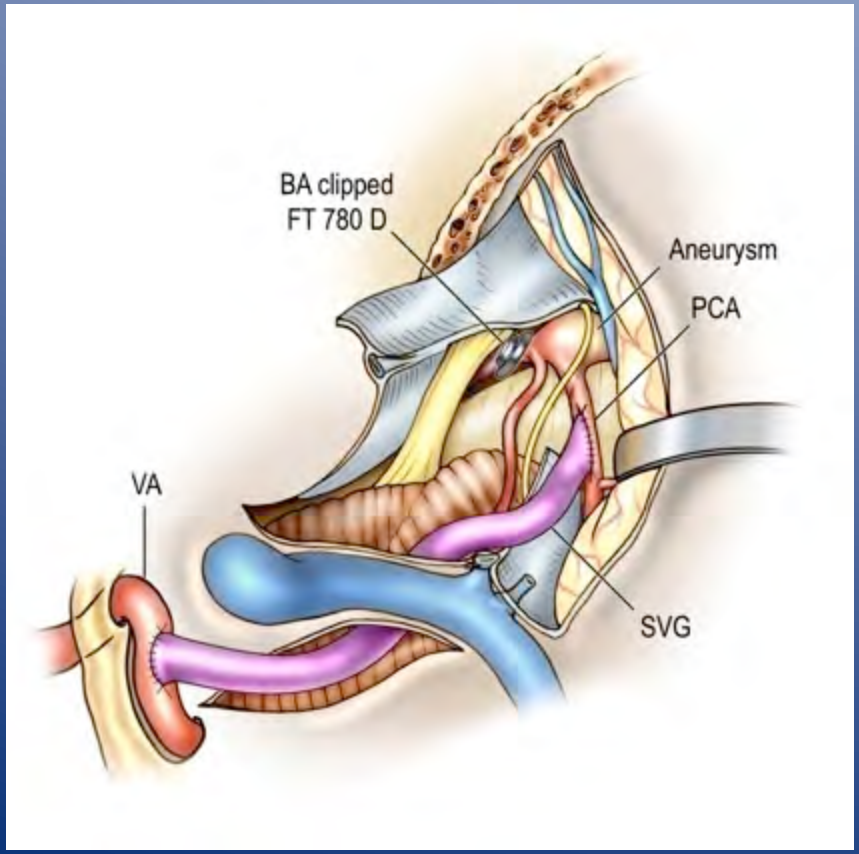


Giant Basilar Tip Aneurysm
Multiply Coiled Previously

Video 6

7/2008 First Operation Endoscopic Fenestration of Cyst, and Shunt Insertion (RGE)

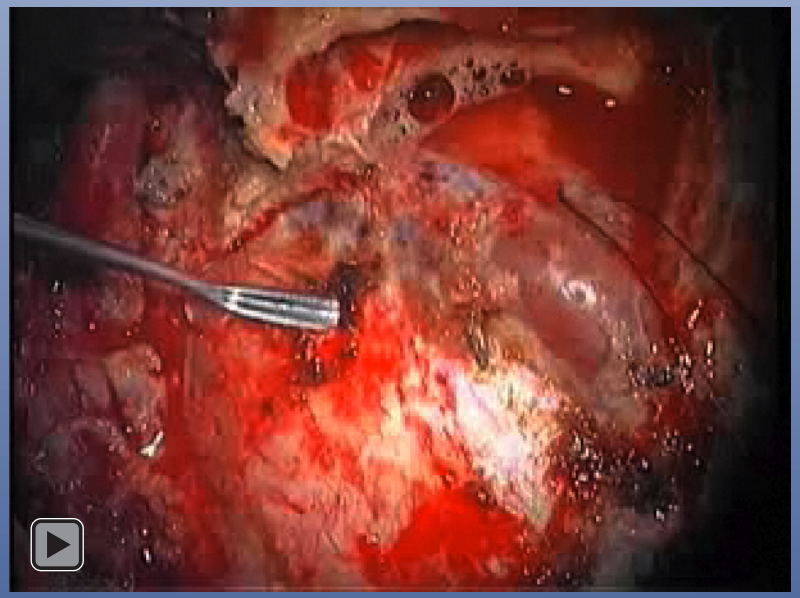
Finding: Coils had migrated into Previous Ventricular Catheter; New VP Shunt Inserted…



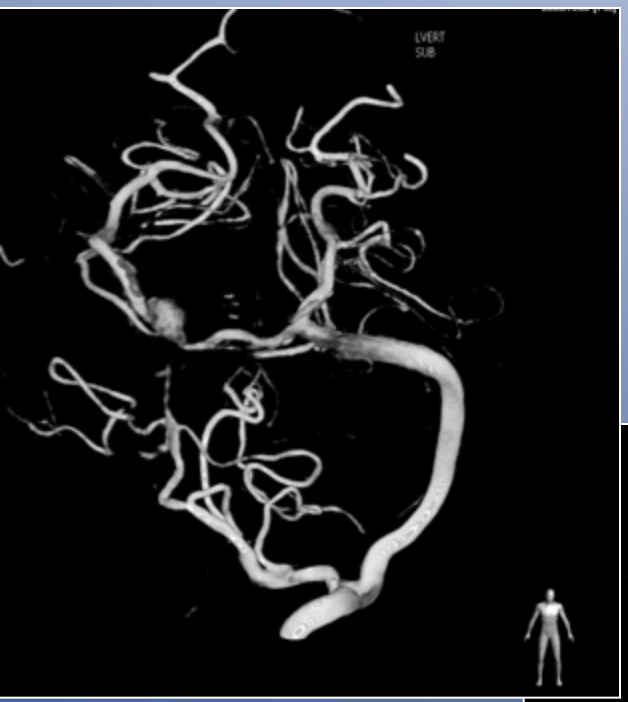
7/2008 Second Operation

- Transpetrosal and Extreme Lateral Approach
- SVG Bypass from Left VA (V3) to left PCA ; Occlusion of BA just below the SCA
- Postoperative Course: Transient Deterioration days 2-4, Gradual Improvement over 1 week

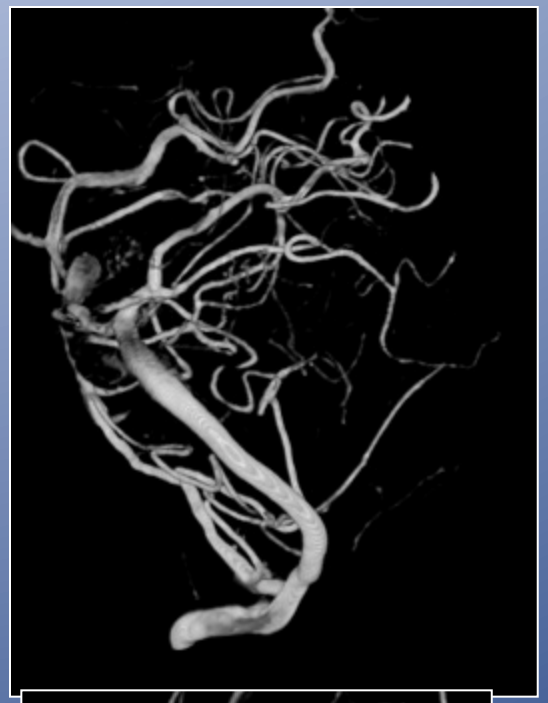
Video 7:



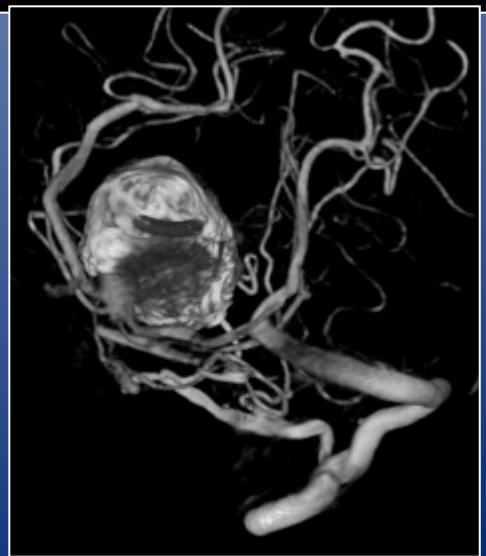
At 18 month follow up



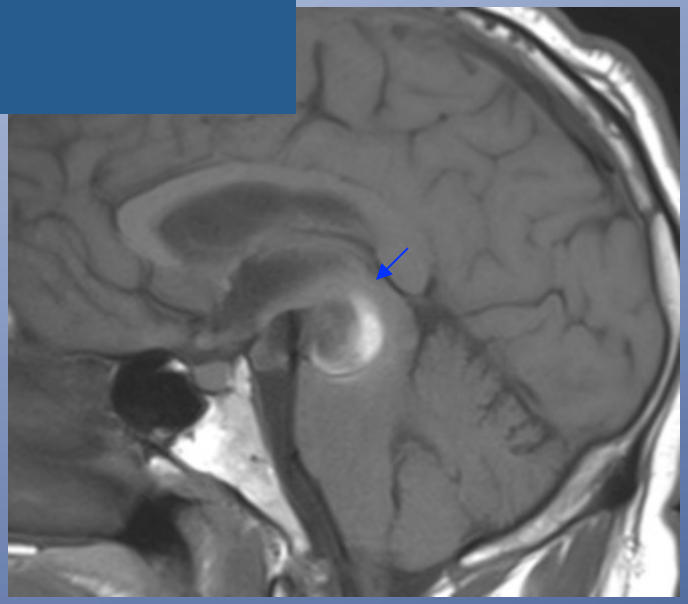
Graft patent with a small
Stable aneurysm remnant.
Both PCAs filling well, one by
RAG and other by PCOM

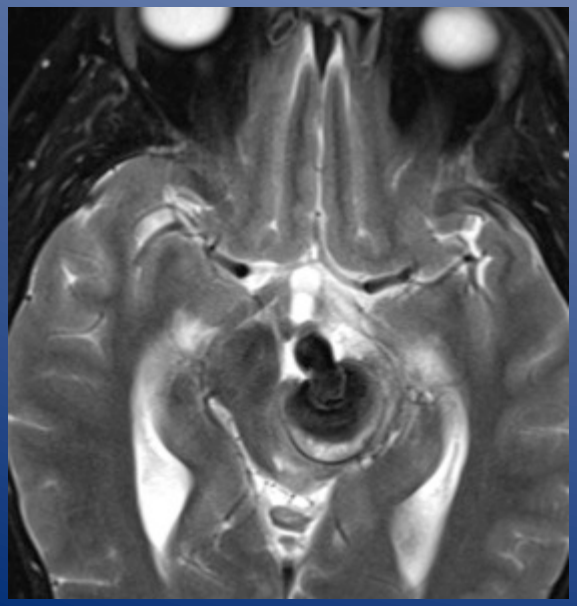


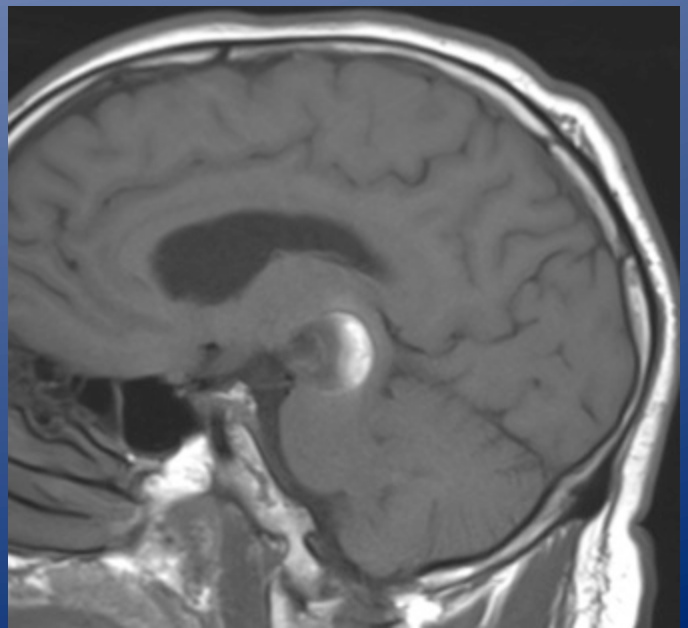
Patient much improved,
Speaking a few words, eating
By herself, hemiparesis
improved
And able to walk with help
mRS 3



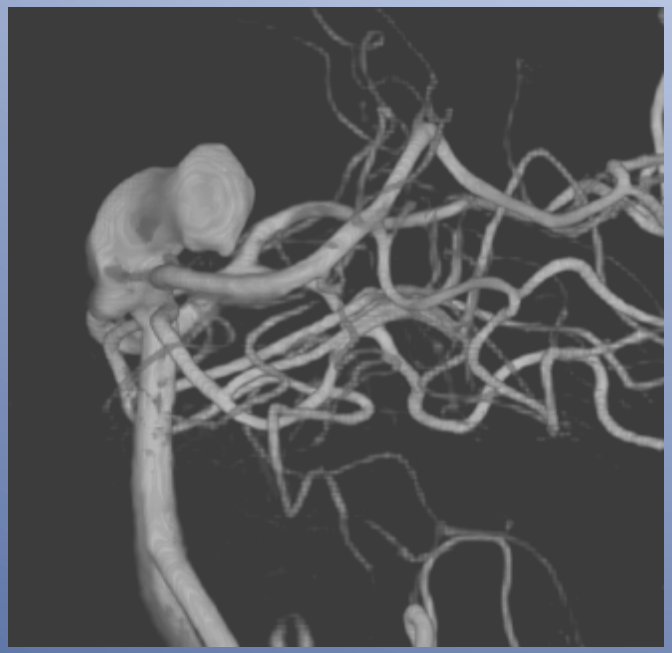
47 years, Male
1 mo progressive R Hemiparesis, R Pronator drift
Intermittent R facial numbness
2 mo dizziness



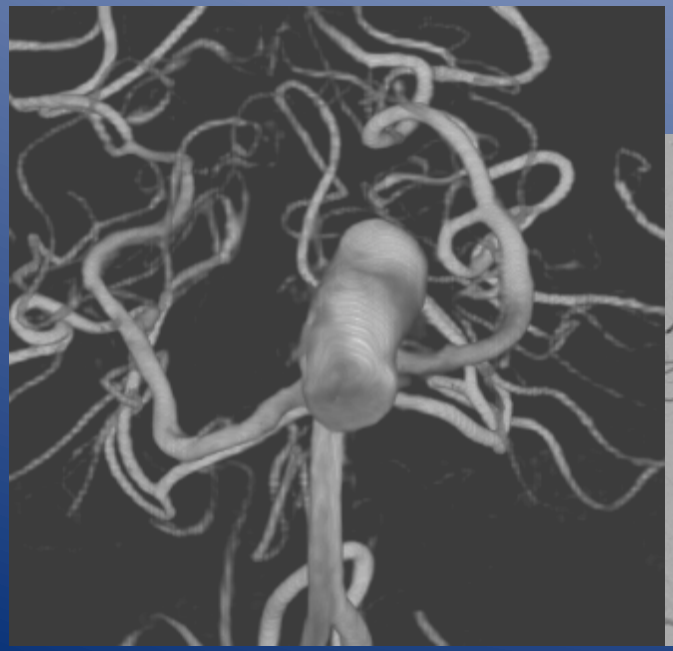


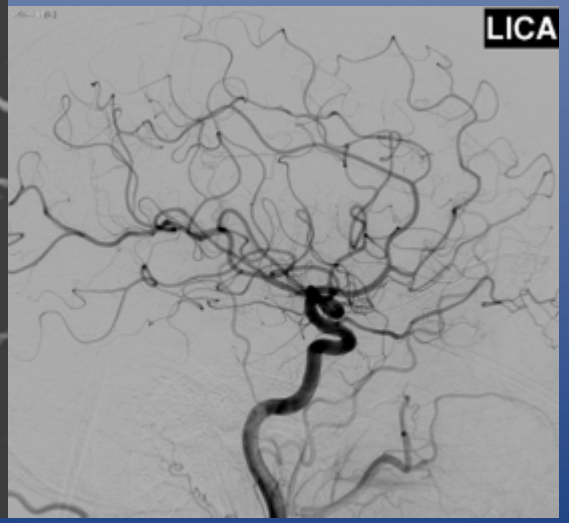


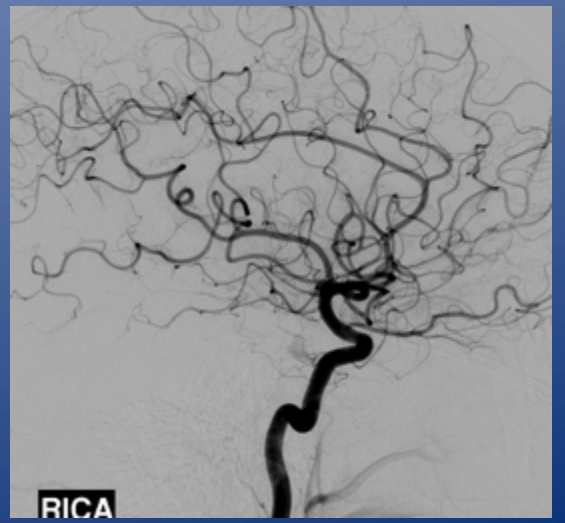
BA Tip Aneurysm
32 x 25 x 23 mm
Unruptured



- Aneurysm Fills Partially
- BA Tip is 270°Involved by the Neck



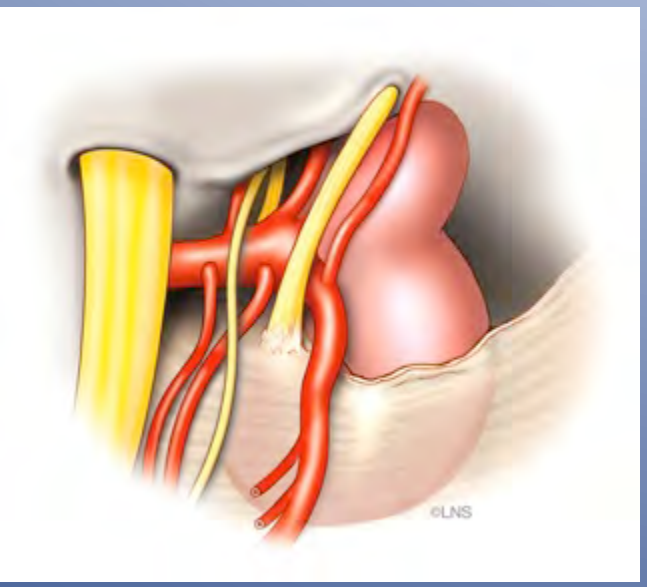




No PCOM Collaterals

Surgical Plan: Creation of New PCOM, then Proximal BA Occlusion

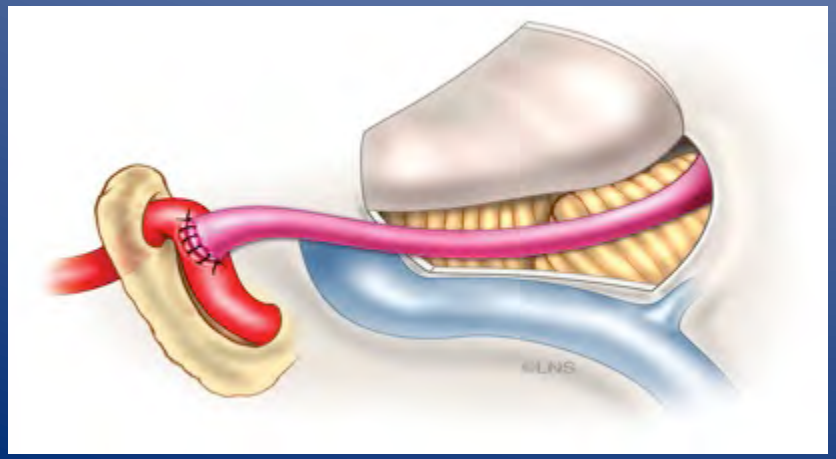
Initial View



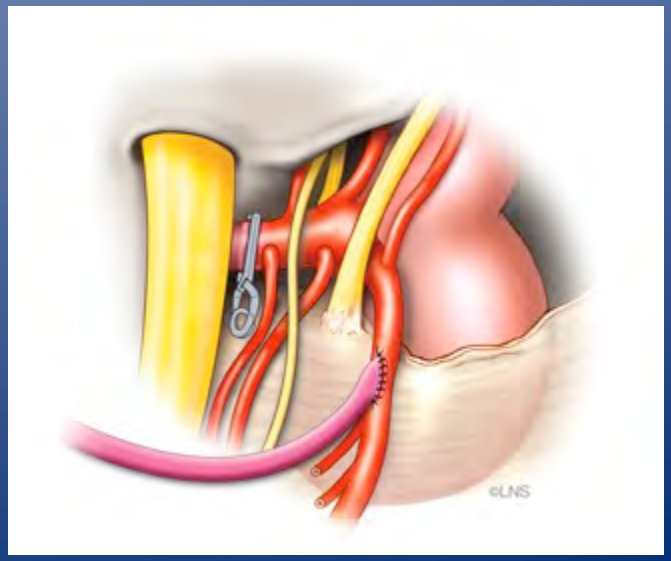
Stage I: Approach
Left Presigmoid, Transpetrosal, Subtemporal
Aneurysm Had Ruptured Between stages 1 and 2

Stage II: Bypass, and Proximal Occlusion (next day)
Right radial artery harvest
Left V3 to Left PCA Bypass
BA Clip Occlusion Just Below SCA

Overview of Graft



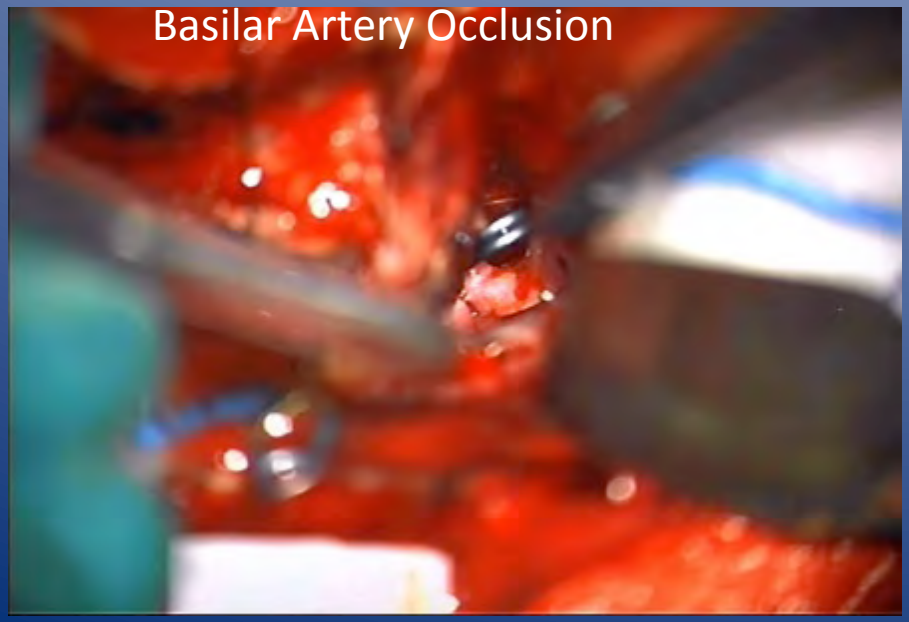
BA Occlusion



Graft sutured Distally

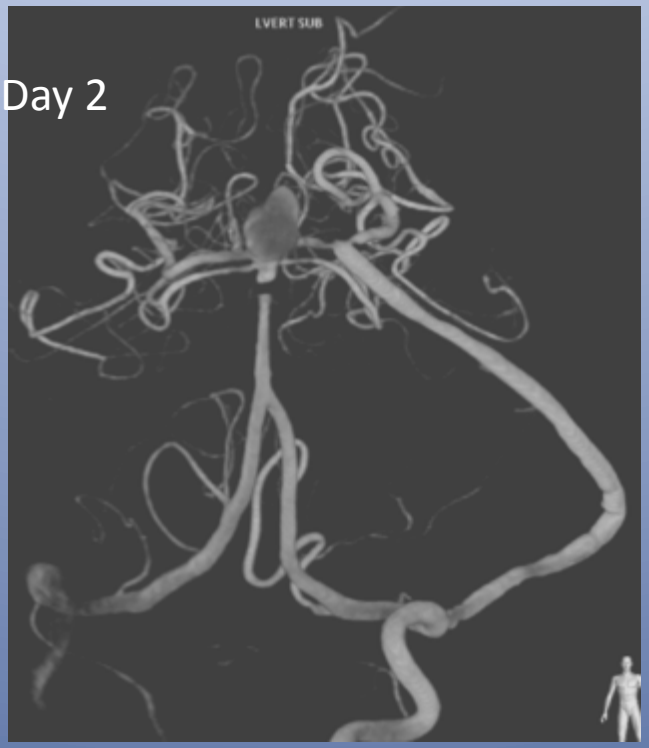
Graft Sutured Proximally

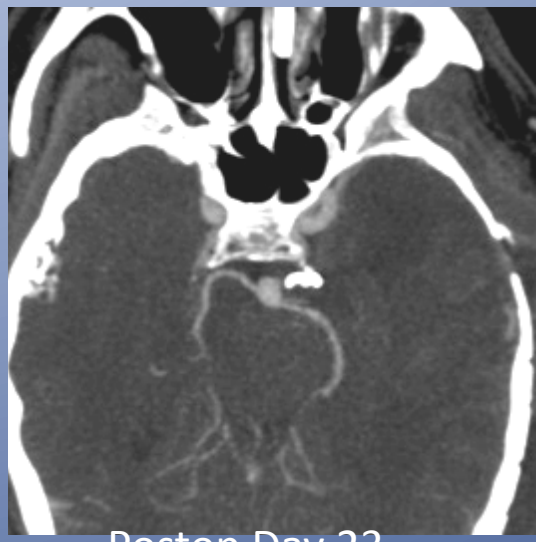
Basilar Artery Occlusion



Radial Artery Graft, Doppler

Postop Day 2



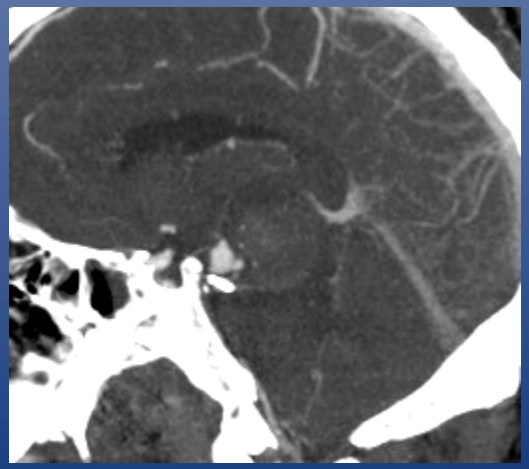


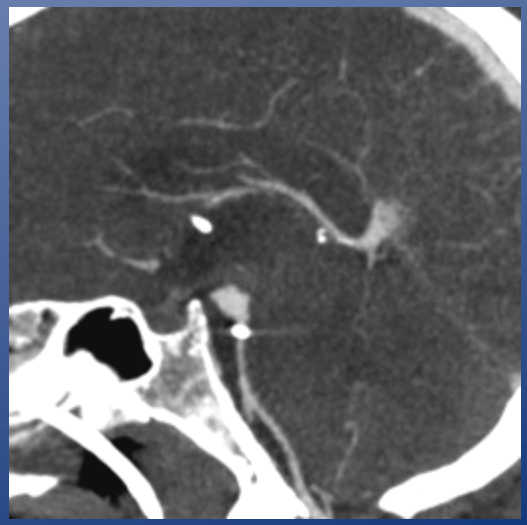
Postop Day 23

Postoperative Course
Hemiparesis, Obtundation
Recovered after about 10 days

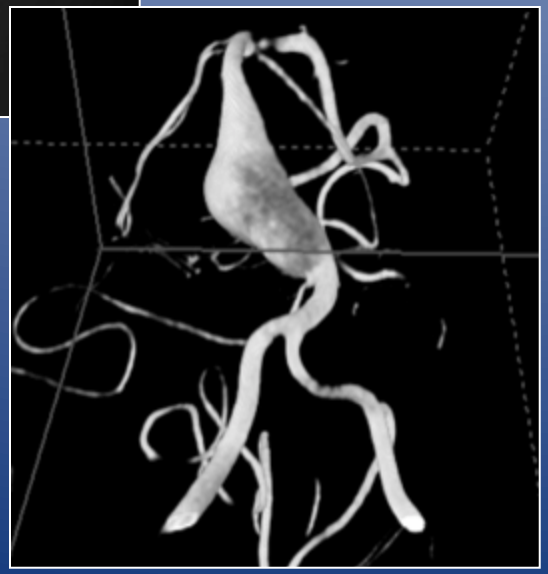
At 6 Months:
Fluent speech, Normal Cognition
Ambulates, and Drives
Mild Left Arm Paresis, mRS 2
Small Aneurysm Remnant

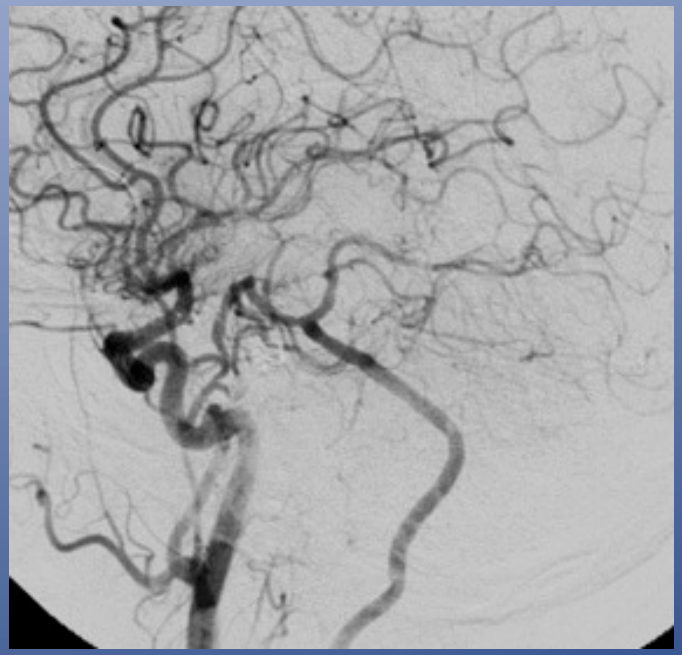
Postop Day 7





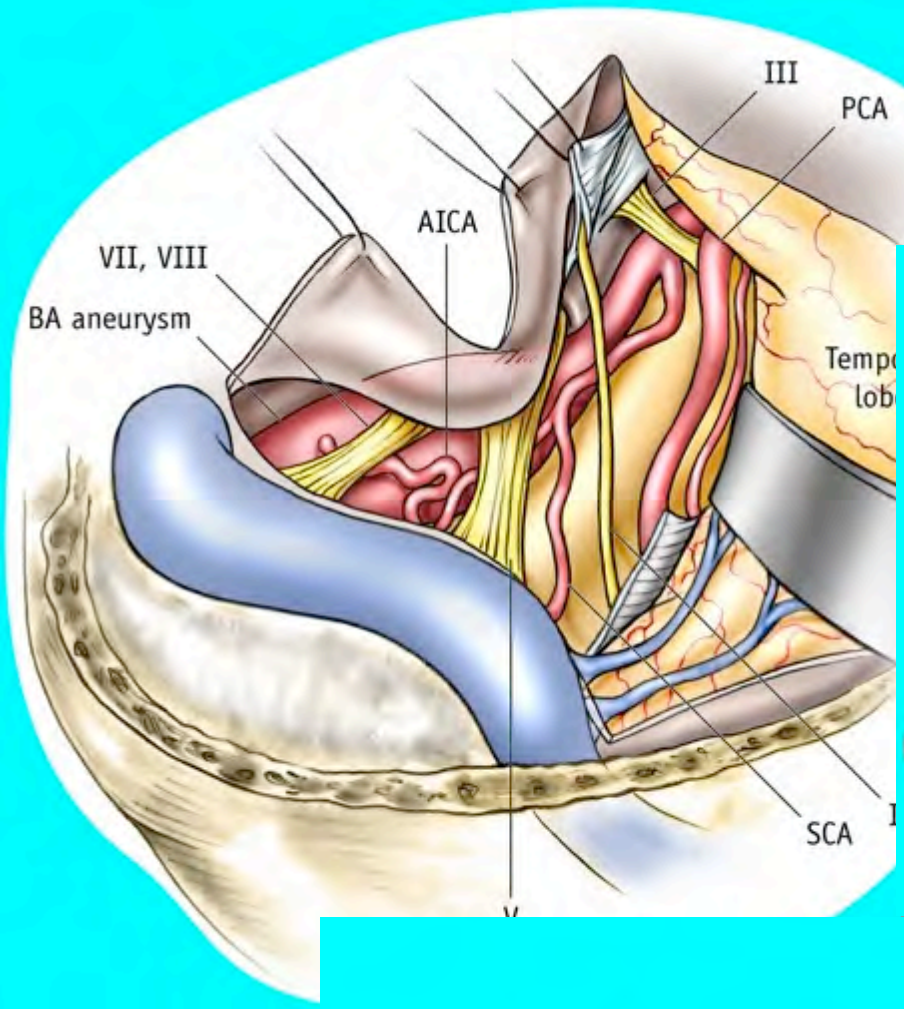
43 yr old man presented with dizzy spells and passing out episodes.
Angiogram showed Fusiform Mid Basilar Aneurysm

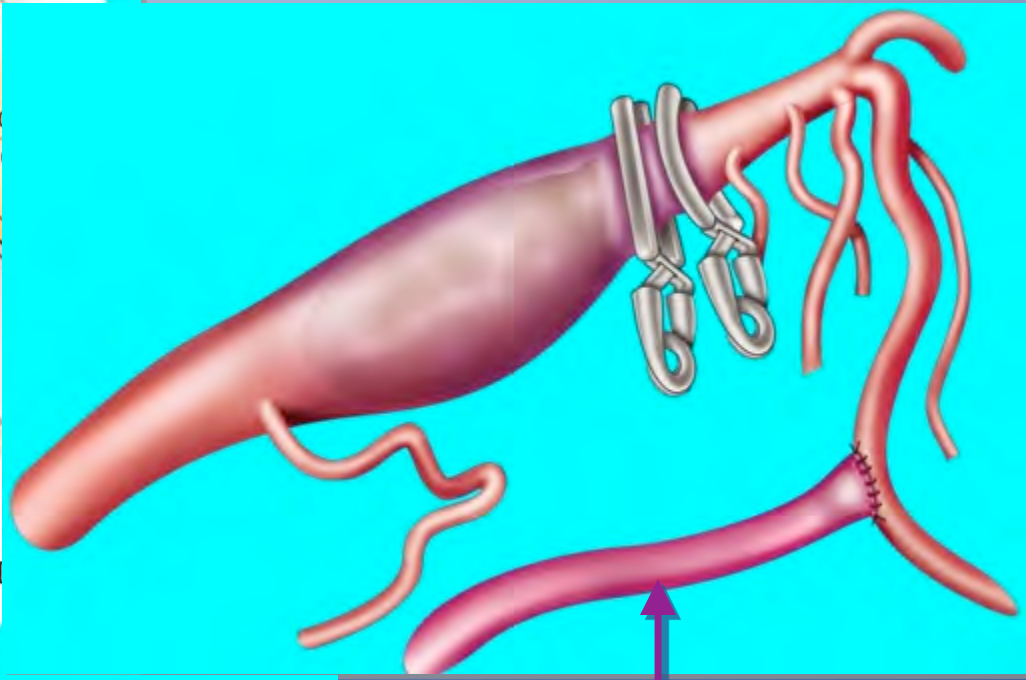


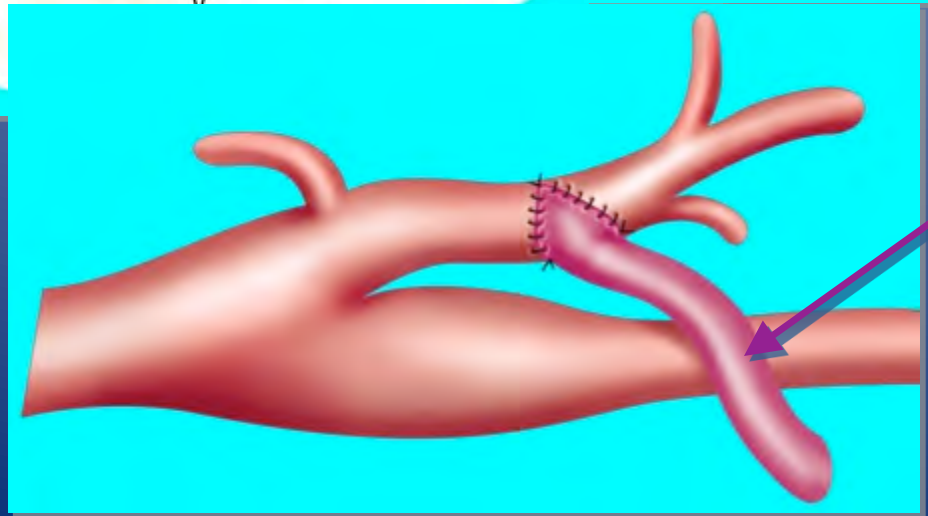


Left ECA to PCA Bypass using RAG and Distal occlusion of mid basilar aneurysm

Basilar artery occluded distally inferior to perforators

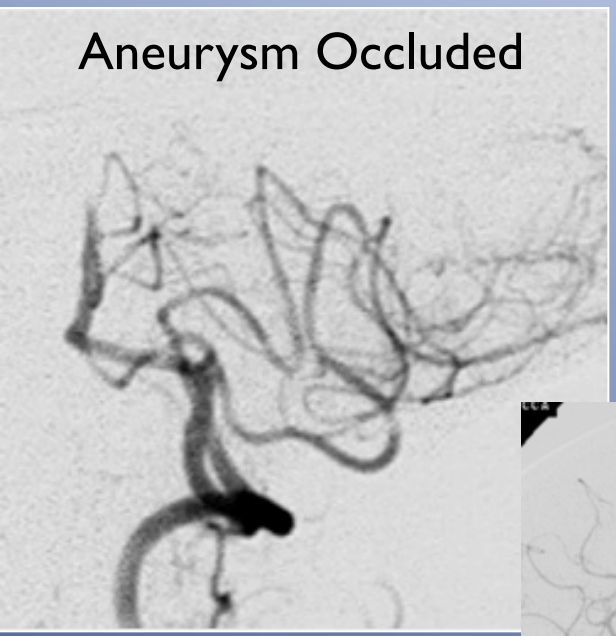


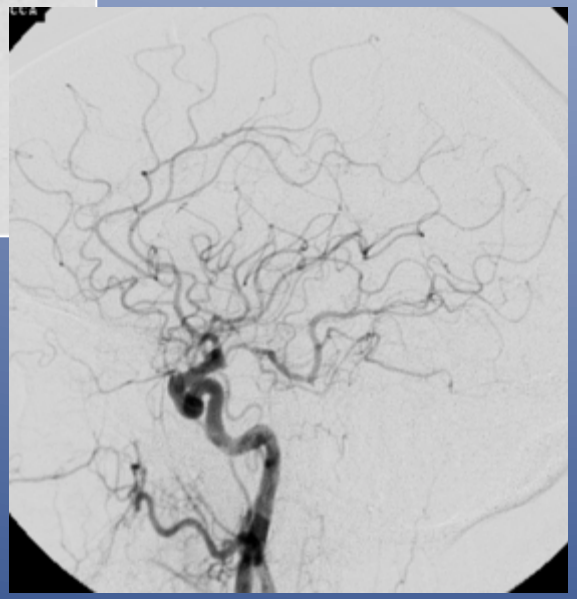




Radial artery graft

Follow-up





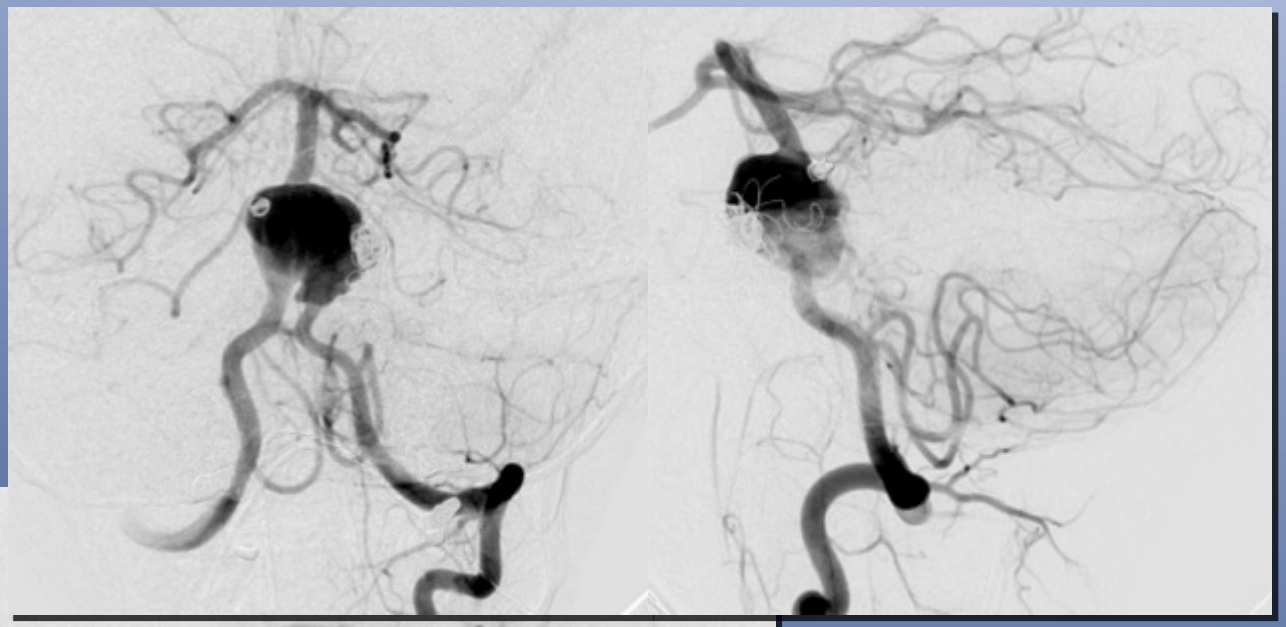
3 months

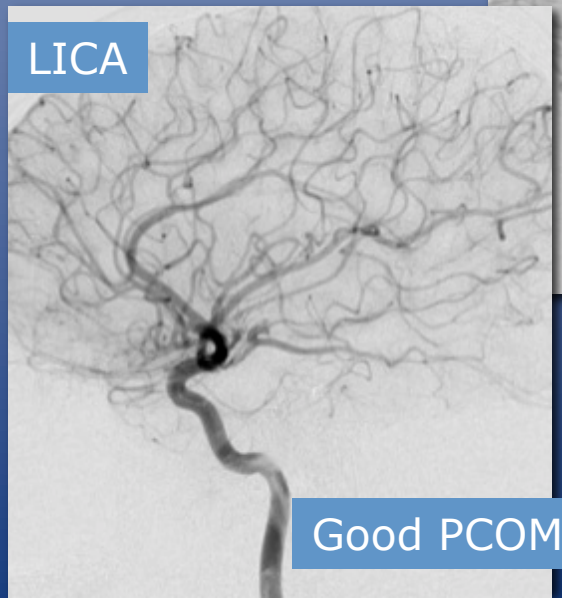
Follow up angiogram showing no graft flow; PCOM enlarged

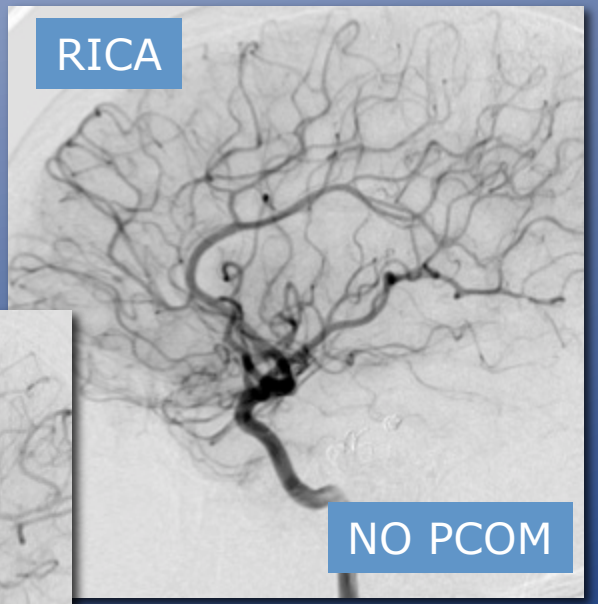
Widely open graft during the **20 month** follow up, PCOM still large

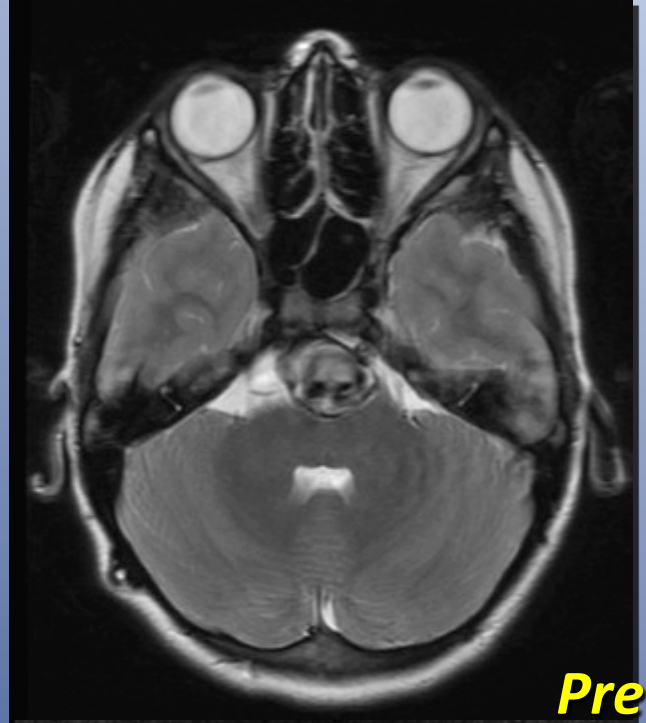
Recurrent Complex Lower BA Aneurysm

- **10 y.o. boy**
  - **Complex Vertebrobasilar Aneurysm**
  - **Failed Coiling X 2**

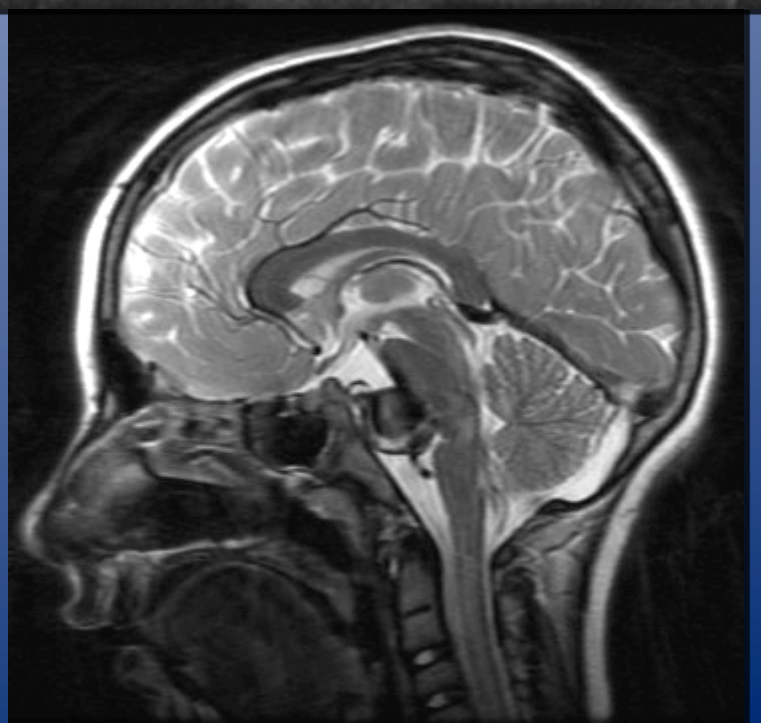








Preoperative MRI

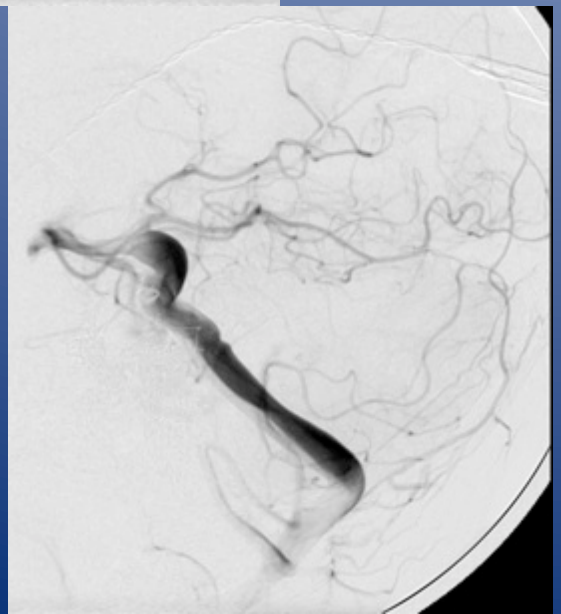


Right VA Angio – SVG
VA to PCA

Postoperative MRI and Angio- Persistent filling of Aneurysm thro Opposite VA

Aneurysm fills thro Left VA, stenotic

Angiogram at 1 year follow up



Revascularization
1988 to July 2012

- Total Bypasses 430
- **Patients 404**
- Aneurysms 204
- **Patients 187**
- Tumors 142
- **Patients 138**
- Ischemia 84
- **Patients 79**

My Recent Bypass Experience (2005 -2012)

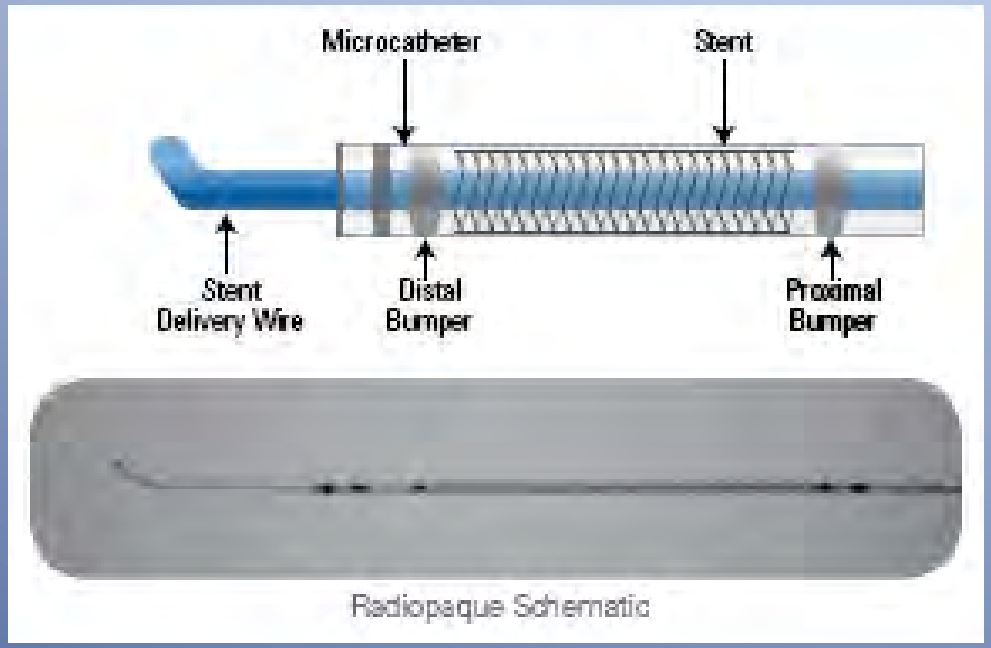
Total Cases 102

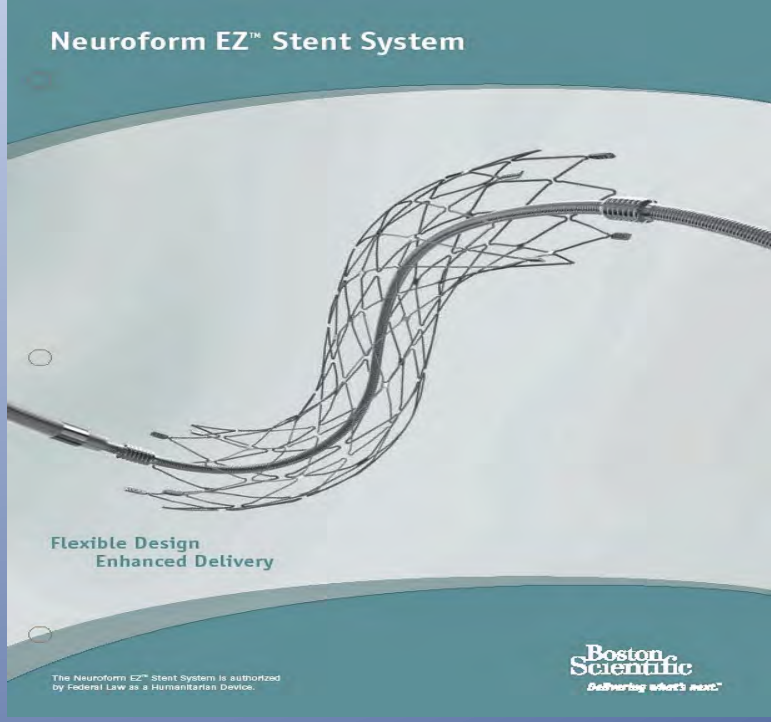
- Ruptured Aneurysms 38 (37%)
- Unruptured Aneurysms 64 (63%)
  - > Pipeline Eligible 19 (18.6%)
  - > Not Eligible for Pipeline 45 (44.1%)

Patency Rate (after salvage)	98%
Stroke	8 (7.8%)
Complete recovery	3 (37.5%)
Mortality	5 (5 %)
Death Related to bypass	1 (1%)
mRS 0 -3	87(85.2%)
mRS 4- 6	15 (14.7%) (11 Patients had bad outcome due to SAH)

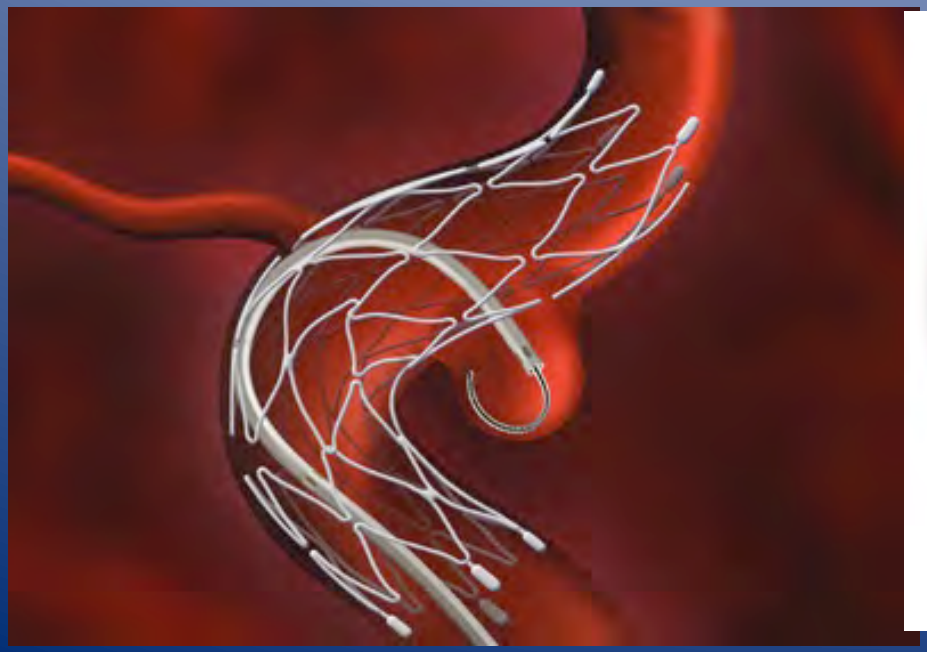
Intracranial Stents for Aneurysms

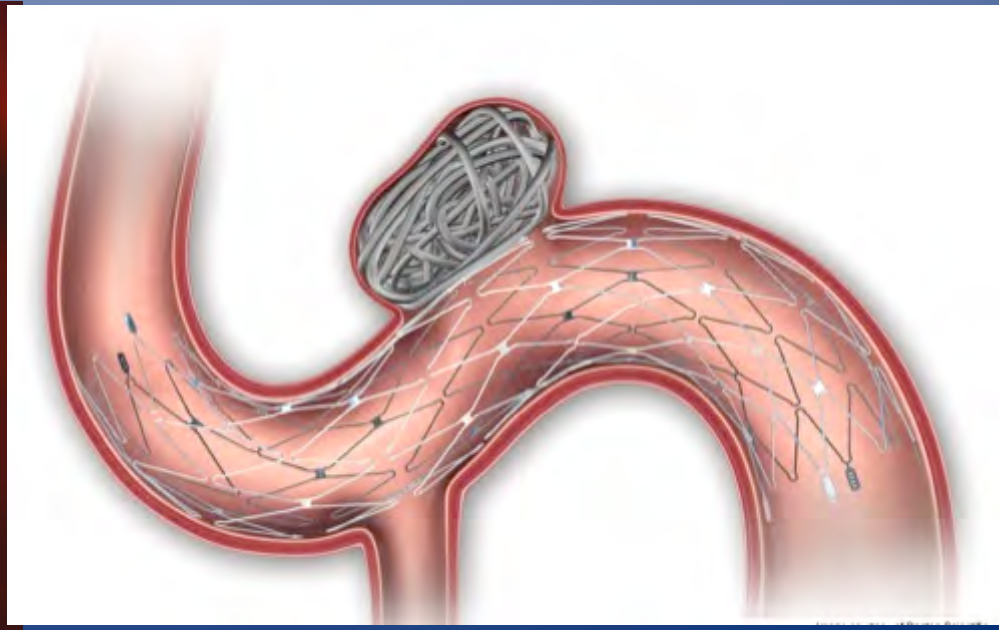
- High Porosity Stents : Neuroform ®, Enterprise ®:
  > Primary purpose is to keep the coils inside the Aneurysm; used with coils
  > Ineffective for Fusiform Aneurysms
- Low Porosity or Flow Diversion Stents:
  Used without coils in On Label Cases
  Can be used for Fusiform Aneurysms
  Higher Risk of Hemorrhagic Complications



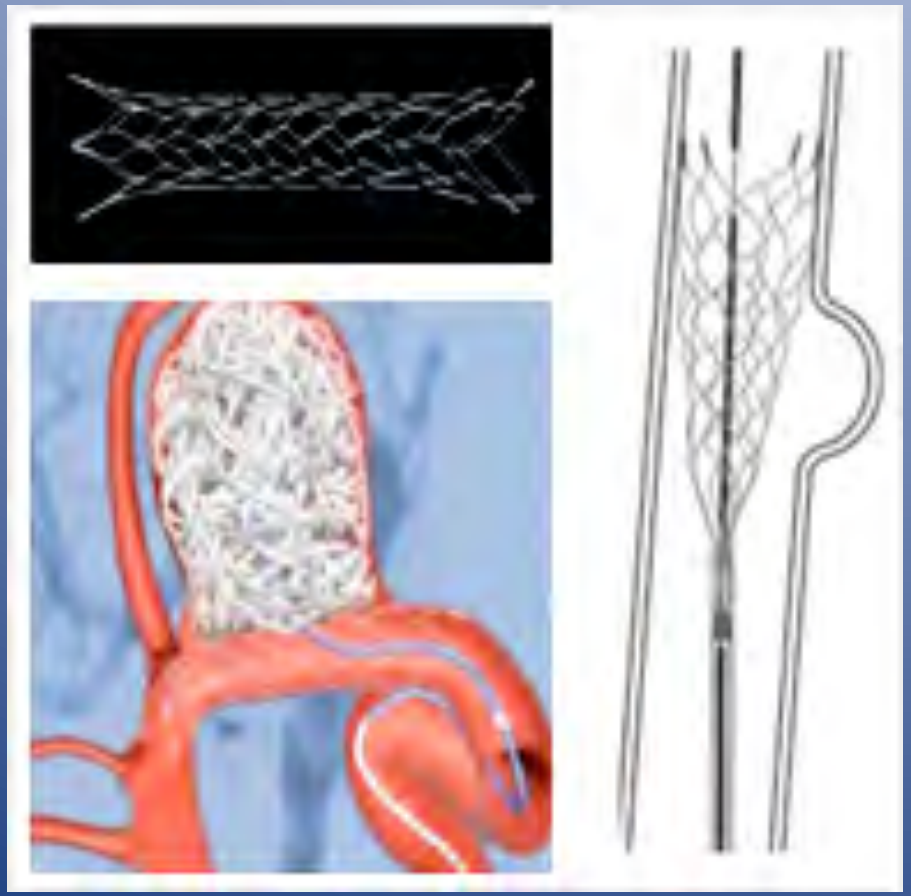


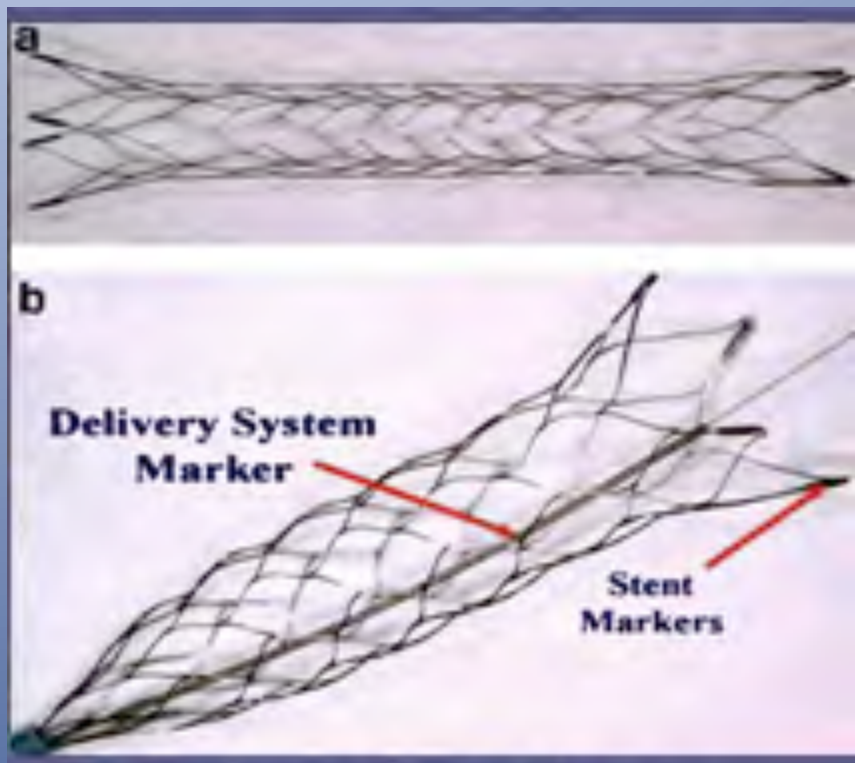
Neuroform EZ Stent System





Enterprise Stent



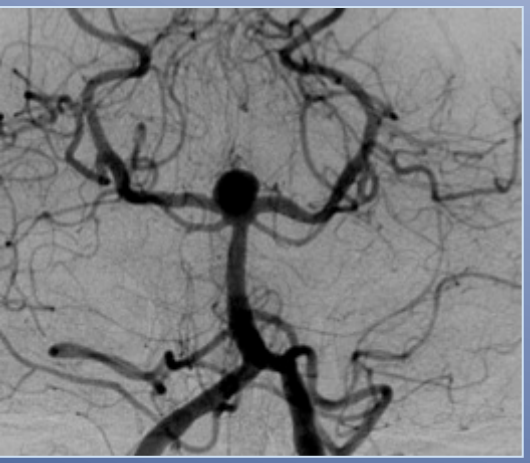


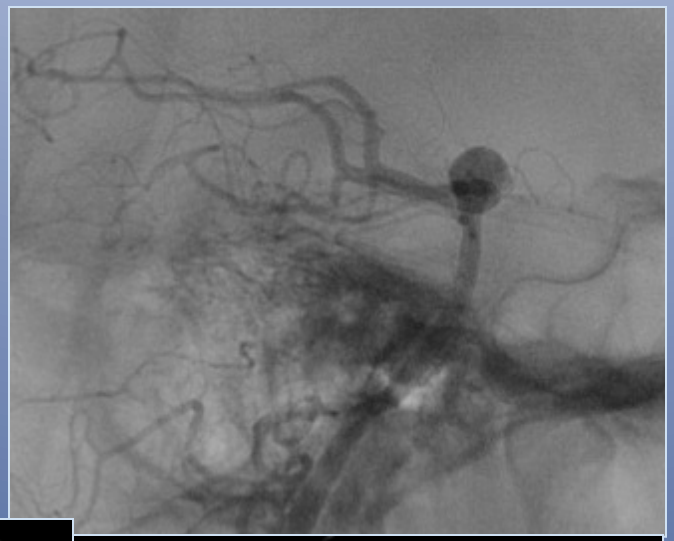
Enterprise® Stent

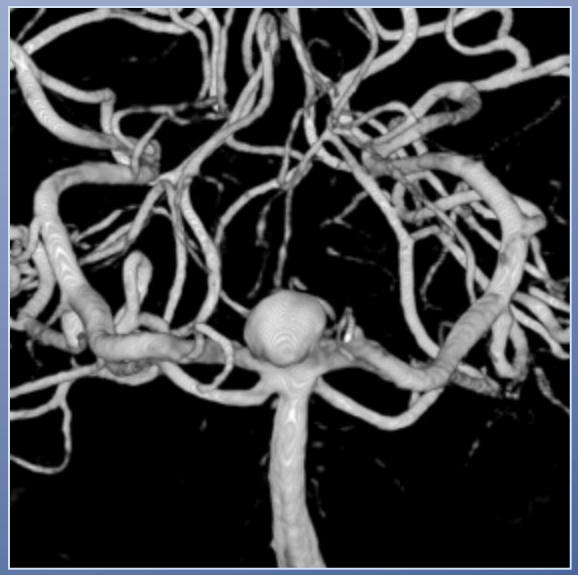
closed-cell design

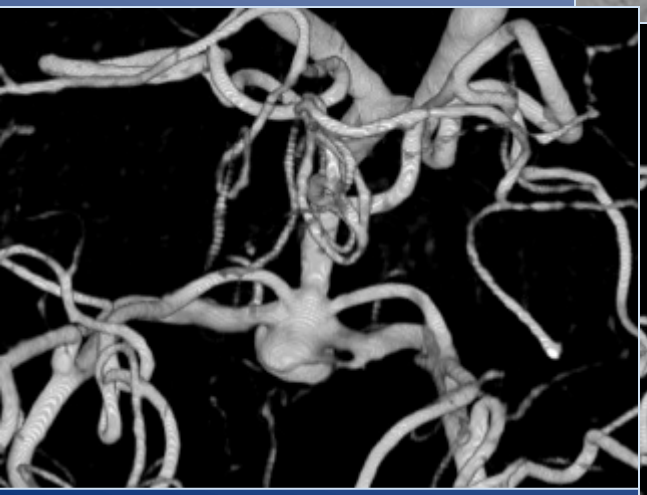
Can be re-sheathed and repositioned after partial deployment

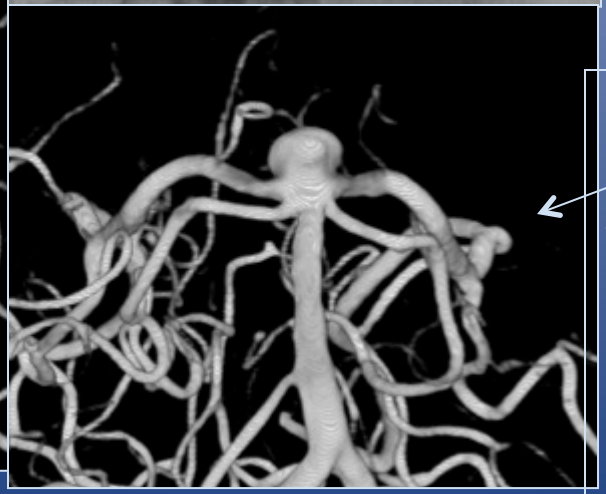
45 year old presented with migraines, blurred vision and Diplopia for 5 days





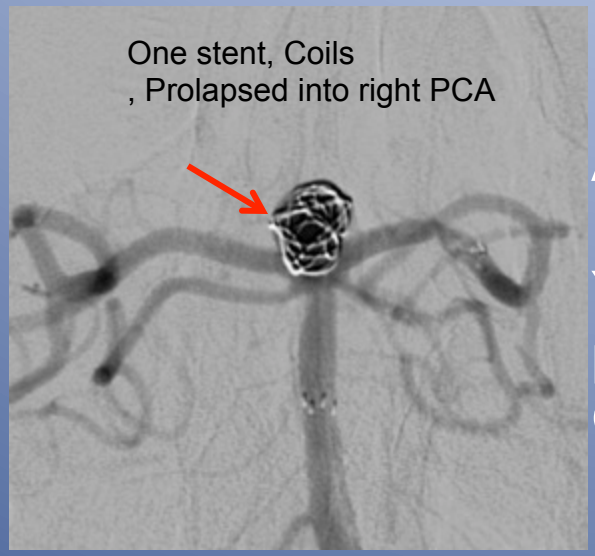




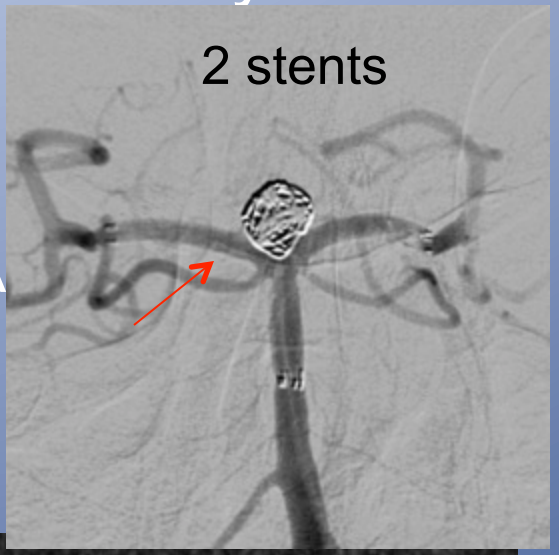


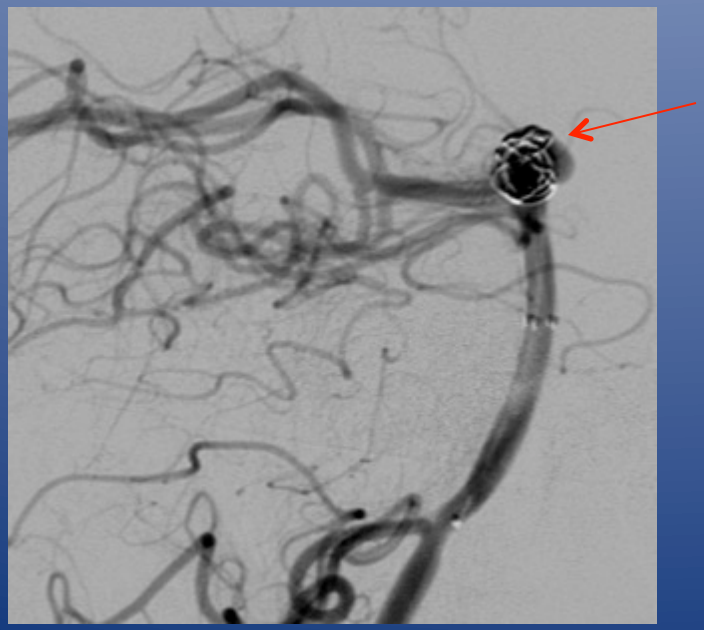
Broad Necked
Basilar tip aneurysm
Wide Neck =8.4mm
Dome/ Neck=11mm/8.4mm=1.3
Height/Neck=7mm/8.4mm=0.83

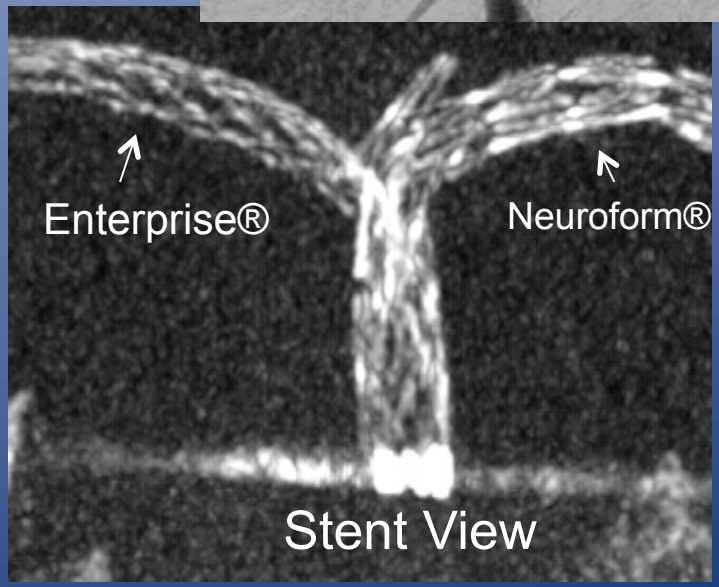
Y stent and Coiling of the basilar tip aneurysm



Aneurysm Coiled with
Neuroform® stent into left PCA
Y Enterprise® stent
placed to keep coils
Out of right PCA





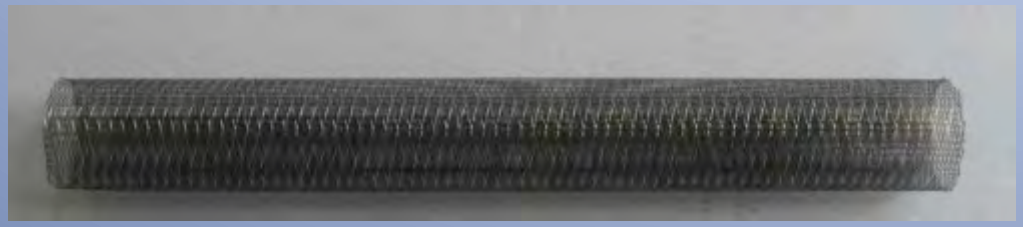


Patient had good outcome
No recurrence on Follow Up

Types of Flow Diversion Stents

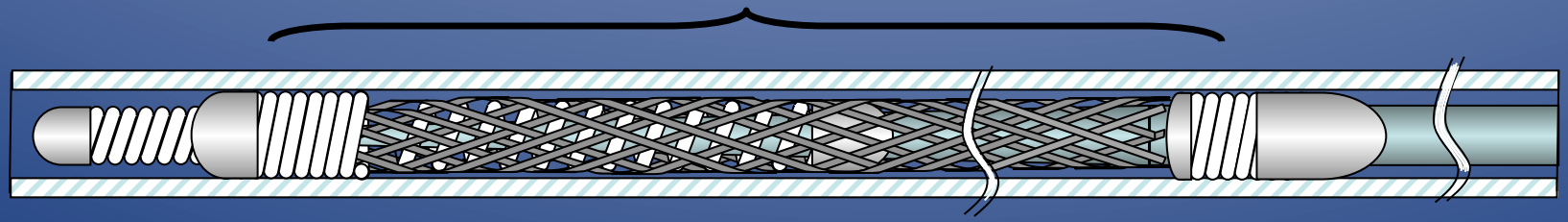
- "Pipeline Embolization Device" : Approved in the USA for ICA aneurysms of the Petrous, Cavernous, and Paraclinoid Segments of the ICA .
  > Off label Uses in Other Areas
- "SILK Flow Diversion Device" : Widely used in Europe and Other countries
  > Not approved for use in the USA
- Other Flow Diverters, and Intermediary Devices Being Developed

PED



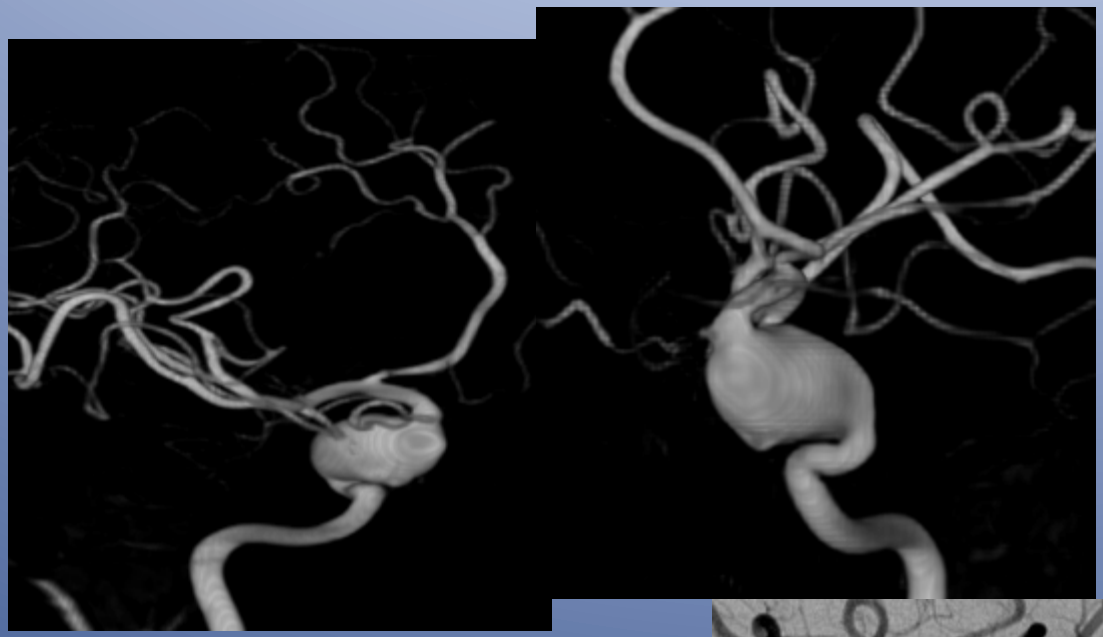
- Microcatheter delivered, micros tent, delivered thro 3 F catheter
- Flexible
- 48 strand Cobalt Chromium and Platinum Braid

- Delivered through 0.027” Microcatheter (3F)
  - Marksman (EV3)
- Constrained over a stabilizer microwire within a delivery sheath

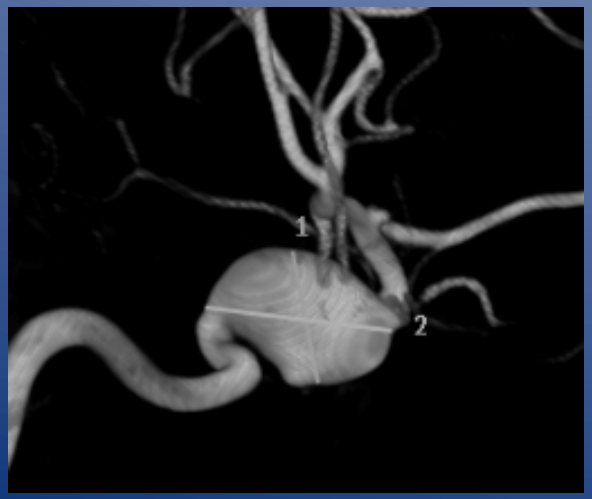


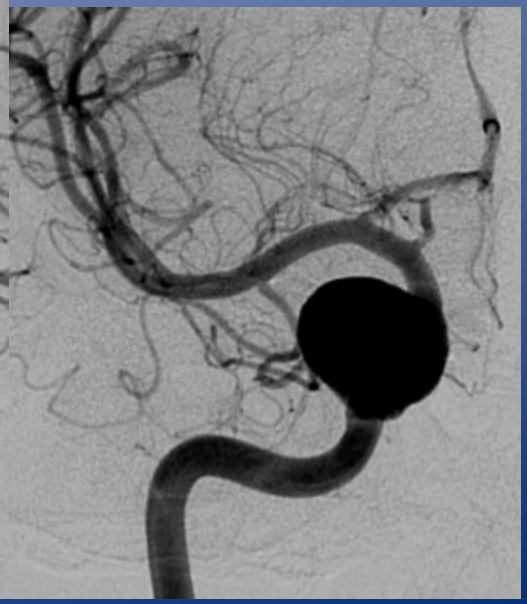
Pipeline Embolization Device
compressed in introducer sheath

Large Intracavernous Aneurysm 1.4 x 1.8 cm, Unruptured

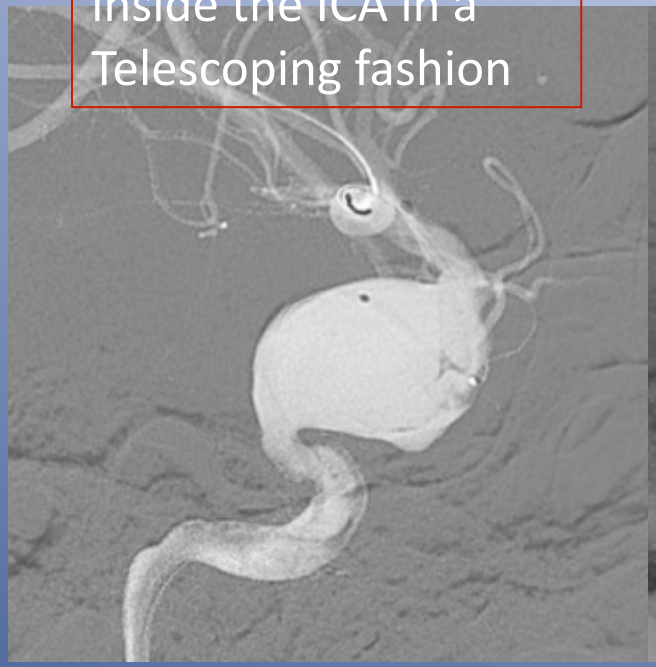


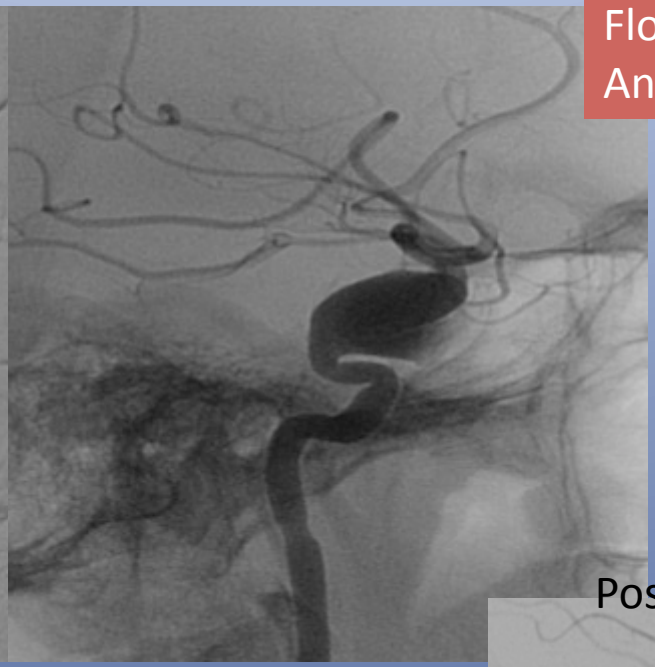
32/ Male
Retro orbital Pain, Photophobia
Failed Stent assisted Coil Embo



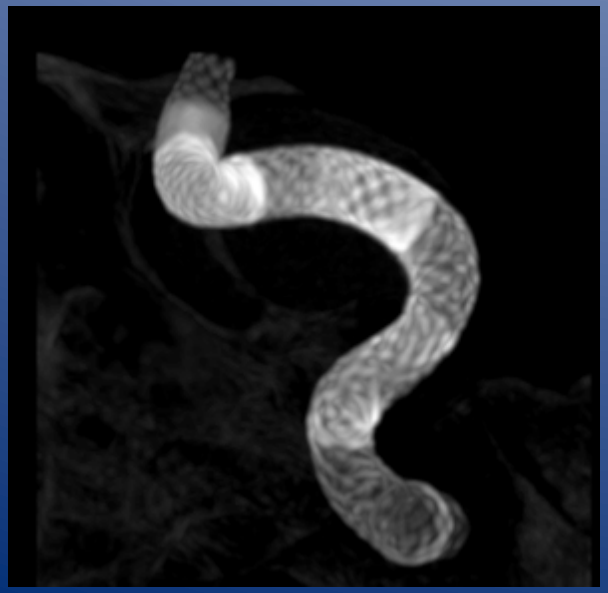


5 stents were stacked inside the ICA in a Telescoping fashion

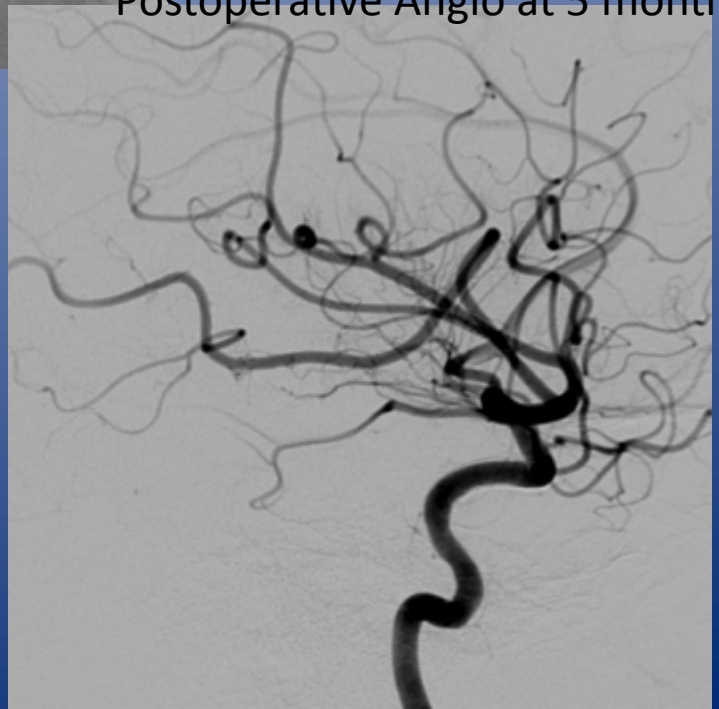




Post Deployment Shows Flow Stagnation Inside Aneurysm

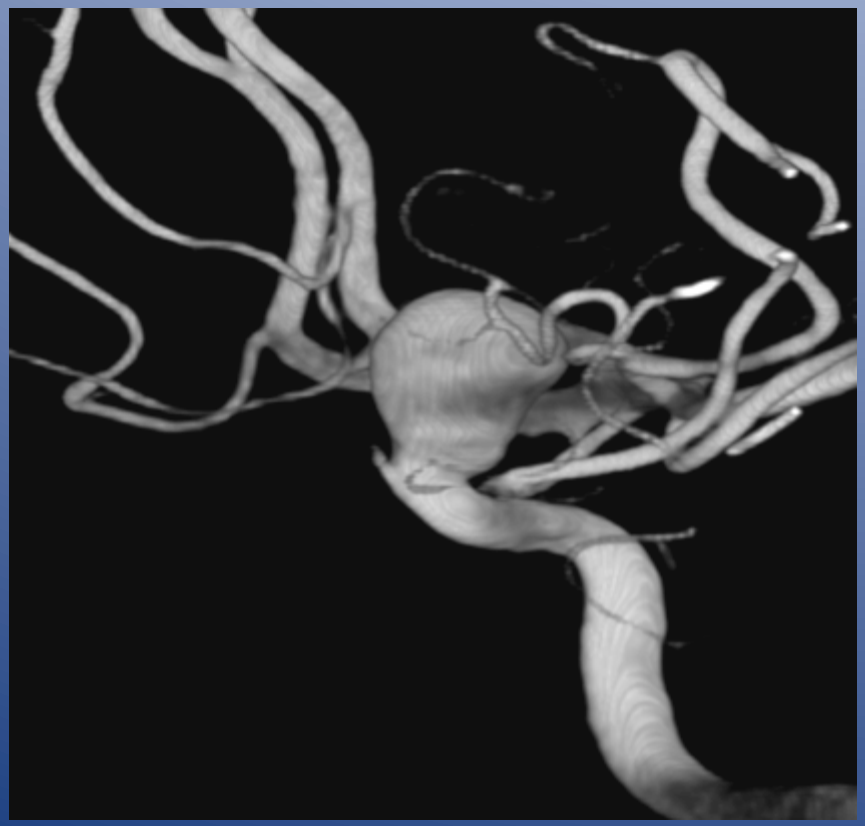


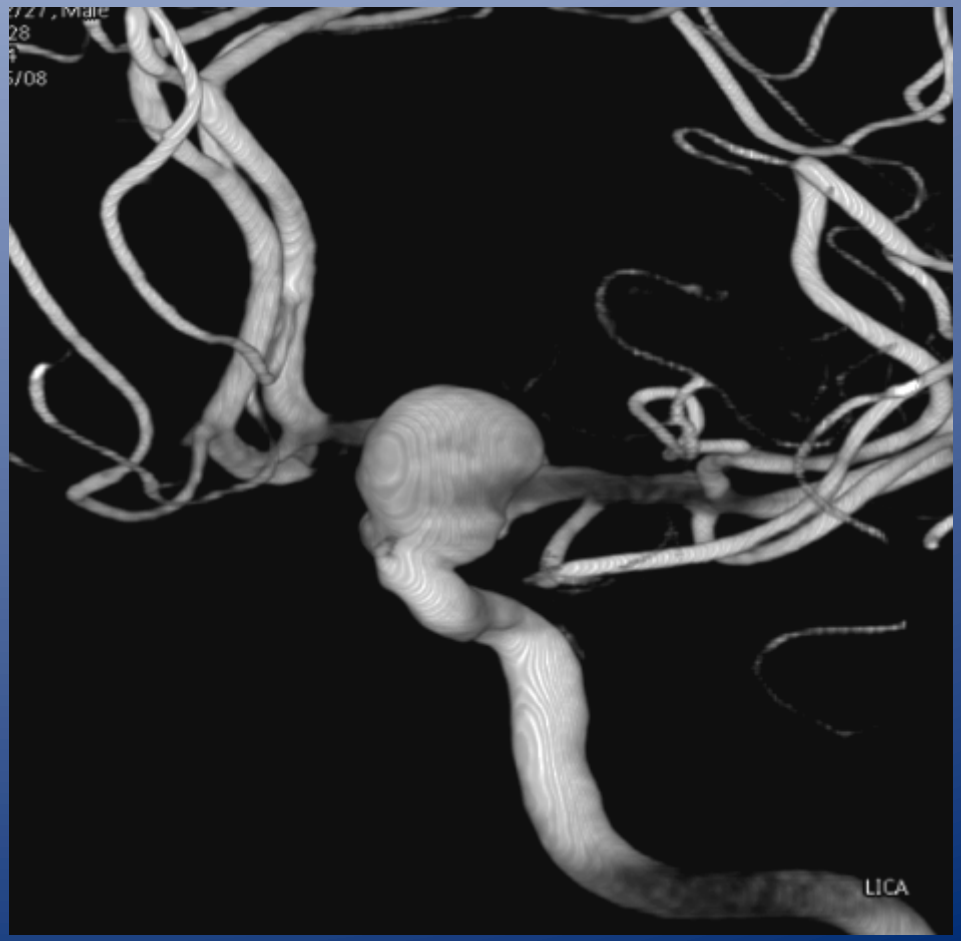
Postoperative Angio at 5 months

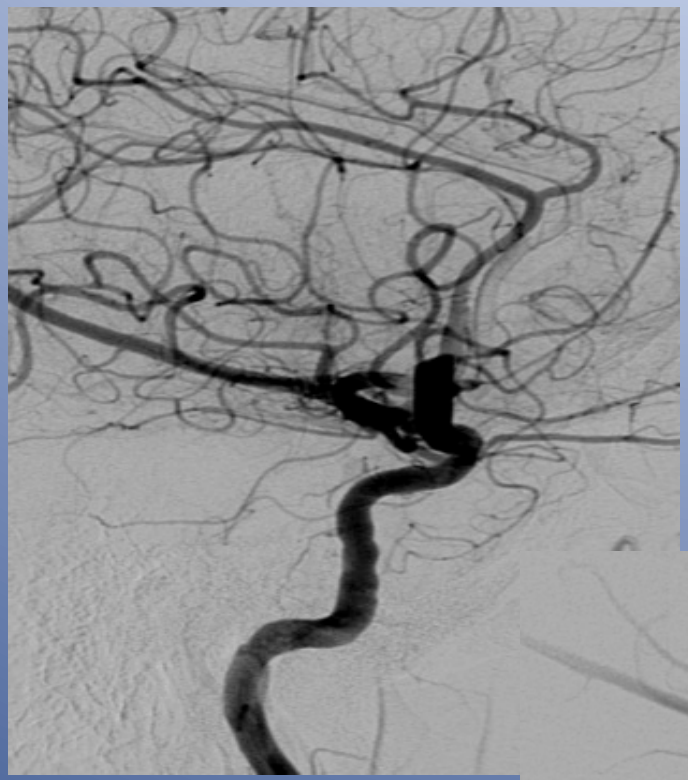


Paraclinoid Unruptured Aneurysm

51/ Male, Incidentally discovered. Blurred Vision
Aneurysm measures 12 x 12 x 13 mm; Neck 8mm,
Involves 180 ° of ICA circumference

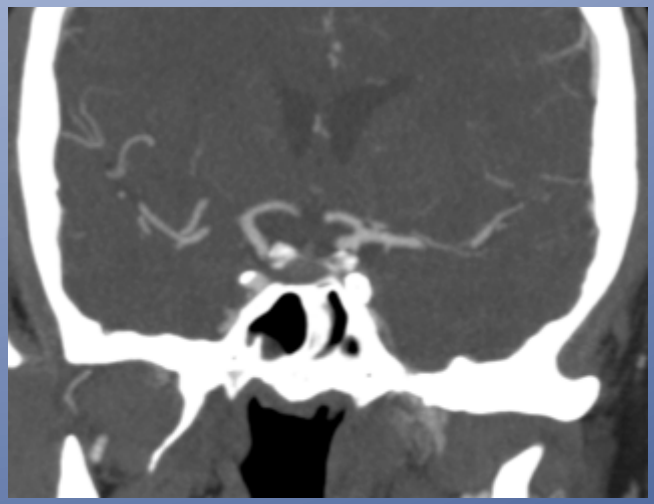


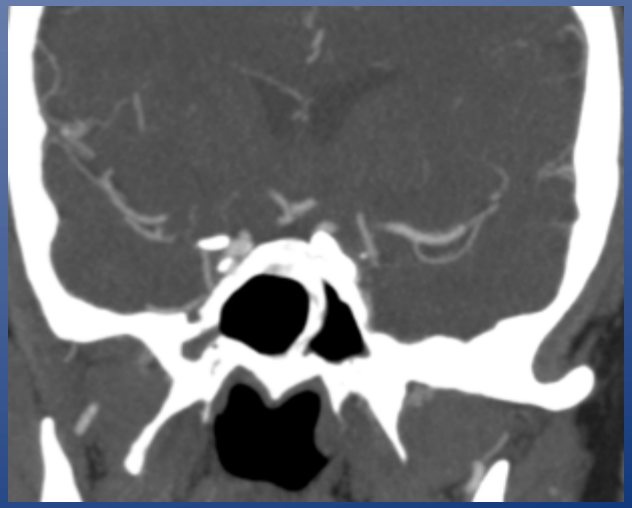




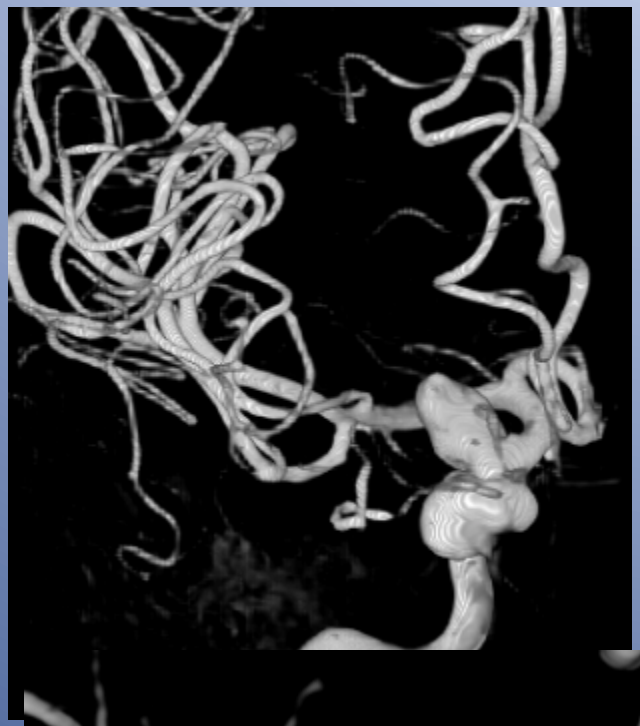
After PED Insertion
Partial Thrombosis
of Aneurysm

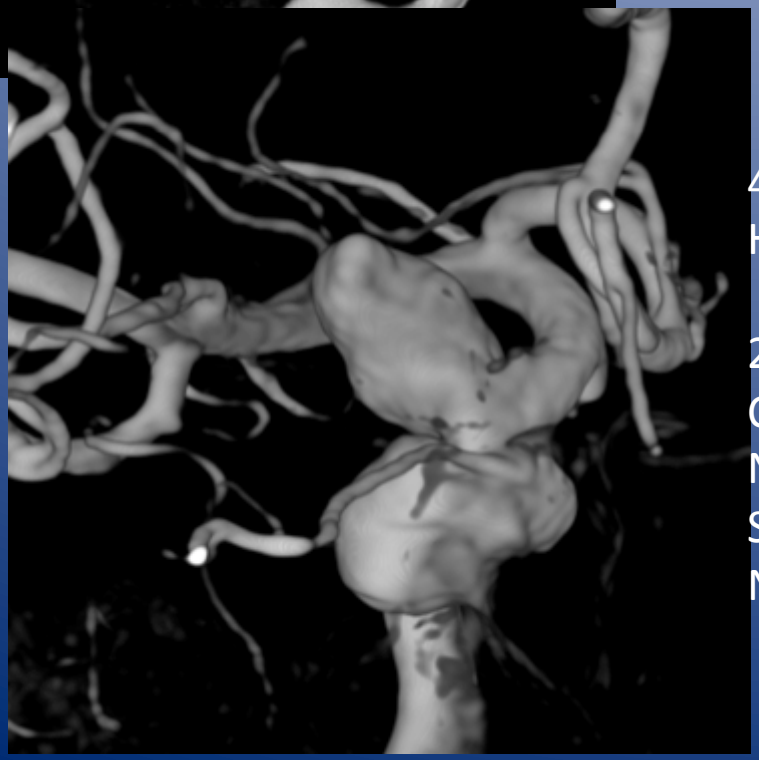
CTA at 4 months

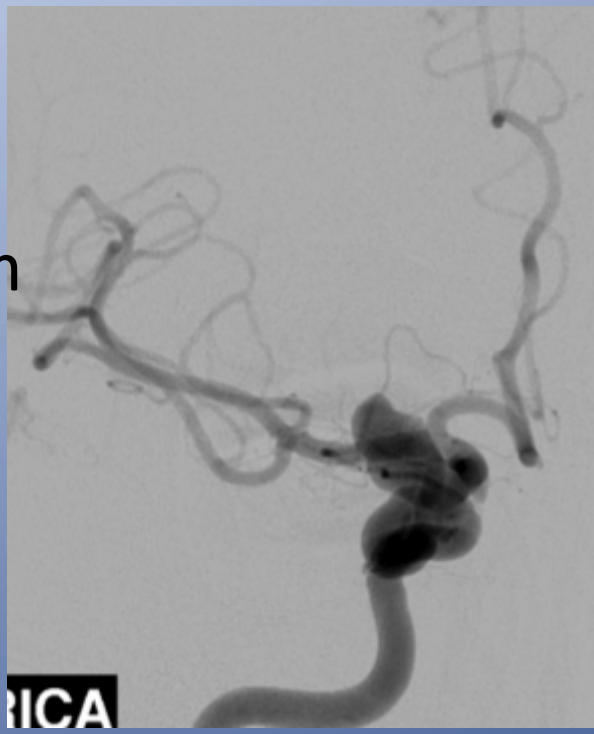


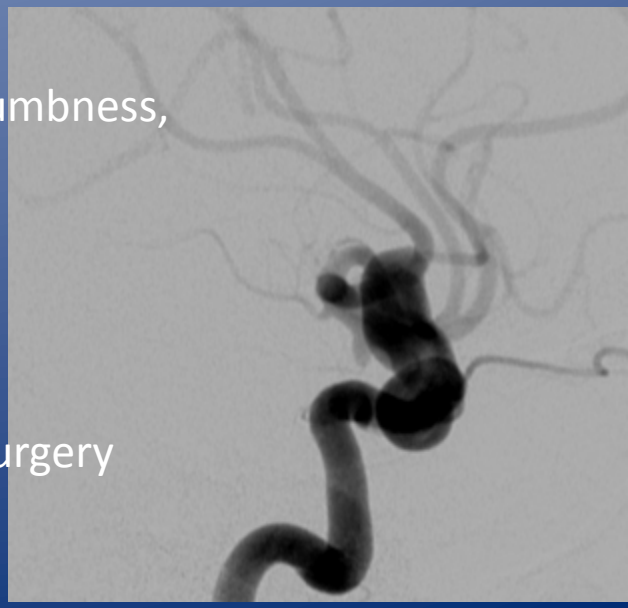


Paraclinoid and Cavernous Aneurysm









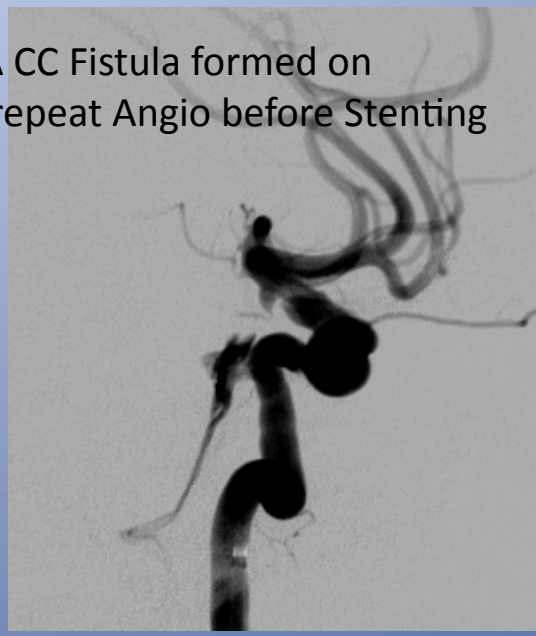
47/ F
History of Arm and Leg Numbness,
shaking of arm and leg
2 Aneurysms
CS 12.2x 8.2mm
Neck 6.5 mm
Sup Hypo 11.9x8 mm
Neck 5.1 mm; Bigger at surgery

Treatment

- Superior Hypophyseal Aneurysm was clipped, small residual Neck 10/11/2011
- RAG exposed, not used
- 5 Months Later: Pipeline Embolization Device
- Transient 3rd CN Palsy
- At 9 months: CN palsy resolved completely, working Full Time, but has very bad headaches
- Cavernous Aneurysm still filling slightly

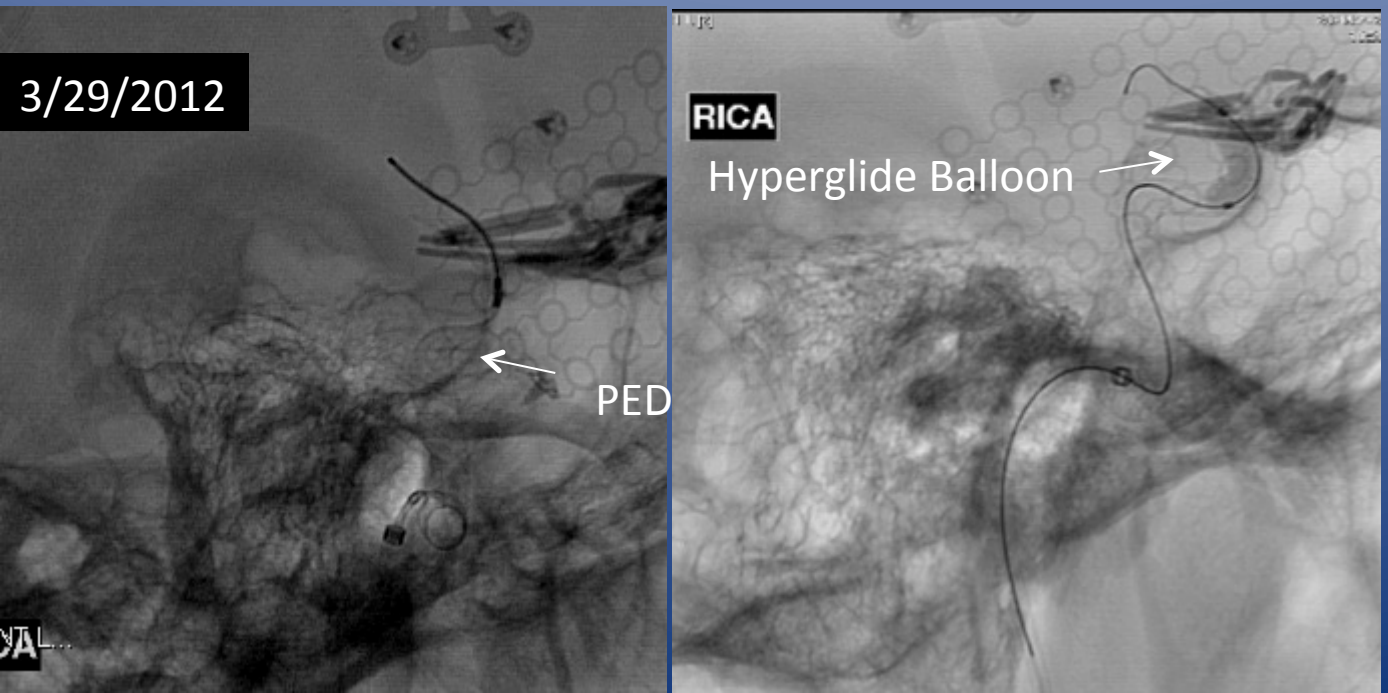
Post Clipping

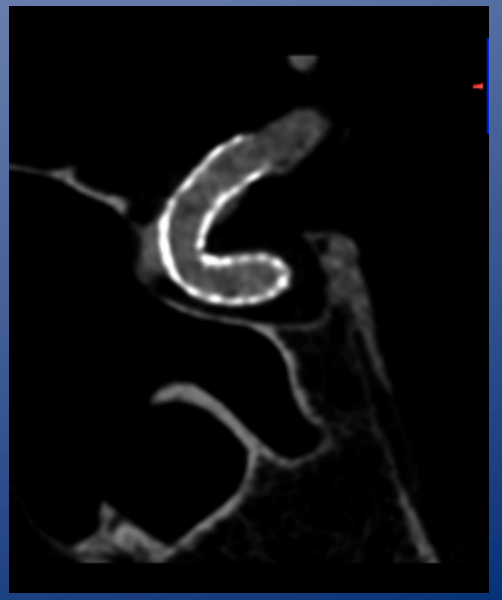
A CC Fistula formed on repeat Angio before Stenting

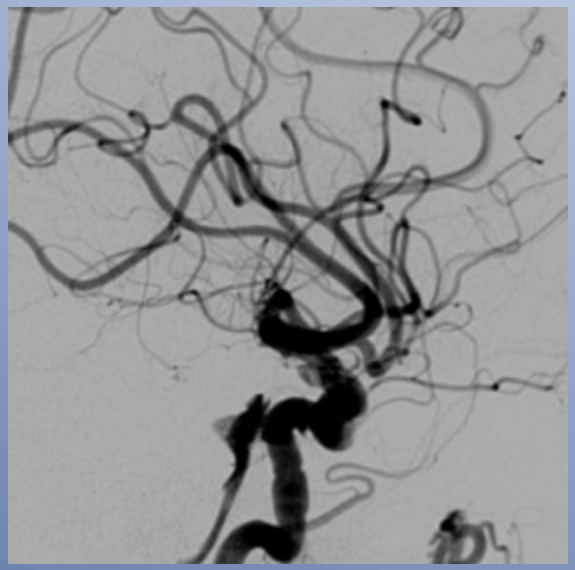


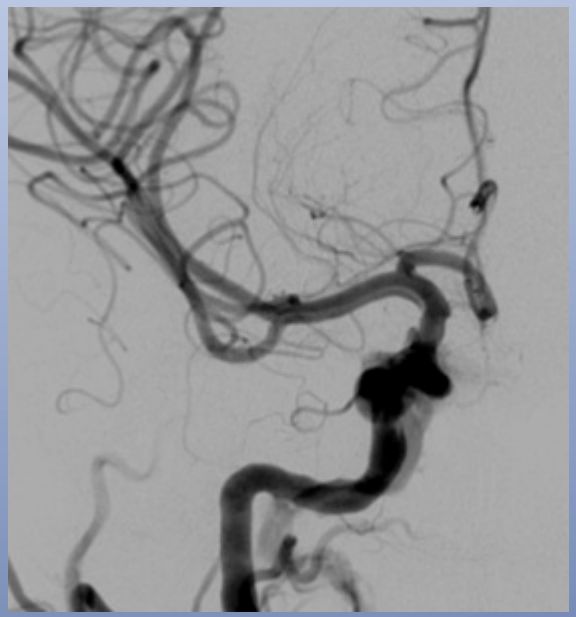
PED Deployment as a Second Treatment

Stent Had to be Opened up with a balloon





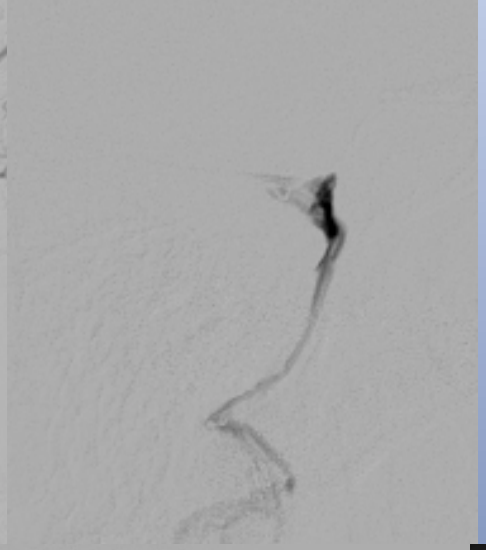




Immediate
Post-treatment

Small CCF and Residual Aneurysm at 5 months post treatment;
Patient presented with severe headaches

CCF was accessed through IPS and coils were placed



PED Treatment of Aneurysms
UW Experience 6/2011 – 7/2012

- **Total Patients** 25
- **Age** 54.1 (20 – 77)
- **Male: Female** 10:15
- **Aneurysm Shape: Saccular** 19
  Fusiform 6
- **Size**
- **Mean /Range** 10.6 mm (2 -23 mm) (including one 40mm
- **cavernous segment with multiple aneurysm)**
- **Locations : Cavernous** 6 (24%)
  Paraclinoid/ Ophthalmic 17 (68%)
  PCOM segment 1 (4%)
  Vertebral 1 (1%)
- **Number of PEDs** < 2 18 (72%)
  ≥ 2 7 (28%)

- **Resistance to Plavix** 4(16%)

Complications

- Stroke (Lacunar) 1 (4%)
  Frontal Lobe Hemorrhage 1 (4%)
  Dissection ICA 1 (4%)
  Femoral Artery 1 (4%)
  Visual Loss (partial) 1 (4%)
  Diplopia 1 (4%)
  Bruising/malena due to Antiplatelet 2(8%)
  Stent Displacement,
  Retreatment Needed 1 (4%%)
  Death None
- Total With Post Stent Angiograms 11
  Complete Aneurysm Occlusion 9 /11 (80%)
- Recovery (≥ mRS 2) 100%

PUFs Trial was Conducted in the USA to Obtain FDA approval
Total Patients = 108

Location	N (%)
Cavernous	44 (40.7%)
Paraophthalmic	35 (32.4%)
Superior Hypophyseal	10 (9.3%)
Supraclinoid	9 (8.3%)
Petrous	4 (3.7%)
Carotid cave	2 (1.9%)
Lateral clinoidal	2 (1.9%)
Posterior communicating	1 (0.9%)

	Mean	Range
Size, mm	18.2	6.2* - 36.1
Neck, mm	8.8	4.1 - 36.1

* One subject had size <10 mm

Safety Endpoint Events

Cause	N
Parent artery thrombosis with stroke	2 (1.9%)
Stenosis with stroke	1 (0.9%)
Hemorrhage (not SAH)	2 (1.9%)
Possible neurologic death	1 (0.9%)
Total	6 (5.6%)

Secondary End Point: Total Aneurysm Occlusion

- At 180 days: 82%
- At 1 year: 86%

Major Pipeline Series Reported to Date

Author/year	Total # of pts./ # of an.	Successful Deployed	Location				Complications								An. Occln AT 6 M	Re-t/m
			ICA	MCA	VB	O	Technical issues	Death	Major stroke	Minor stroke	HGE	Dissection		Optic N LOSS		
												Groin	ICA			
Saatci I et al/ 2012	191/ 251	100%	220	7	14	10	4.2% in stent stenosis	0.5%	0%	1	2IPH 1RPH	0%	0%	0%	91.2%	3.2%
Lylyk et al 2009	53/63	100%	53				10% in stent stenosis	0%	0%	0%	0%	0%	0%	0%	93%	0%
Szikora et al 2010	18/19	100%	18				5.6% stenosis	5.6%	0%	0%	5.6%	0%	0%	0%	94.4%	0
Nelson et al 2011	31/31	100%	31					0%	3.2%	0%	3.2%	0%	0%	0%	93.3%	0
Fischer et al 2011	88/101	100%	88				2.3% in stent stenosis	2%	0%	0%	4.6%	0%	0%	0%	52%	7.9%

*O=other miscellaneous aneurysms, RPH=Retroperitoneal hematoma, HGE=Hemorrhage

Author/year	Total # of pts./ total # of an.	Successful Deployment	Location				Complications								An. Occln AT 6 M	Re-t/m
			ICA	MCA	VB	O	Technica-l issues	Death	Major stroke	Minor stroke	HGE	Dissection		Optic N LOSS		
												Groin	ICA			
McAuliffe et al 2012	54/57	100%	54				3.5% in stent stenosis	0%	0	0	0	0%	0%	0%	0%	3.5%
Rohan Chitale et al 2012	36/42	100%	40	1	1		0%	0%	5.5%	11.1 %	11.1 %		2.7 %	2.7%	85%	0%
Siddiqui AH et al	25	100%	18		7		0%	16%	20%	0%	8% SAH	0%	0%	0%	0%	0%
O'Kelly CJ et al	97/97	96%	78	1	15	3	0%	6%	0%	0%	3% SAH, 3% IPH	0%	0%	0%	83%	0%
Colby GP et al	34/41	97%	37		4			0%	3%	2.7%	0%	2.7%	0%	0%	0%	0%
PUFs Trial	104/106								2%	1%	2%				82%	

Complications
Total Cases = 731

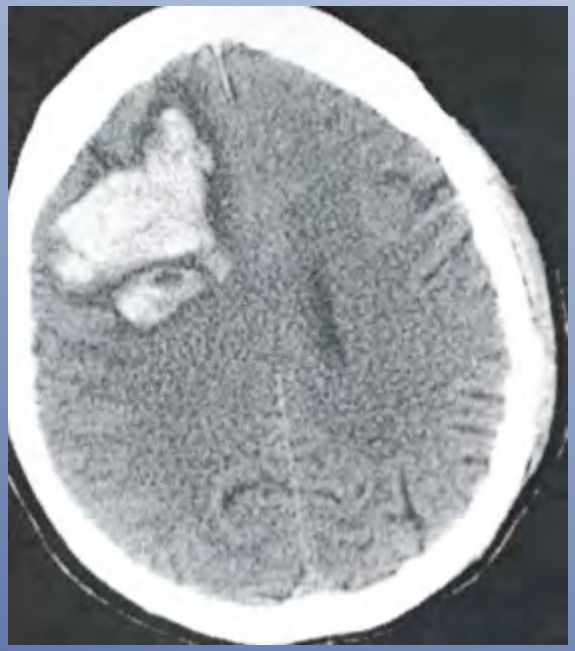
- Death 0.5 -16%
- Major Stroke 3.2-20%
- Minor Stroke 1-11.1%
- Intraparenchymal Hemorrhage 3.2-11.1%
- PED Thrombosis 4%
- Aneurysm Rupture 8%
- Optic Nerve Injury 2.7%
- ICA Dissection 2.7%
- Access Complications (Femoral Artery Dissection, retroperitoneal Hemorrhage 2-5%

Complications after PED Embolization

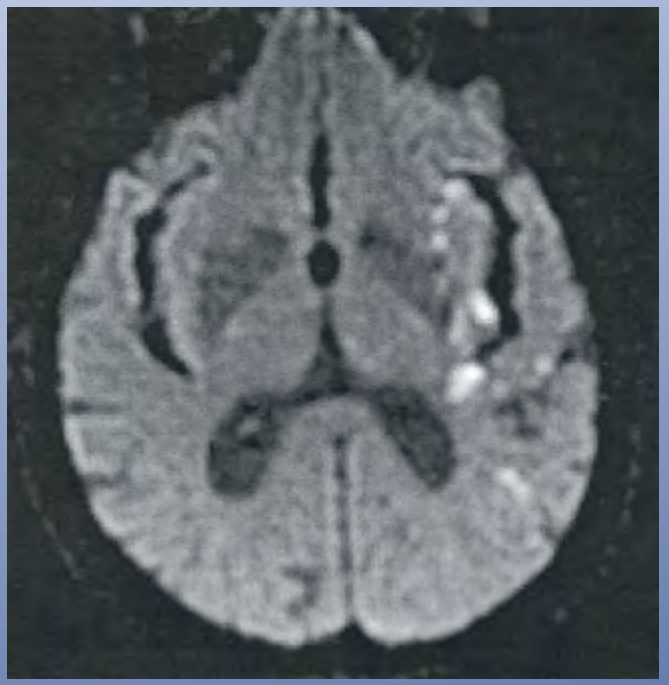
- Rupture of a previously Unruptured Aneurysm
- Intracerebral Hemorrhage (ipsilateral hemisphere, contralateral hemisphere)
- Emboli from the Stent site
- Carotid Dissection
- Femoral Artery Dissection and Thrombosis
- Delayed Stent Thrombosis, stenosis
- Delayed Stent Retraction, with Aneurysm Refilling

Hemorrhagic Complications

- Intra parenchymal Hemorrhage: Possibly due to embolic stroke, combined with Antiplatelet activity
- Also occur on the Contralateral Side from the stent
- Aneurysmal Hemorrhage (Unruptured Aneurysms): Due to alterations of flow jet after the PED.
- Some operators are placing a few coils in addition to PED inside supra ophthalmic aneurysms



Right Frontal ICH, 2 days after PED for Cavernous ICA Aneurysm



MRI of patient with post-procedure headache, Showing Asymptomatic Emboli

Single Center Experience with Pipeline Stent: Feasibility, Technique and Complications
Rohan Chitale, MD et al. Neurosurgery. 2012 Jul 31

Autopsy Study of ICH

In 3 patients showed Embolic material of foreign bodies inside the Artery, suggesting that the Hemorrhage was induced by a stroke, combined with Significant Antiplatelet activity

**Deshmukh V et al. Histopathological assessment of delayed ipsilateral parenchymal hemorrhages after the treatment of paraclinoid aneurysms with the pipeline embolization device. Neurosurgery. 2012 Aug;71 (2):E551-2*

Off Label Use of Pipeline

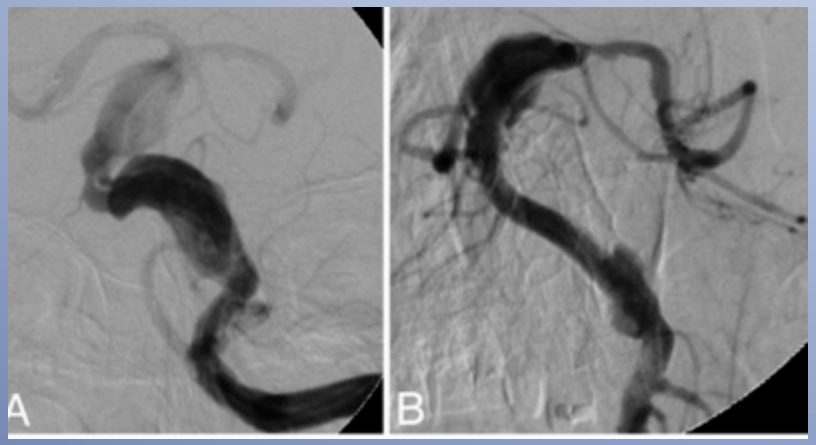
- ICA distal to PCOM – No special complications reported, A Choroidal, fetal PCOM arteries preserved
- MCA – Aneurysm Thrombosis reported
- Vertebral Artery – Successful (one of our cases, others, thrombosis reported)
- Mid Basilar Artery (6/7 died or severely disabled) AH Siddiqui et al. (**Panacea or problem: flow diverters in the treatment of symptomatic large or giant fusiform vertebrobasilar aneurysms. J Neurosurg 116:1258–1266, 2012)*

Giant fusiform distal basilar trunk aneurysm.

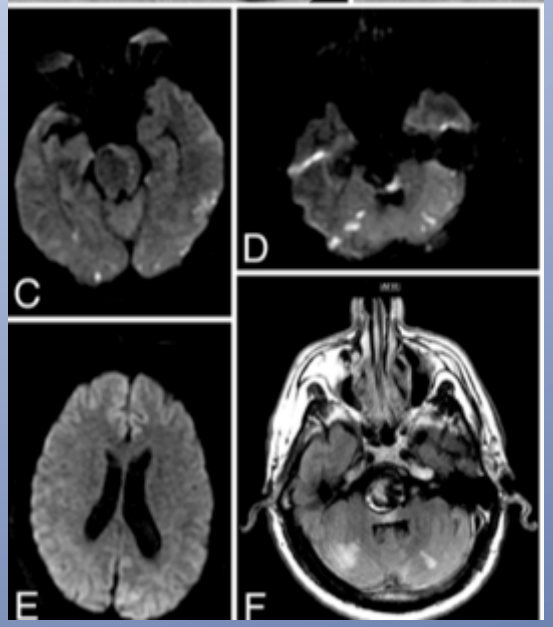
3 PEDs (4.0 × 20 mm, 4.0 × 12 mm, and 3.75 × 12 mm) with no coil embolization

Aneurysm rupture and active extravasation from the dorsal wall of the aneurysm morning after the procedure. The patient quickly progressed to the state of brain death

**Complications After Treatment With Pipeline Embolization for Giant Distal Intracranial Aneurysms With or Without Coil Embolization Siddiqui, Adnan H. et al. Neurosurgery. 2012 Aug;71(2):E509-13.*



Left VA angiogram demonstrating a large vertebrobasilar fusiform aneurysm. B: Post-treatment AP angiogram after 9 PED's were placed.

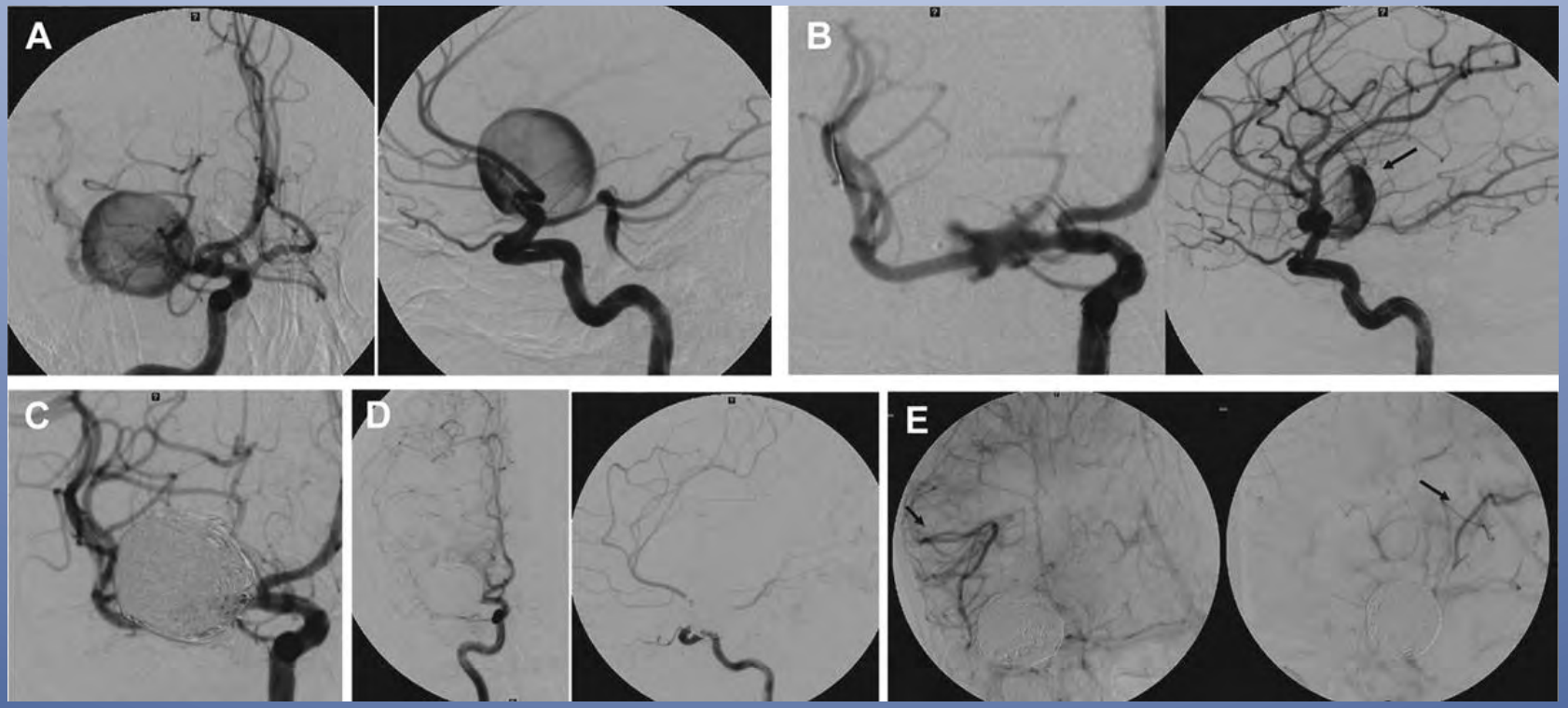


C–F: Magnetic resonance images demonstrating bilateral cerebellar infarcts and ischemia in the medial left and right occipital lobes

H-I: Post-treatment angiograms

- Patient developed hemiplegia,
- Dysconjugate gaze, was non-verbal
- Dependent on ventilator for 2 weeks
- Discharged to SNF, mRS5.

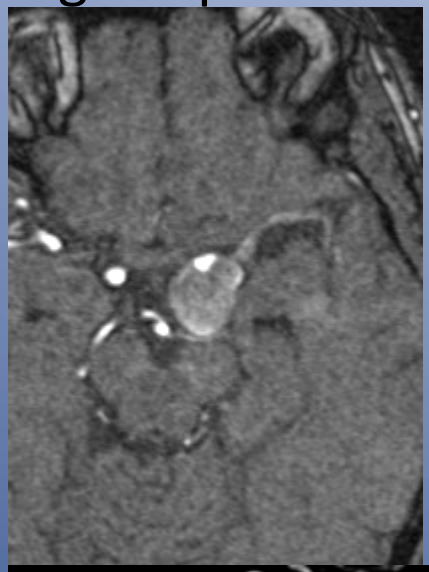
*AH Siddiqui et al. Panacea or problem: flow diverters in the treatment of symptomatic large or giant fusiform vertebrobasilar aneurysms. J Neurosurg 116:1258–1266, 2012

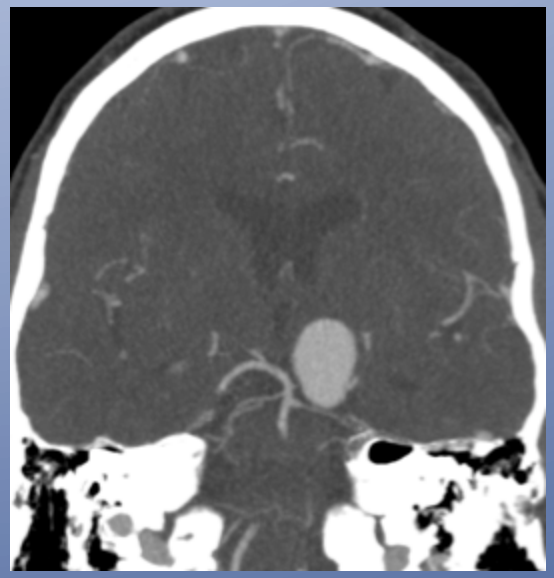


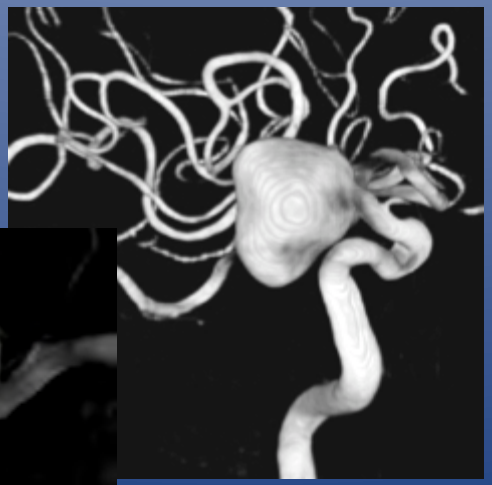
Giant MCA Aneurysm treated with Coils and PED
Stent Thrombosis
Patient had Good Collateral Flow
Suffered a Stroke, but with good recovery

**Complications After Treatment With Pipeline Embolization for Giant Distal Intracranial Aneurysms With or Without Coil Embolization. Siddiqui, Adnan H. et al. Neurosurgery. 2012 Aug;71(2):E509-13.*

75y old man with I month Blurry vision, and Partial CN 3 Paralysis Large Supraclinoid ICA Fusiform Aneurysm

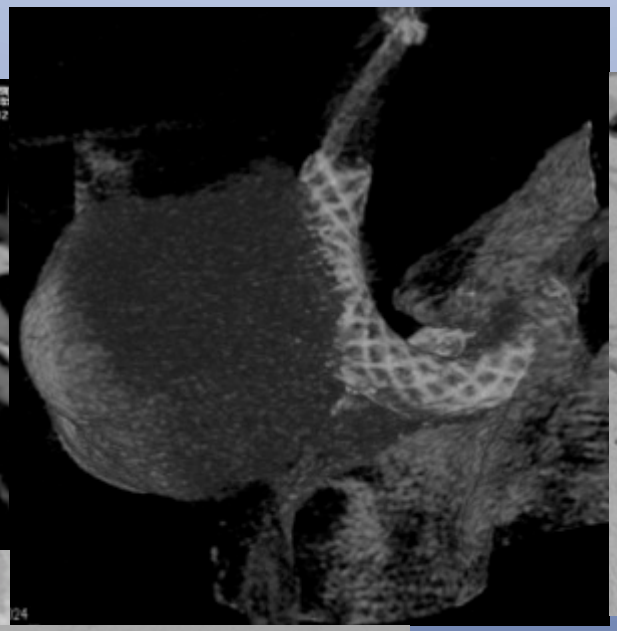


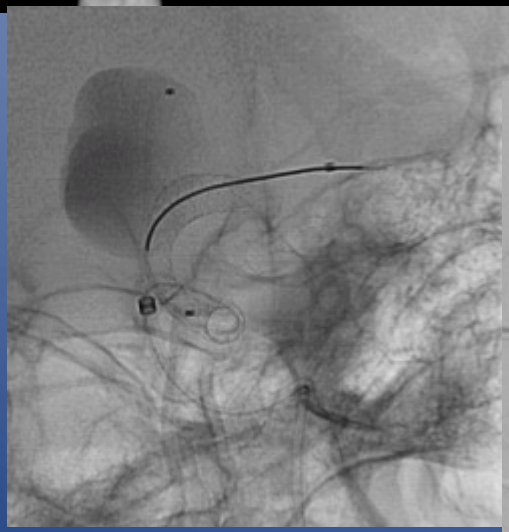


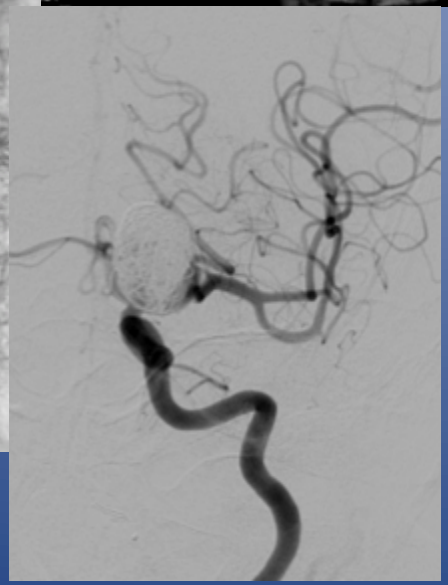


Angiogram revealed:

- 20 x 17 x 12 mm left ICA communicating segment Fusiform aneurysm
- Fetal origin of Lt. PCA
- Patient decided to have PED treatment



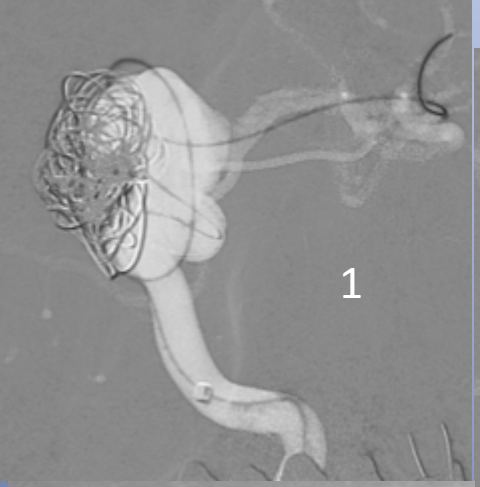


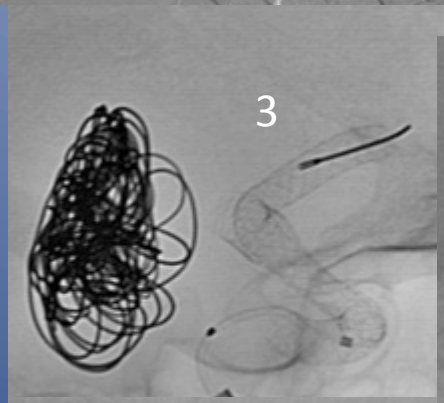


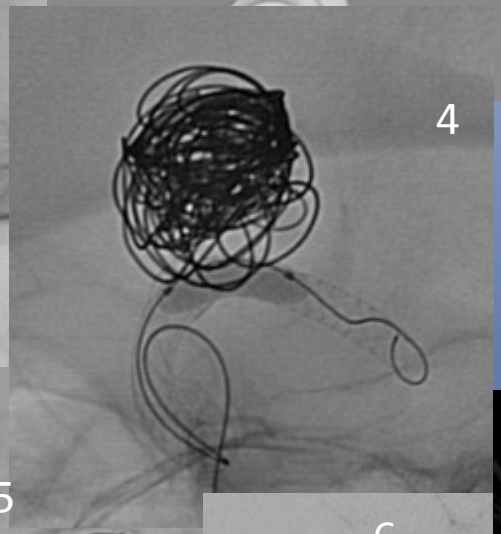
- Pt. underwent placement of PED and Coiling of the aneurysm on 10/2/2012.

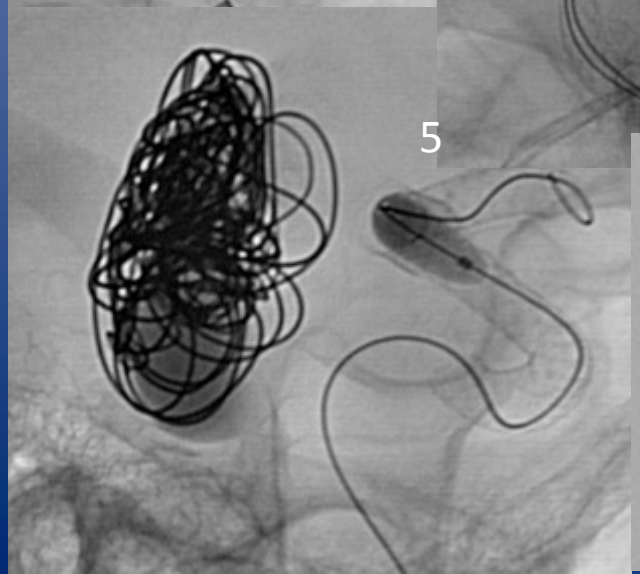
- Post-t/m image showed stagnation
- of blood and no residual.

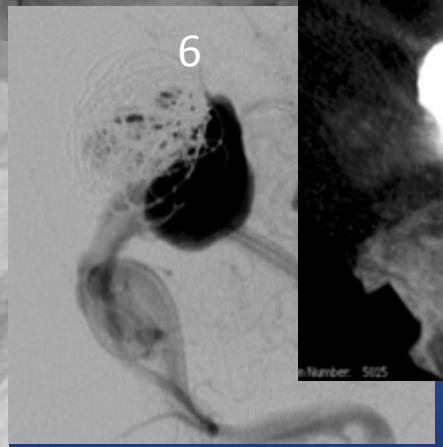
- Patient returned in 3 months with progressive headache, worsening ptosis and dilated fixed pupil.
- Imaging showed progressive growth of the ICA aneurysm and
- Retraction of the PED into the lumen of the aneurysm



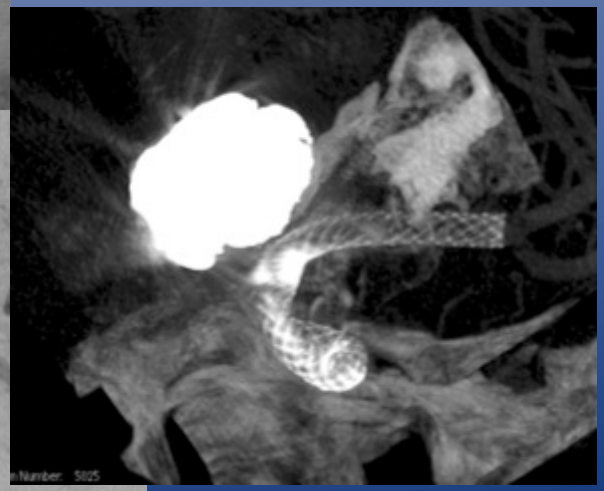








- Marksman microcatheter was placed into the lumen of the MCA.
- Solitaire FR retriever was used to anchor the Marksman catheter.
- Second PED was placed into the prior stent.
- Balloon dilatation of the PED was performed to ensure apposition.
- Stagnation of flow noted at the end of the procedure.
- Pt. developed RUE and RLE weakness on the 2nd day post treatment.
- MRI showed multiple punctate areas of restricted diffusion in the L MCA.
- Pt. discharged home with outpatient PT.



Our Bypass Experience (2005 -2012) was Reanalyzed

- 3 Categories
- Ruptured Aneurysms 38
- Unruptured Aneurysms
  - > Pipeline Eligible 19
  - > Pipeline Not Eligible 45

Total Cases (2005 – 2012) = 102

Location of aneurysms	PED Eligible Unruptured aneurysms	PED non-eligible Unruptured aneurysms	Ruptured aneurysms
ICA Paraclinoid/Ophthalmic Cavernous ICA Others	 11 7 1	 2(with prior stents) 2	 7 2
MCA	0	19	13
ACA	0	8	9
BT	0	6	1
VA	0	3	
Other posterior circulation	0	5	6

Pipeline Eligible Aneurysms

Total number of patients	**19**
Age (mean, median, range)	**55 (20 – 84)**
Complete occlusion of the aneurysm	**100%**
Graft (RAG/SVG)	**14/5**
Graft Stenosis	**2/19**
(1 non-flow limiting, 1 required angioplasty)	
Graft occlusion	**0/19**
Patency of bypass	**100%**
Follow-up outcomes 1 YR:	
mRS 0-2	**18/19 (95%)**
mRS 3	**1/19 (5%)**
	(Same as Pre treatment)

Complications

Hematoma 1(5.2%) (Temporal lobe, evacuated without sequelae)

Infection 1 (5.2%) (Wrist)

Conclusions

- The Treatment of Aneurysm is Evolving
- Both Microsurgery and Endovascular Surgery are Important in their Management