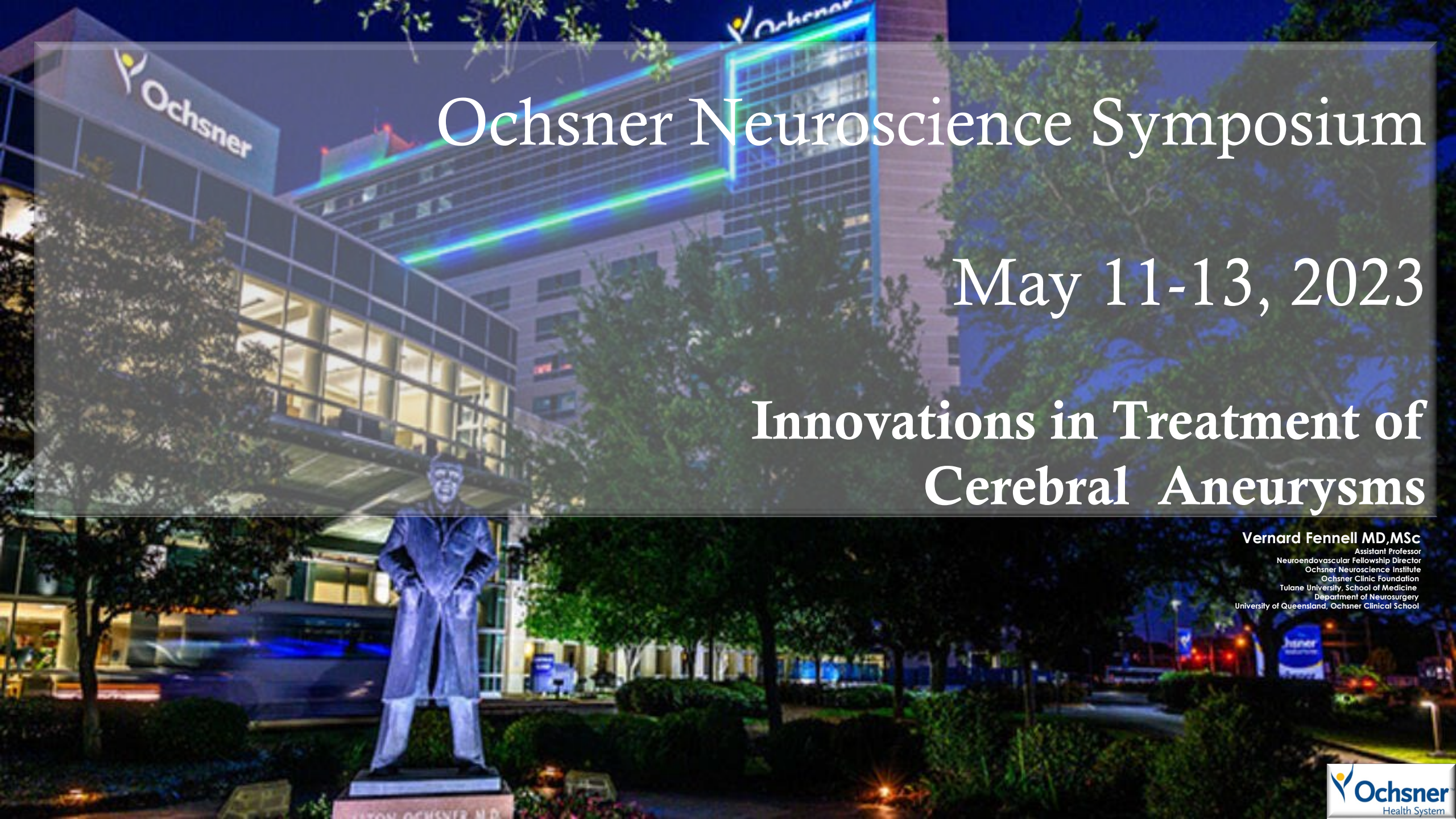


Ochsner Neuroscience Symposium

May 11-13, 2023

Innovations in Treatment of Cerebral Aneurysms

Vernard Fennell MD,MSc
Assistant Professor
Neuroendovascular Fellowship Director
Ochsner Neuroscience Institute
Ochsner Clinic Foundation
Tulane University, School of Medicine
Department of Neurosurgery
University of Queensland, Ochsner Clinical School

Ochsner Health System

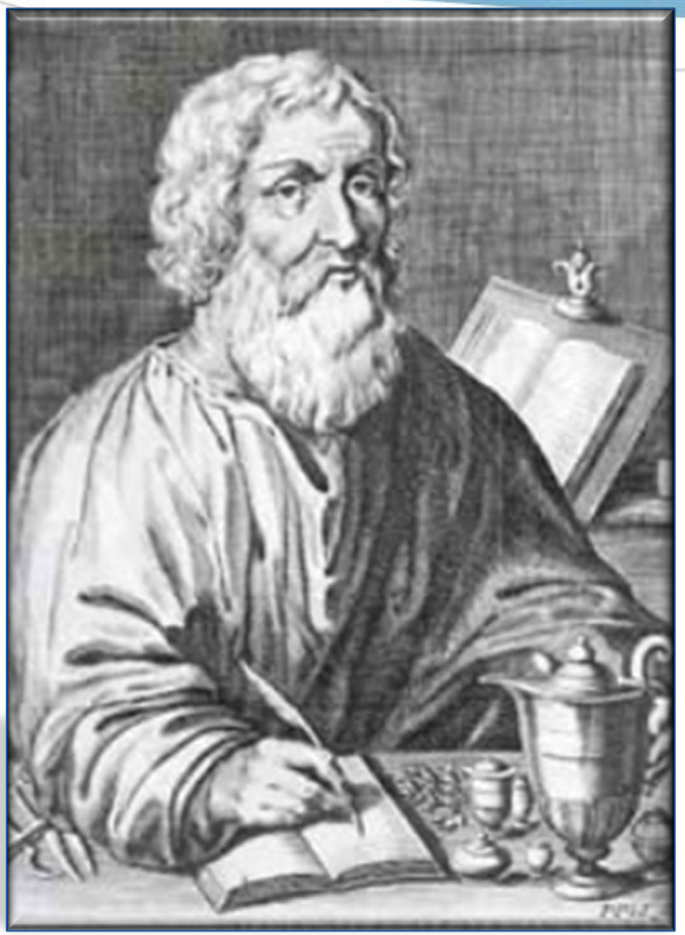

THE UNIVERSITY
OF ARIZONA

Overview

Innovations in Treatment of Cerebrovascular disease

- Where we've been
- Cerebral Aneurysm treatment
- Endovascular Innovations
- Microsurgery for Aneurysms
- Future Directions

Ruptured Intracranial Aneurysm – Subarachnoid Hemorrhage

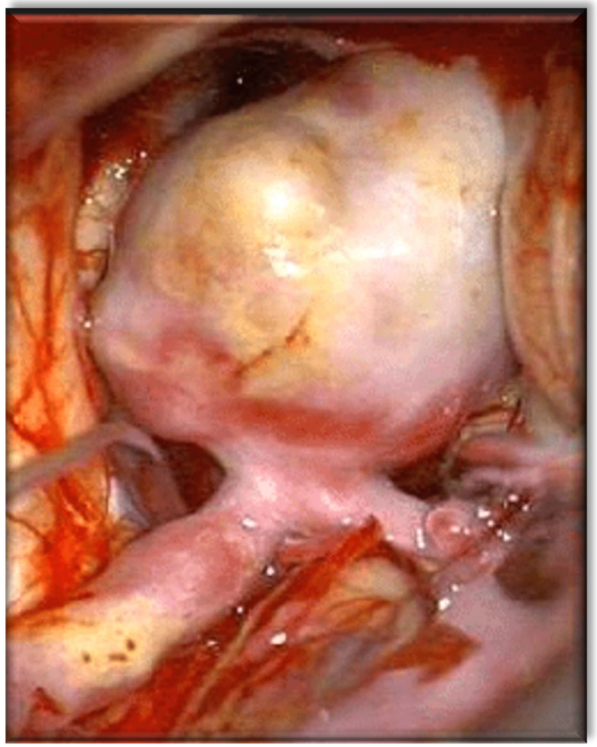


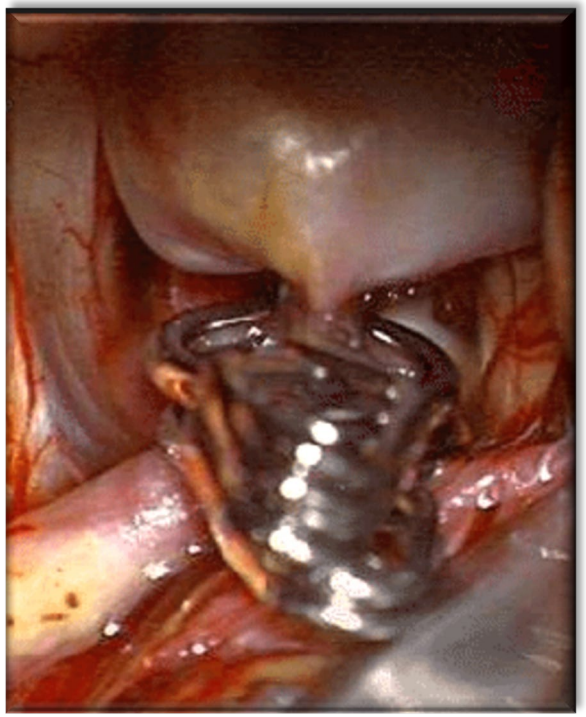
"When persons in good health are suddenly seized with pains in the head, and straightway are laid down speechless, and breathe with stertor, they die in seven days, unless fever comes on."

- - Hippocrates, in *Aphorisms*

Aneurysm Epidemiology

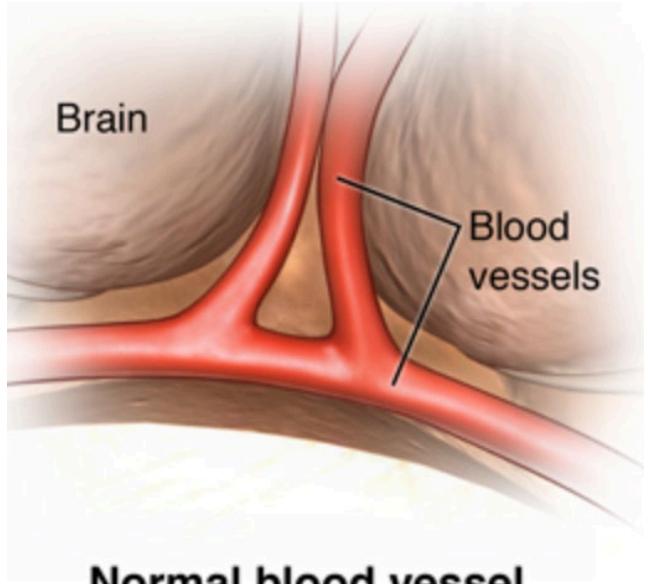
- Intracranial Aneurysms
  - Prevalence
    - 3.2% Population
    - US population 325,145,963
    - ~ 10.4 million aneurysms
- Aneurysmal SAH
  - 6-16 /100,000
  - ~30,000 in US annually



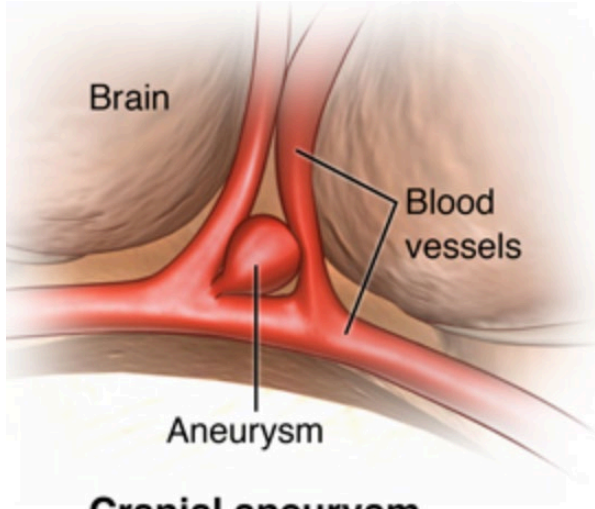


Epidemiology

- Aneurysm rupture
  - Up to 0.7% of all deaths
  - High Mortality and Morbidity
- Location
  - 85% in anterior circulation
- Female preponderance
  - Nearly 60% of total
  - 2:1 ratio >50y/o

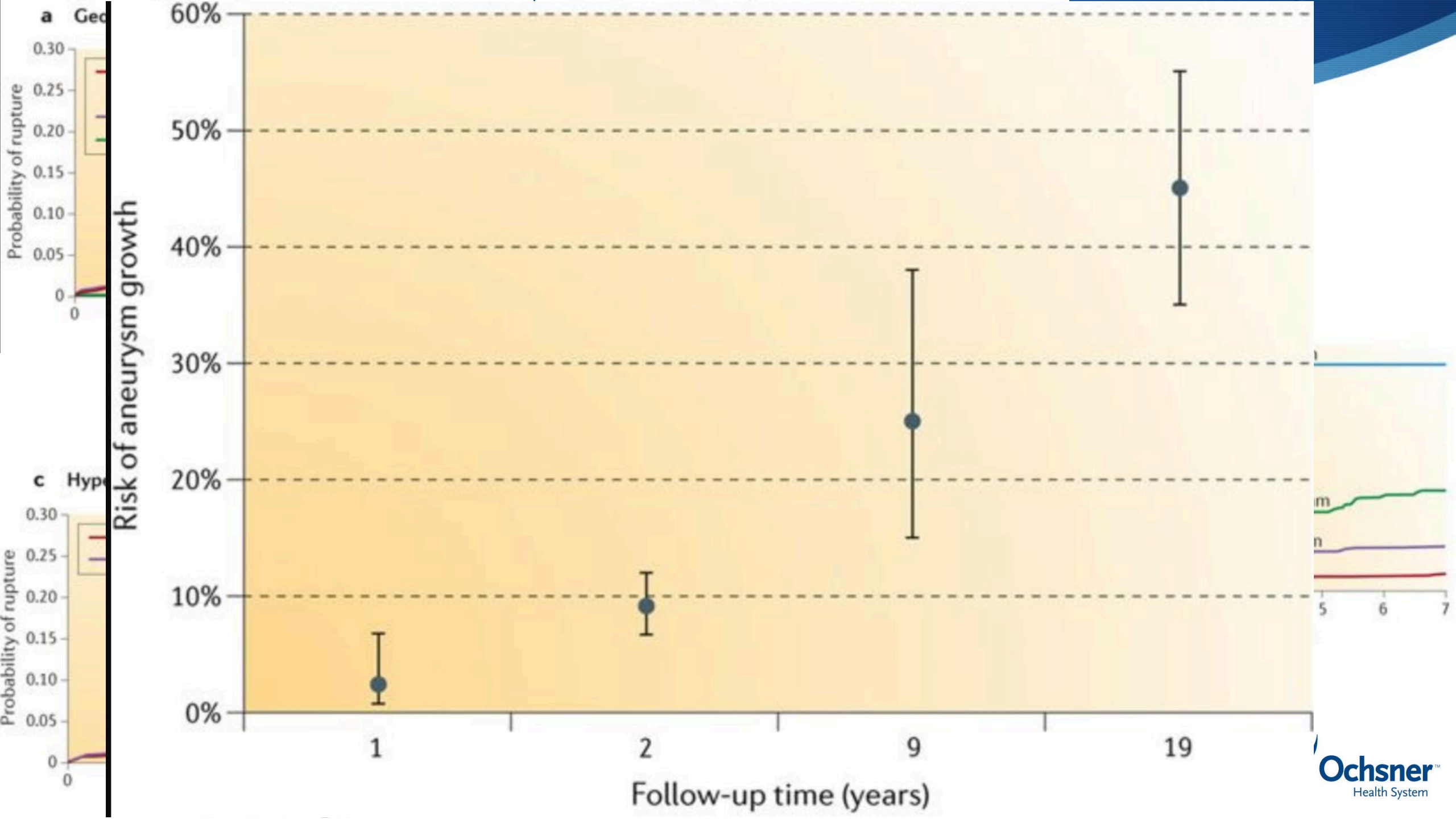


Normal blood vessel



Cranial aneurysm

Ochsner Health System


a
Probability of rupture
0.30
0.25
0.20
0.15
0.10
0.05
0
0
c
Probability of rupture
0.30
0.25
0.20
0.15
0.10
0.05
0
0
Risk of aneurysm growth
60%
50%
40%
30%
20%
10%
0%
1
2
9
19
Follow-up time (years)
m
n
5
6
7

5-Year Aneurysm Rupture Risk: Size and Location

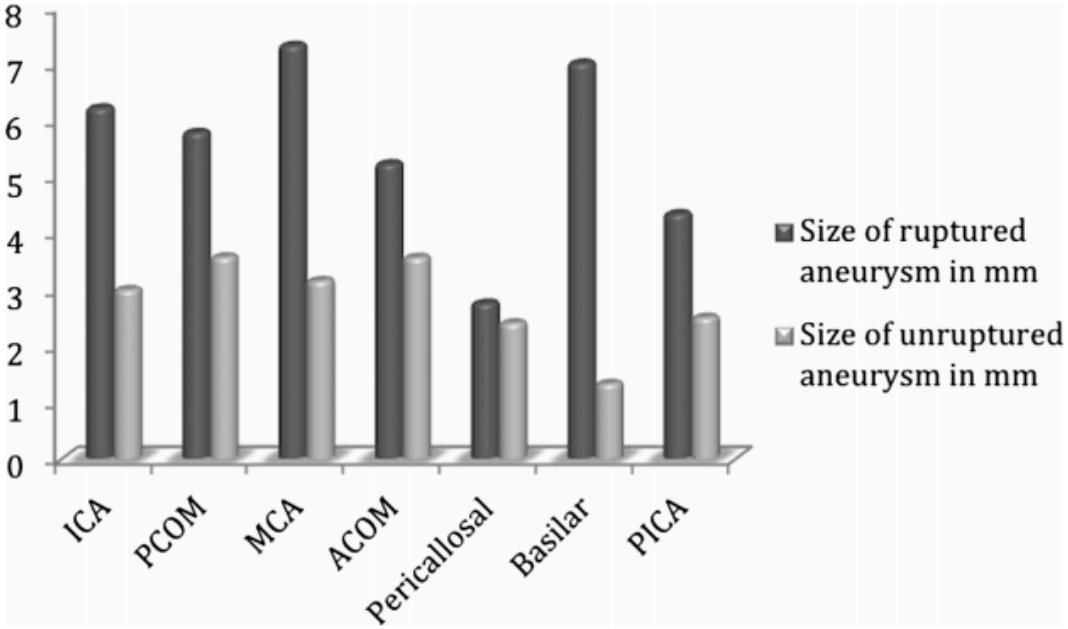


Figure 3 Discrepancy in size (in mm) between ruptured and unruptured aneurysms in patients with multiple aneurysms and subarachnoid hemorrhage. ACOM, anterior communicating artery; ICA, internal carotid artery; MCA, middle cerebral artery; PCOM, posterior communicating artery; PICA, posterior inferior cerebellar artery.

Anterior Vessel Aneurysms Posterior Vessel Aneurysm

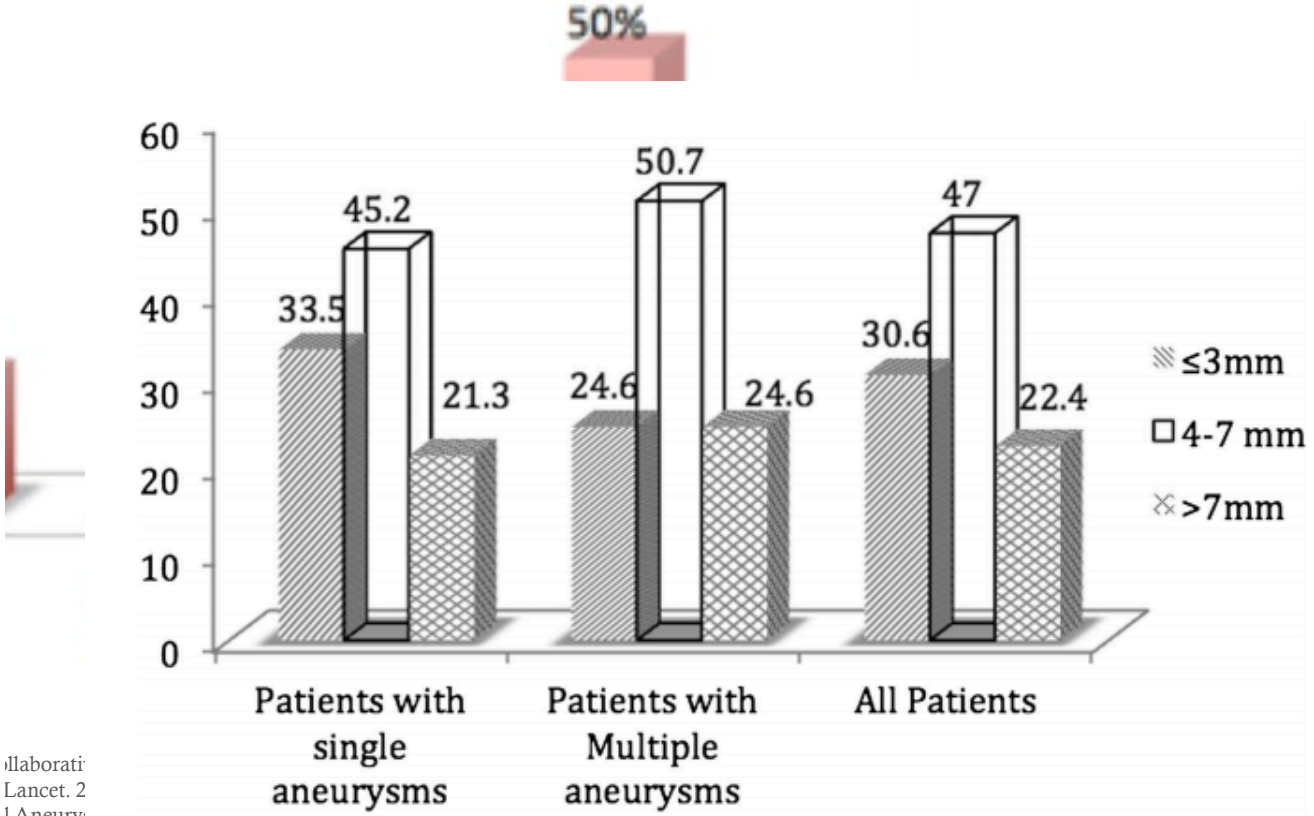
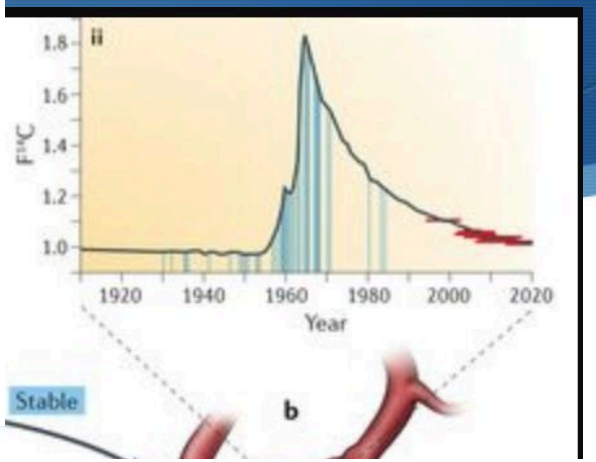


Figure 1 Relative incidence of ruptured (treated) very small aneurysms, small aneurysms and other aneurysms in patients with single aneurysms, patients with multiple aneurysms and in all patients.

Biology of Saccular Cerebral Aneurysms: A Review of Current Understanding and Future Directions

*Vernard S. Fennell, M. Yashar S. Kalani, Gursant Atwal, Nikolay L. Martirosyan and Robert F. Spetzler**

Department of Neurosurgery, Barrow Neurological Institute, St. Joseph's Hospital and Medical Center, Phoenix, AZ, USA



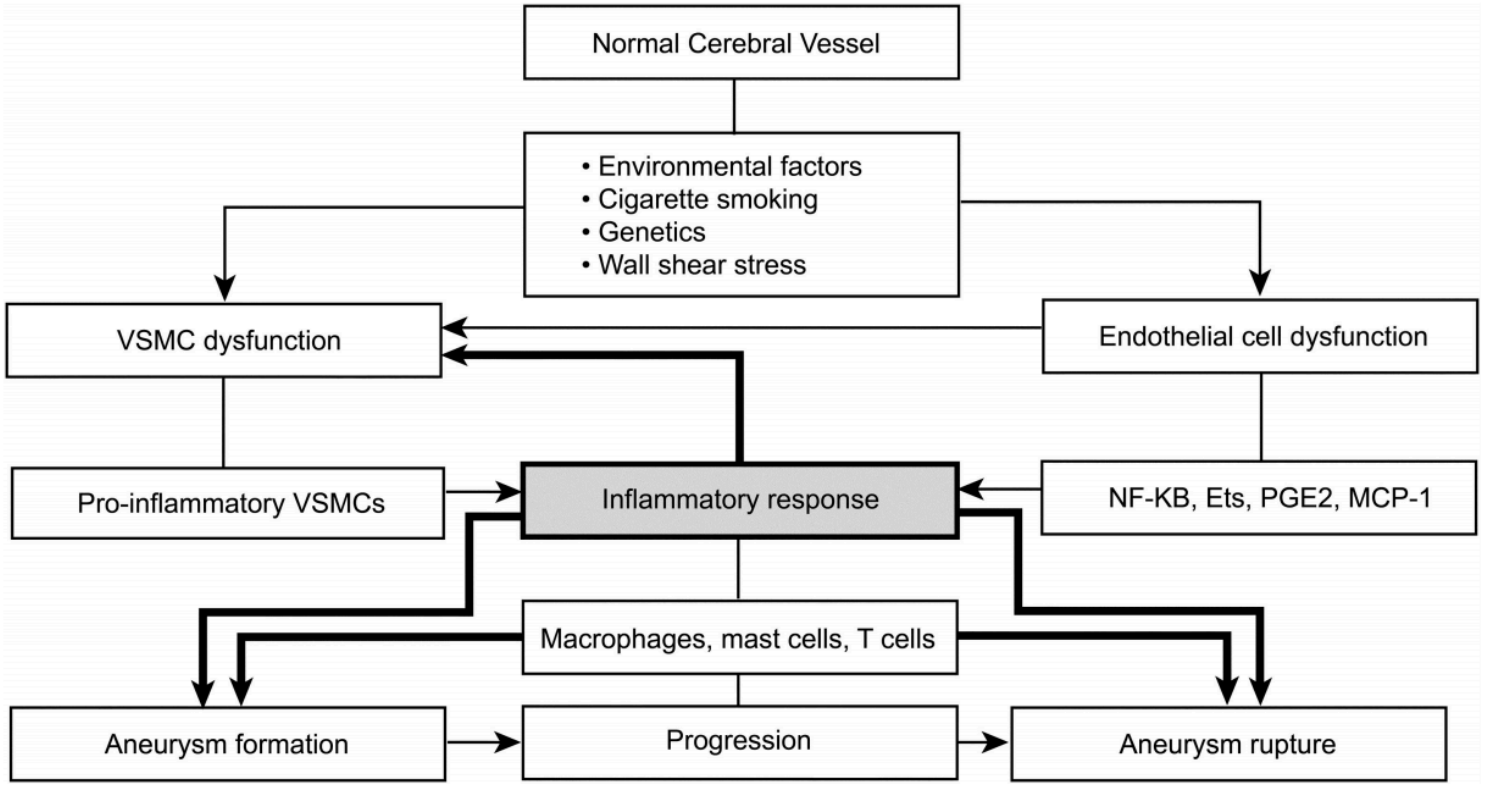
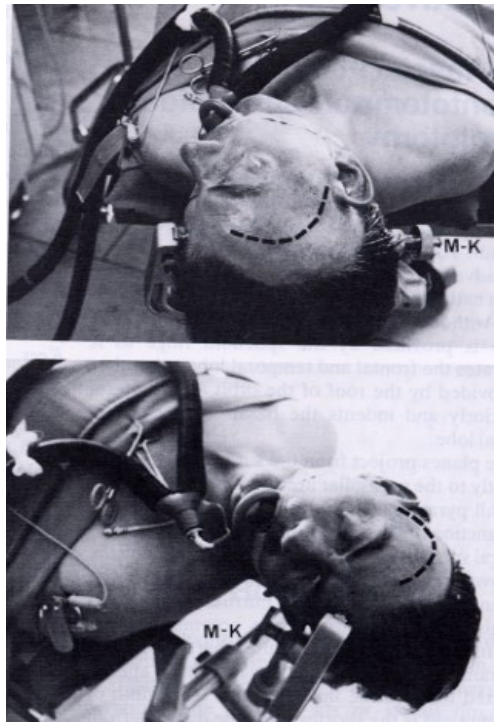


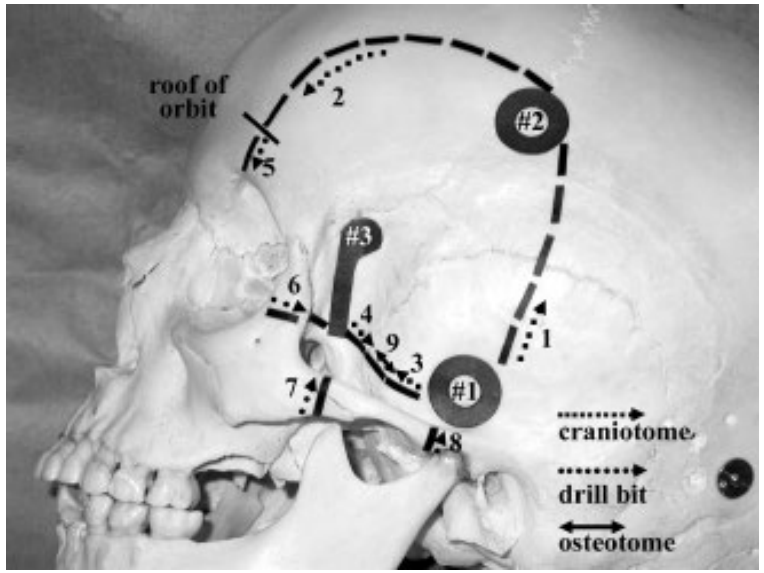
FIGURE 1 | Environmental factors and immunologic pathways and mediators involved in aneurysm formation. Shading emphasizes the contribution of inflammation to the process of aneurysm formation. VSMC, vascular smooth muscle cell; NF-κB, nuclear factor-κB; Ets, E-twenty-six family transcription factors; PGE2, prostaglandin E2; MCP1, monocyte chemoattractant protein 1. *Used with permission from Barrow Neurological Institute, Phoenix, AZ, USA*.

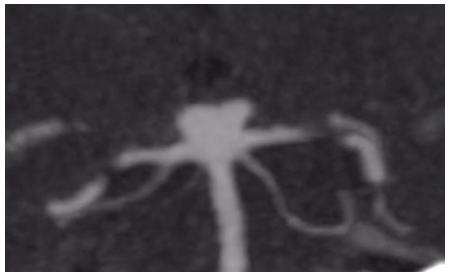
Ochsner Health System

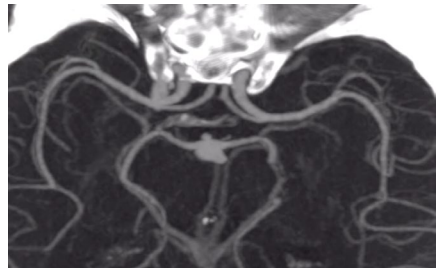
Intracranial Aneurysms

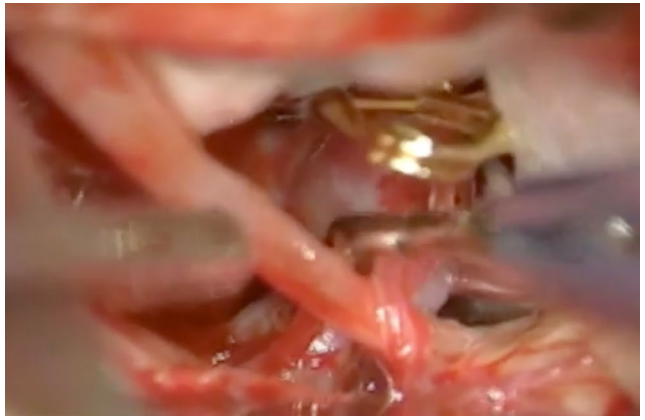
How do we treat them???

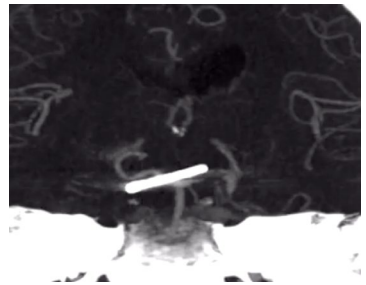




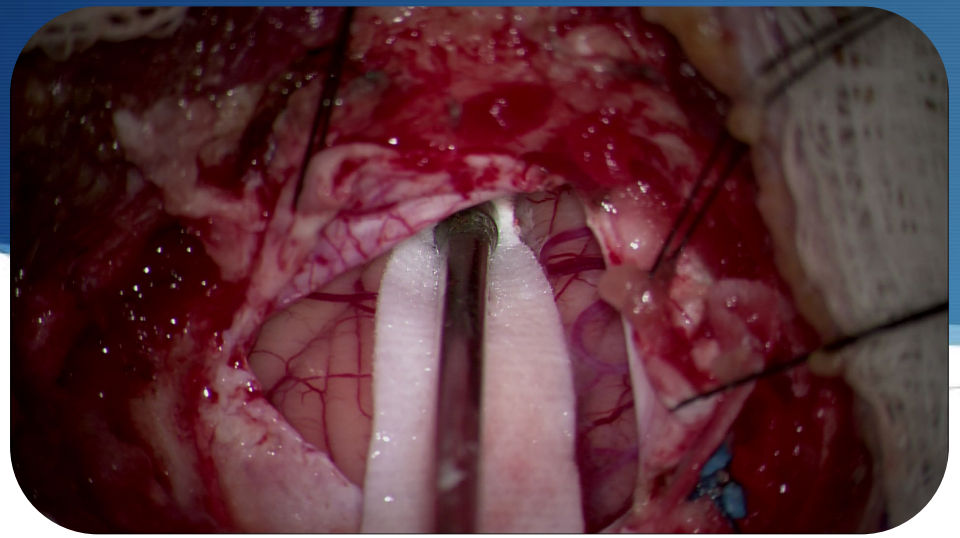


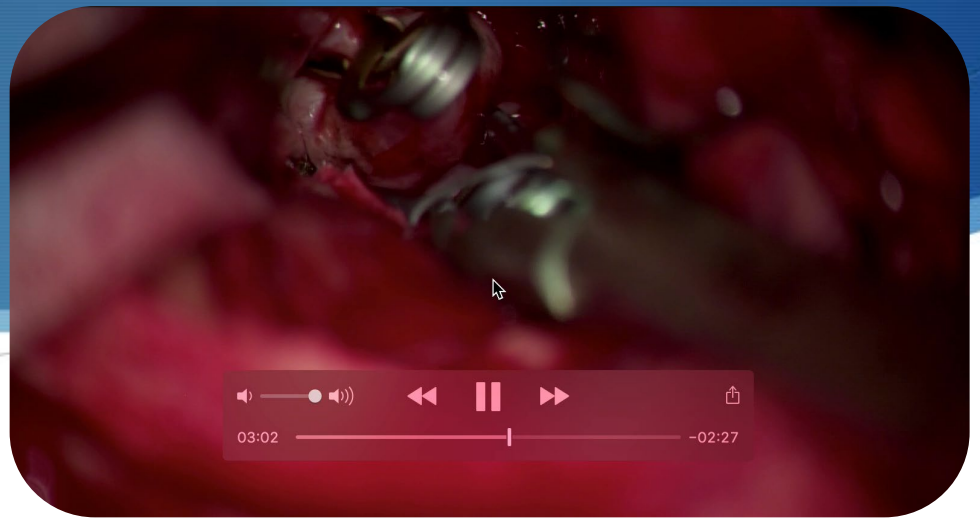


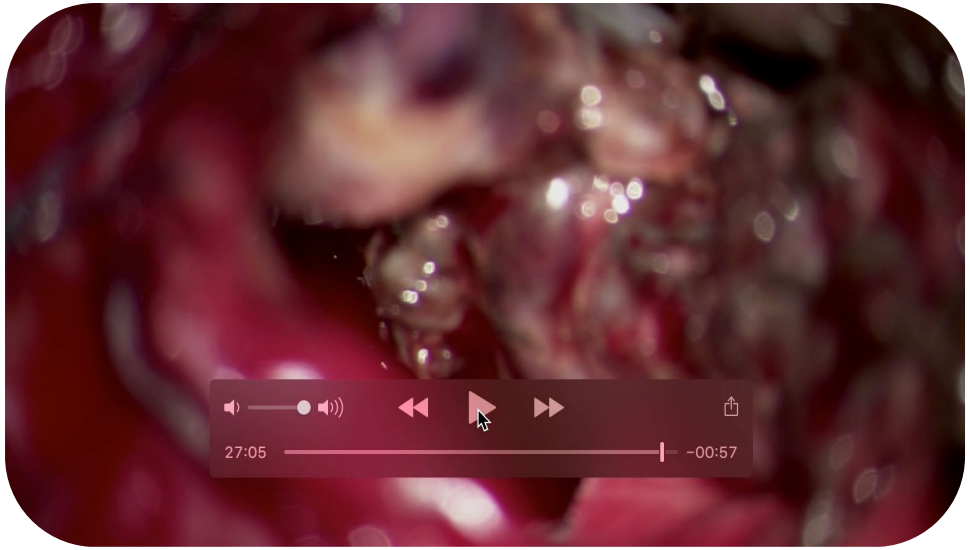


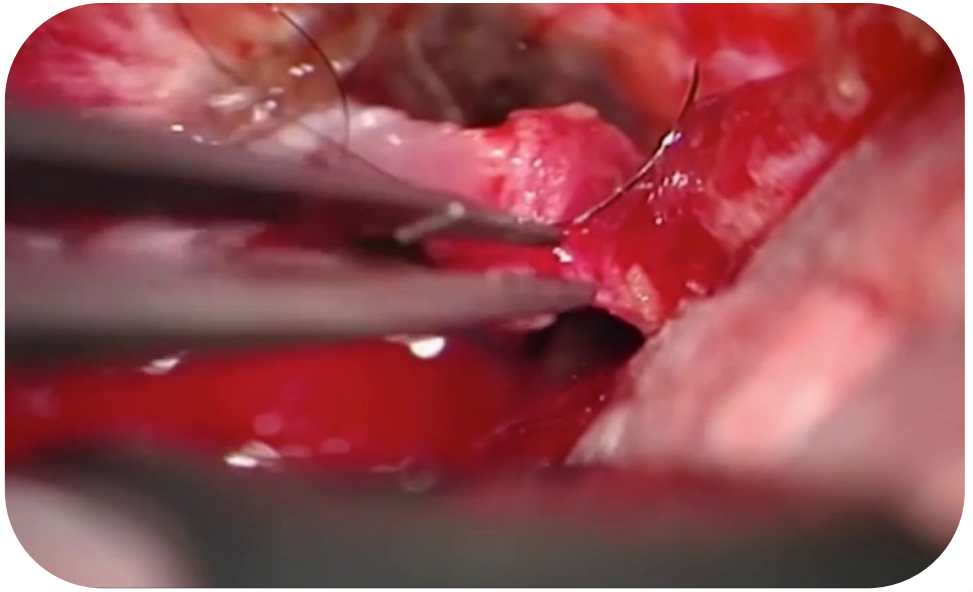


Ochsner Health System



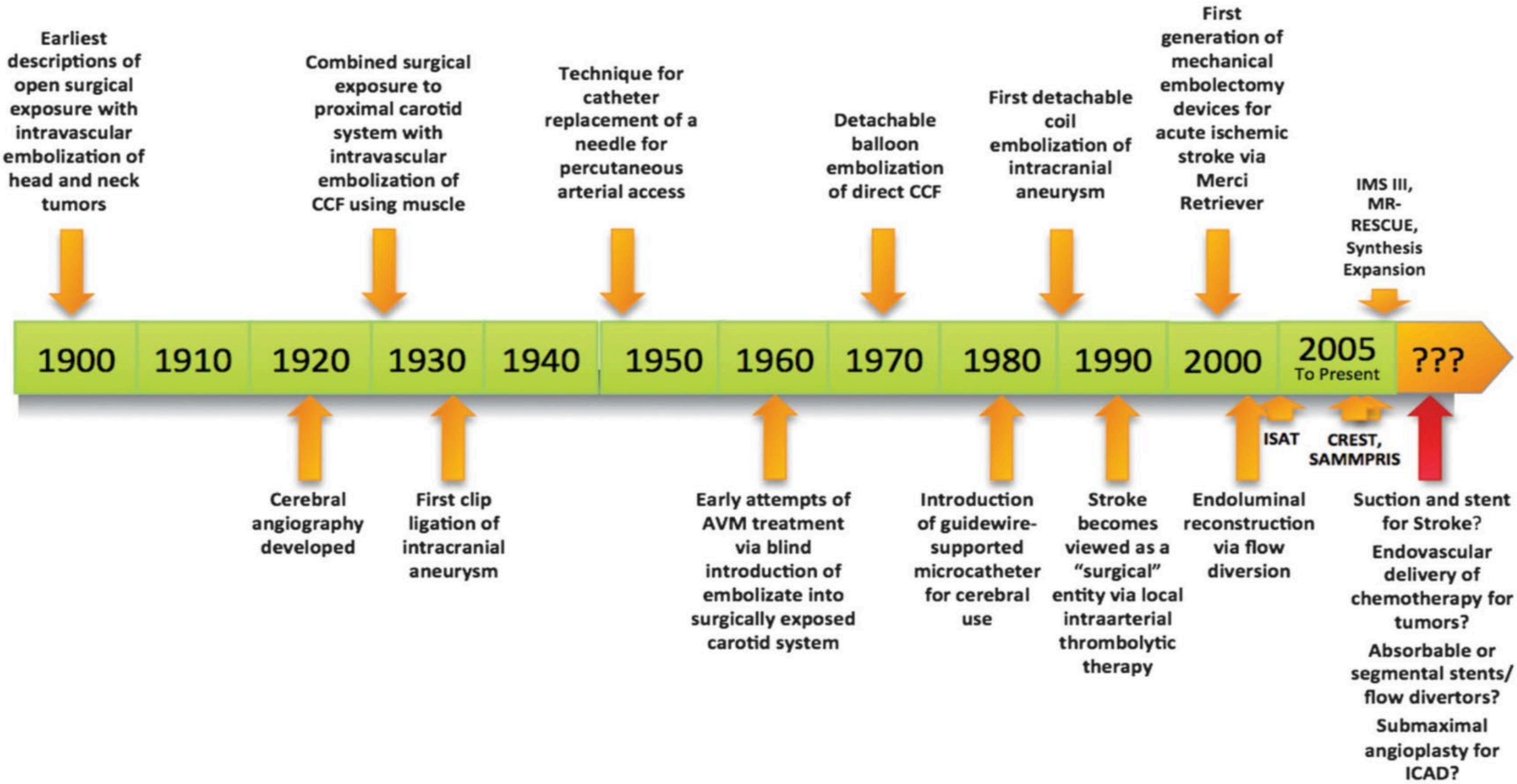






Ochsner Health System

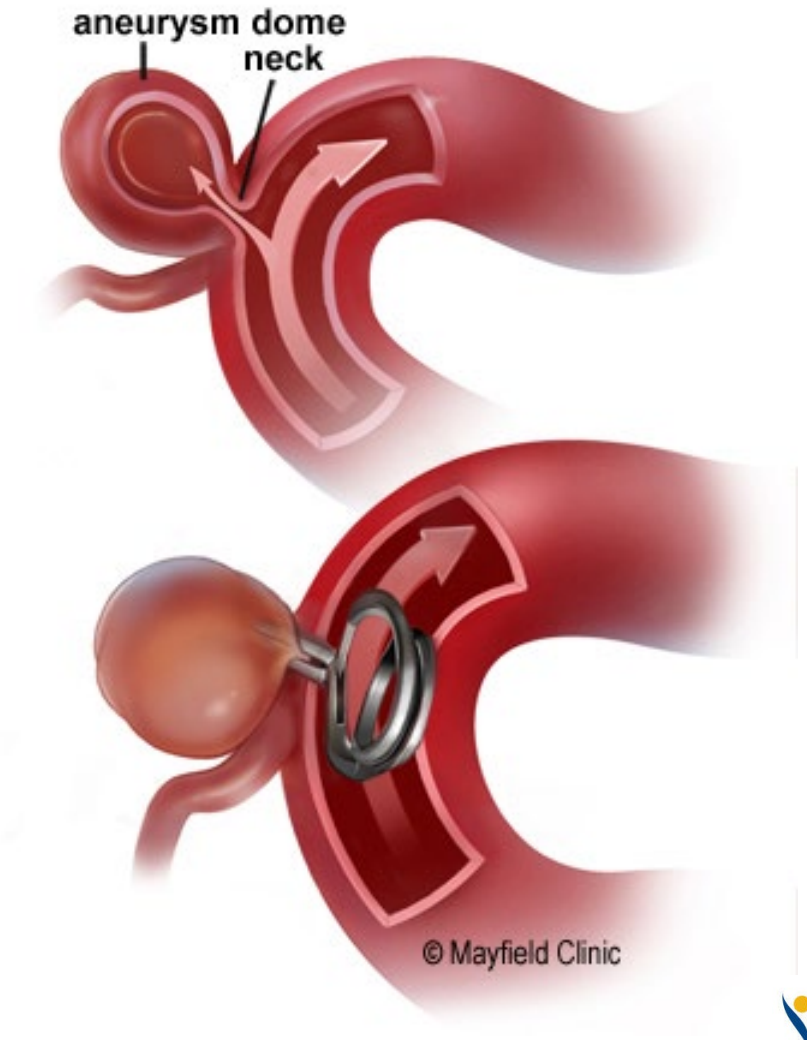
Cerebrovascular Neurosurgery in Evolution:



Clipping vs Coiling

Clipping

- Pro's
  - Established procedure
  - Can treat most aneurysms
  - Lower risk of recurrence
- Con's
  - Invasive
  - General anesthesia
  - Longer recovery (maybe)

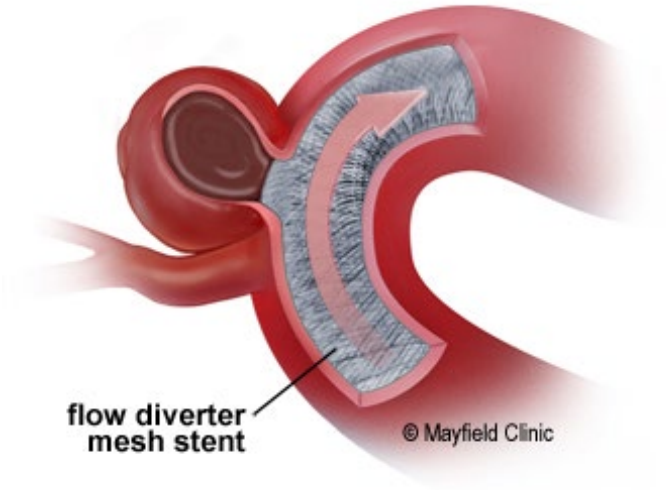


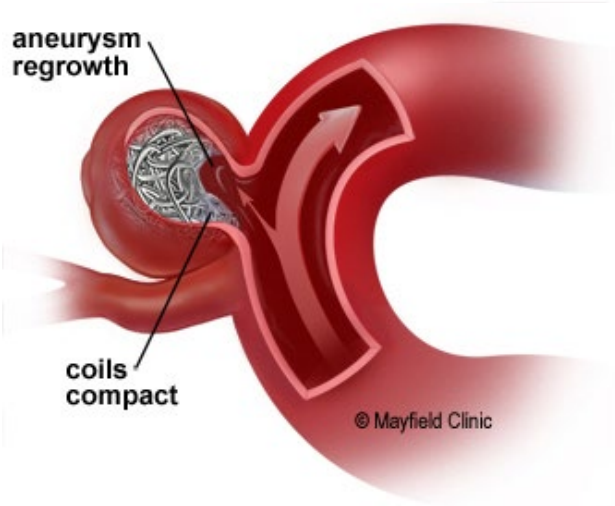
Ochsner Health System

Clipping vs Coiling

Coiling

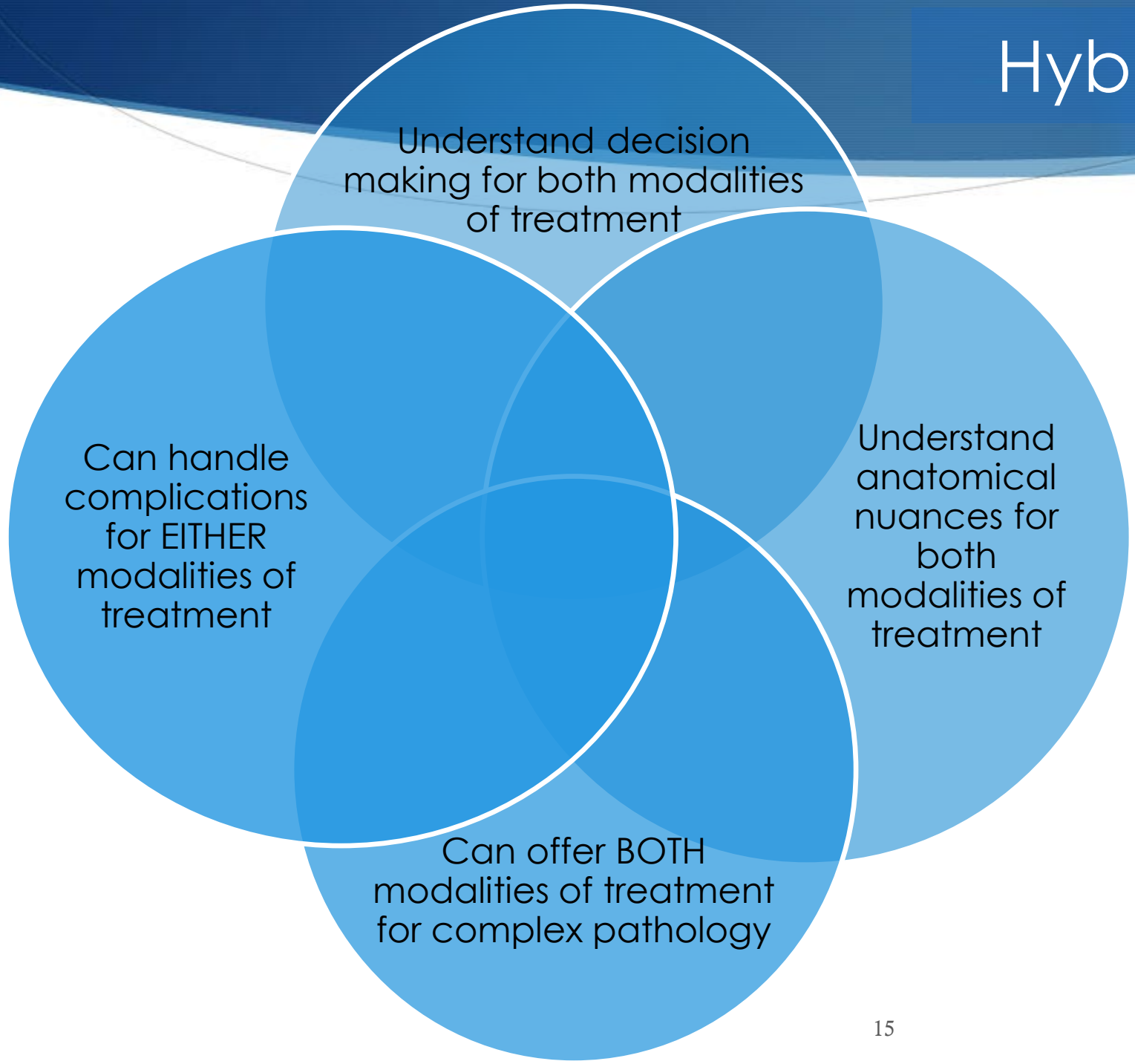
- Pro's
  - Less invasive (at times)
  - Safer for some at risk patients
  - Shorter recovery
- Con's
  - Some aneurysms can't be treated
  - Risk of imaging tools
  - Newer
  - May not resolve aneurysm





Ochsner Health System

Hybrid Neurosurgeons



Ochsner Health System

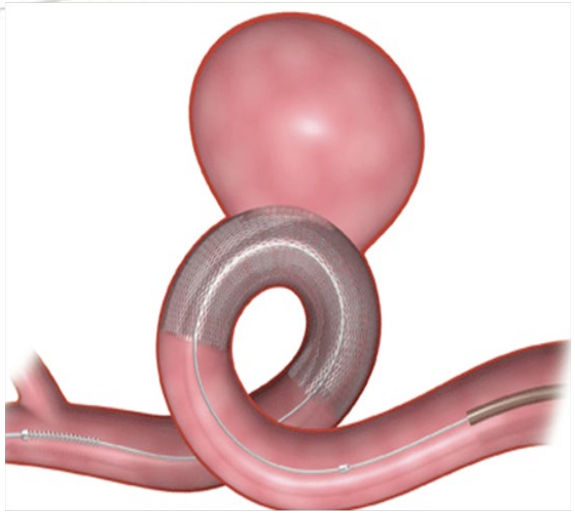
Endovascular options have evolved….

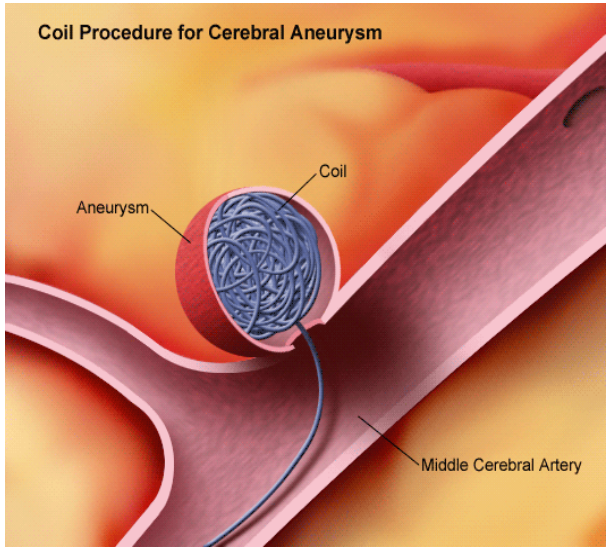
- Coiling
- Stent-assisted coiling
- Balloon-assisted coiling
- Flow Diverters
- Intra saccular devices

Ochsner Health System

Endovascular Surgical Tool Box

- CAS
- Intracranial Stents
- Angioplasty techniques
- Flow Diversion
- Coil Embolization
- Coil Sacrifice
- AVM embolization
- BTO/WADA testing





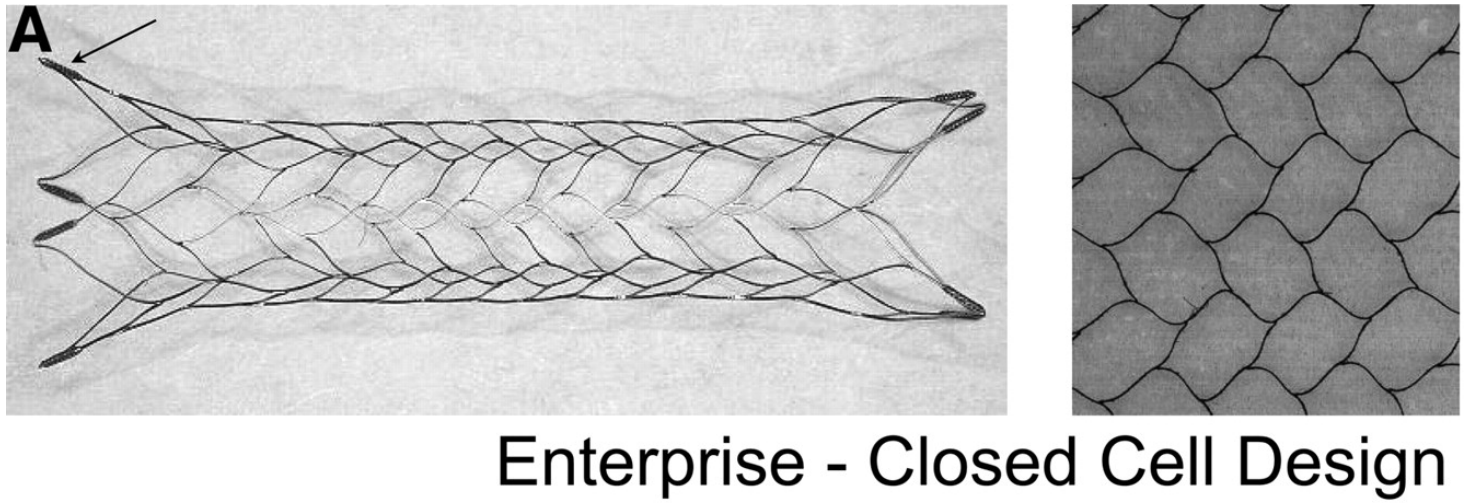
http://www.yalemedicalgroup.org/stw/Page.asp?PageID=STW029076

Ochsner Health System

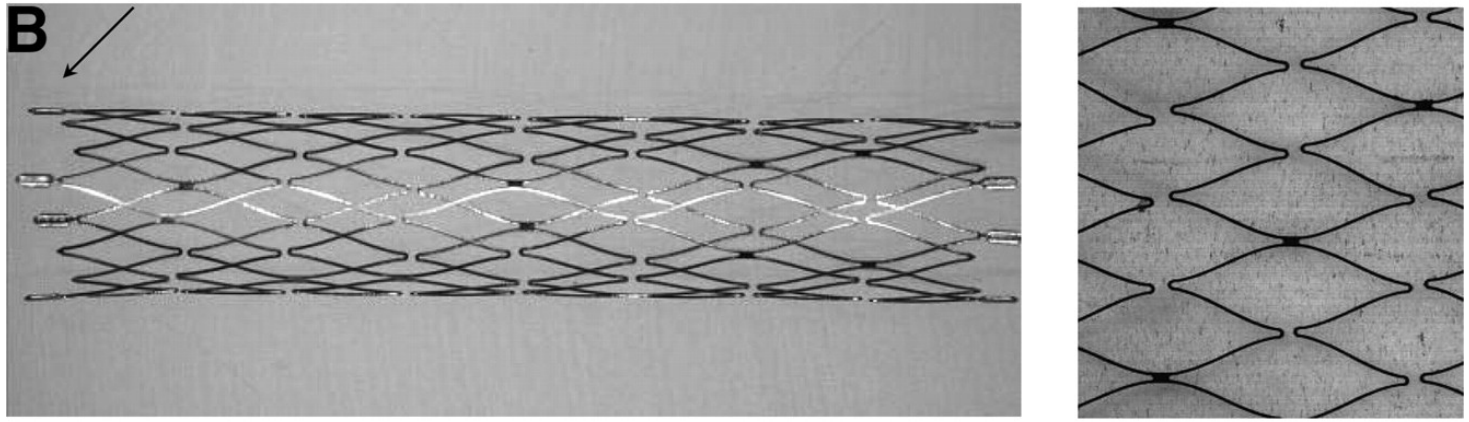
Second Generation Intracranial Microstents

Ochsner Health System

Current Aneurysm Stents Embody 12 Year Old Technology

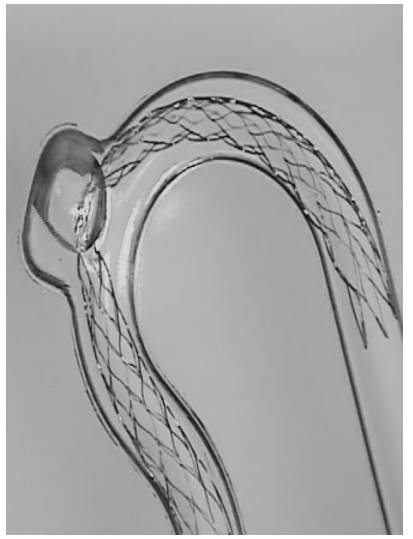


Enterprise - Closed Cell Design

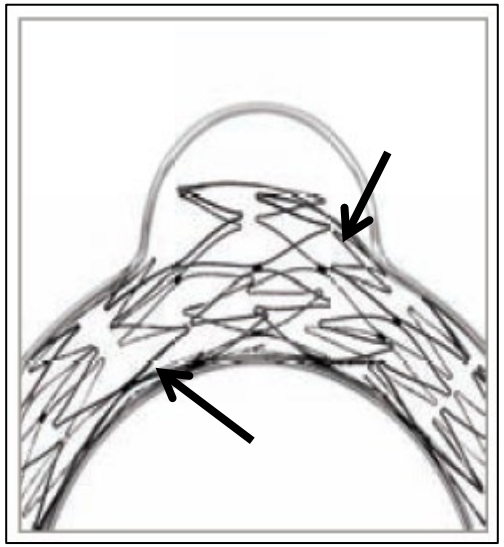


Neuroform - Semi-open Cell Design

Desired Characteristics	Neuroform	Enterprise
Conformability	✓	
Neck Coverage		✓
Resheathability		✓



Enterprise

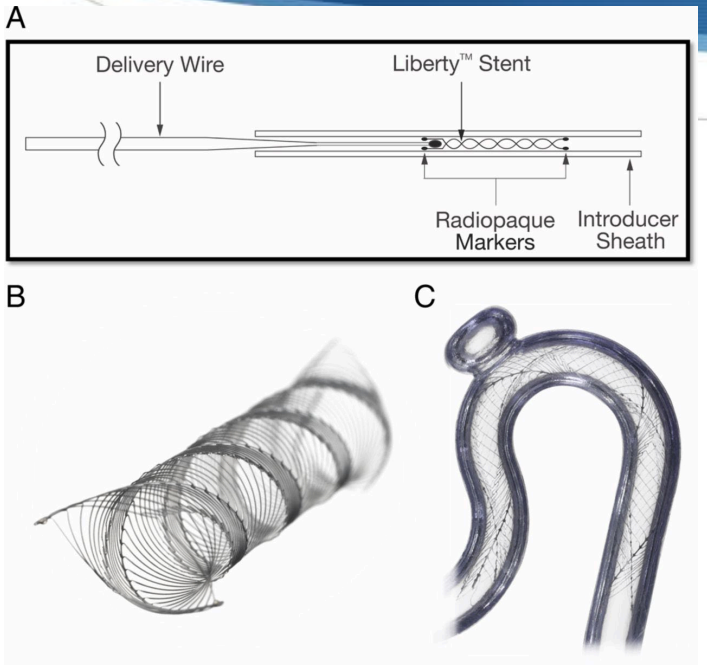


Neuroform

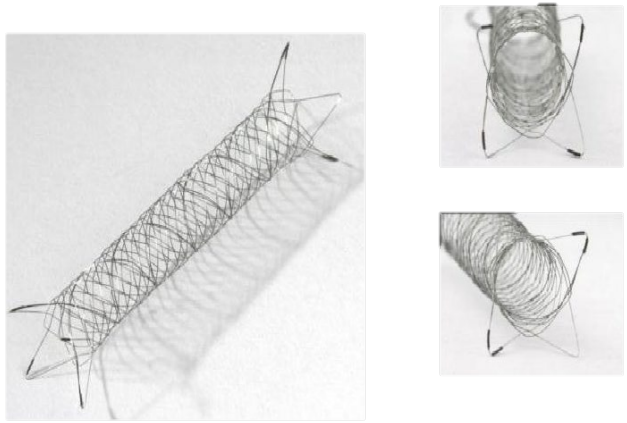
Stroke. 2009; 40: e305-e312

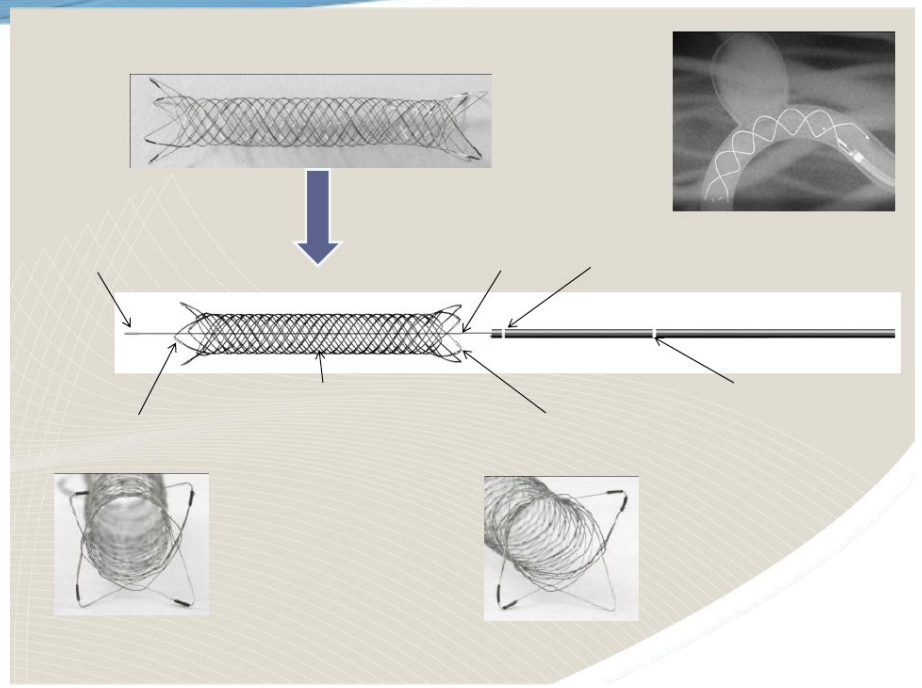
Ochsner Health System

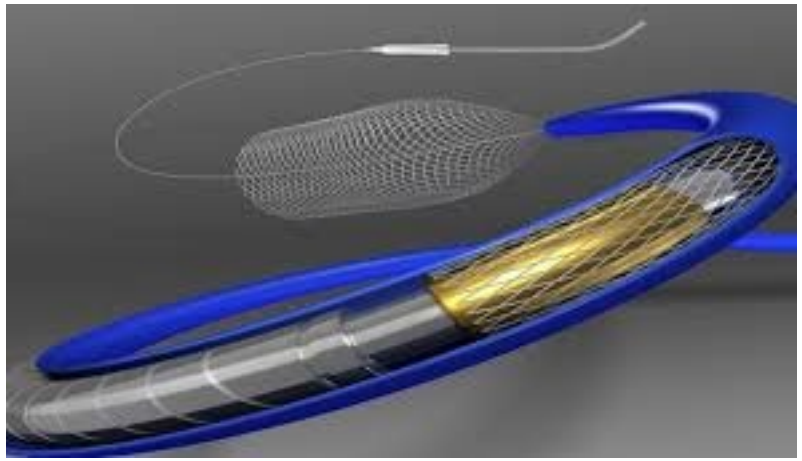
Intracranial stent technology



LVIS- Low-profile Visualized Intraluminal Device

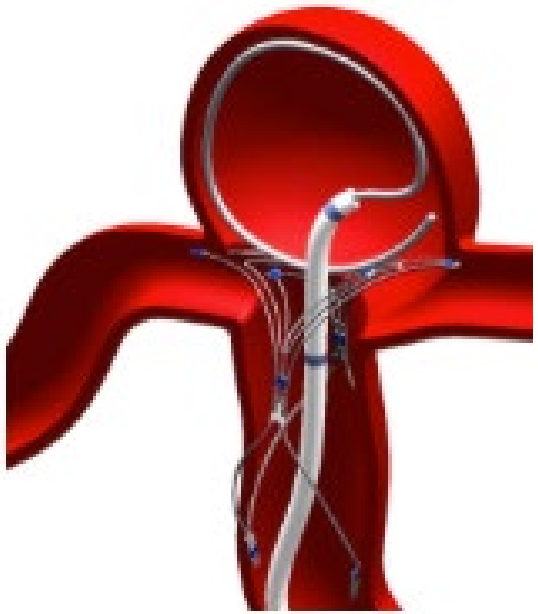


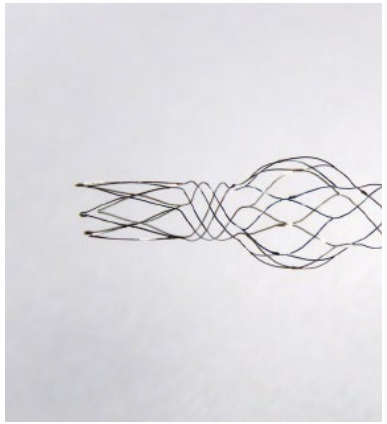


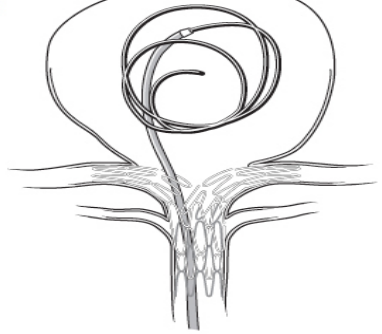


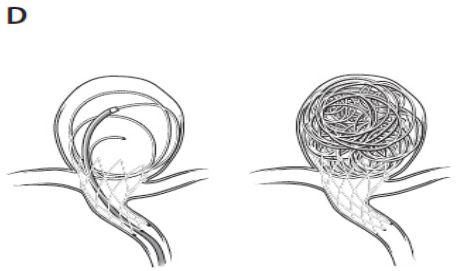
Bifurcation Stents

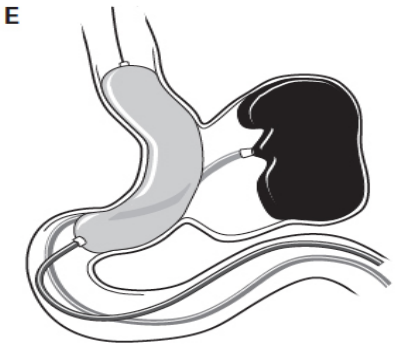
Ochsner Health System

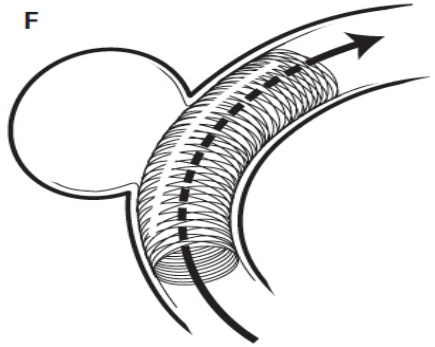


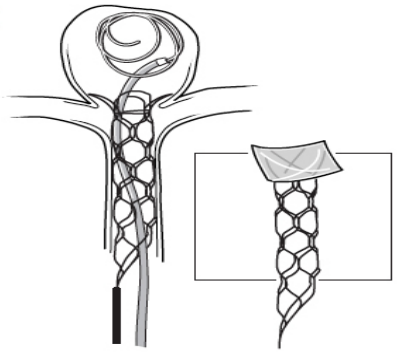


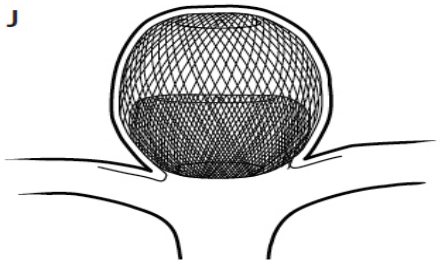


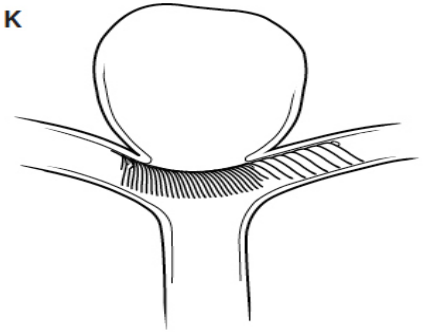


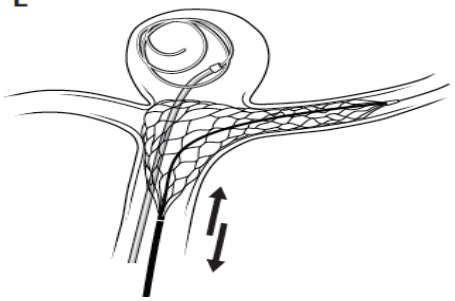


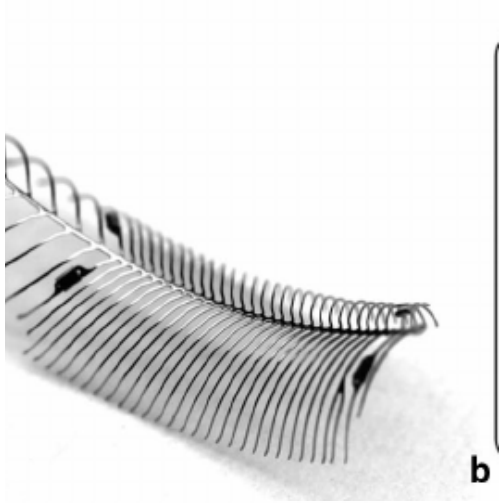


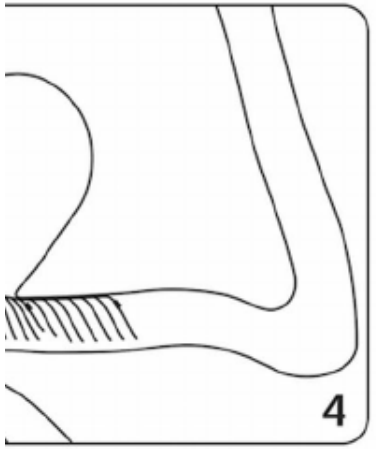












Ochsner Health System

Flow Diversion and Hemodynamic Simulation

Flow Diverters: Evolution of a Concept

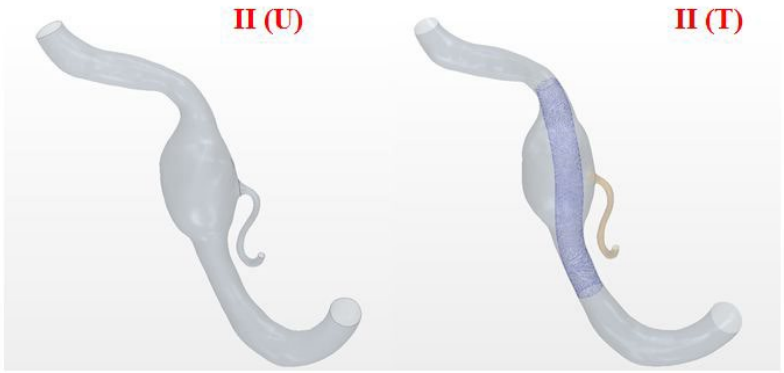
- The concept of comes from observations of intra-aneurysmal flow patterns in models of stented intracranial aneurysms

- Placement of a stent across the aneurysmal neck redirects flow away from the aneurysm and back into the parent artery

Stroke. 2011;42: 2363-2368.

Flow Diverters: Evolution of a Concept

Virtual deployment models:



CFD results:

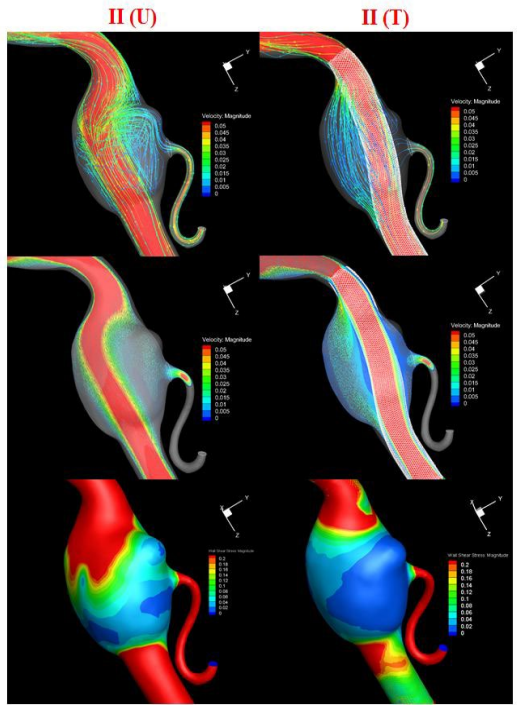


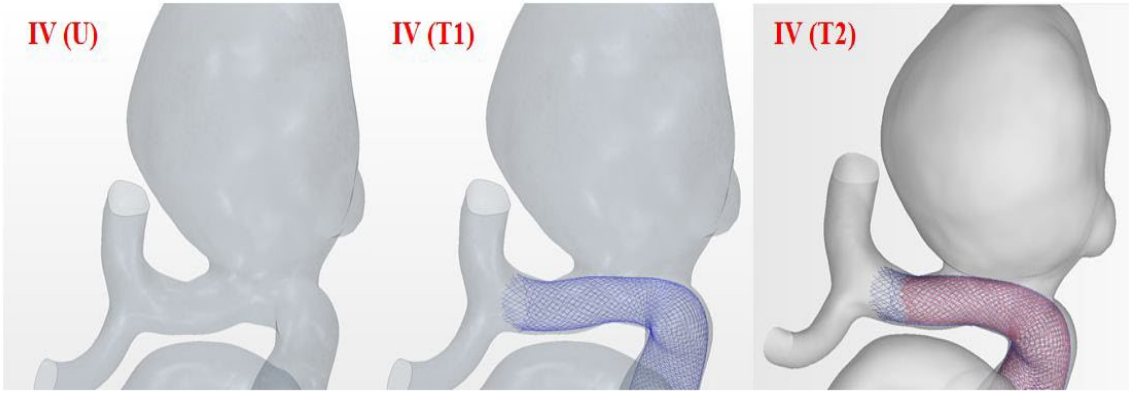
Figure xxx. 3D streamlines (first row), intra-aneurysmal velocity vectors (second row), and WSS distributions (third row) for Aneurysm II

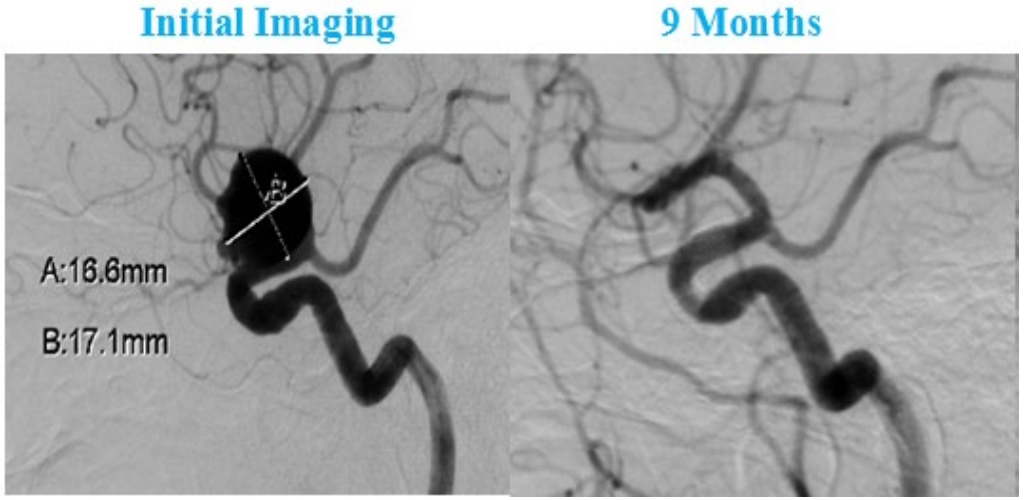
Aneurysm Case	Scenario	Average WSS	Average Aneurysmal Velocity Magnitude	Inflow Rate	Turnover Time
Aneurysm II	II (U)	100.00%	100.00%	100.00%	100.00%
	II (T)	26.04%	23.66%	17.48%	572.06%

Ochsner Health System

Flow Diverters: Evolution of a Concept

Virtual deployment models:





CFD results:

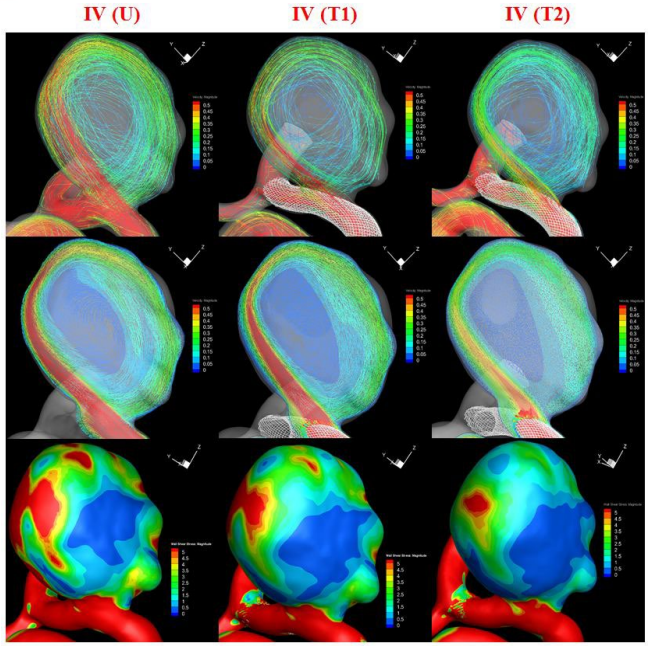


Figure 32. 3D streamlines (first row), intra-aneurysmal velocity vectors (second row), and WSS distributions (third row) for Aneurysm IV.

Aneurysm Case	Scenario		Average WSS	Average Aneurysmal Velocity Magnitude	Inflow Rate	Turnover Time
Aneurysm IV	IV (U)		100.00%	100.00%	100.00%	100.00%
	IV (T1, T2)	1st PED	68.23%	79.70%	80.00%	125.00%
		2nd PED	40.91%	60.60%	61.35%	162.99%

Two main action mechanisms

1. **Flow Diversion** – disruption of blood flow from the parent artery into the aneurysm
2. **Re-endothelization** – formation of a new scaffold upon which endothelial cells can grow

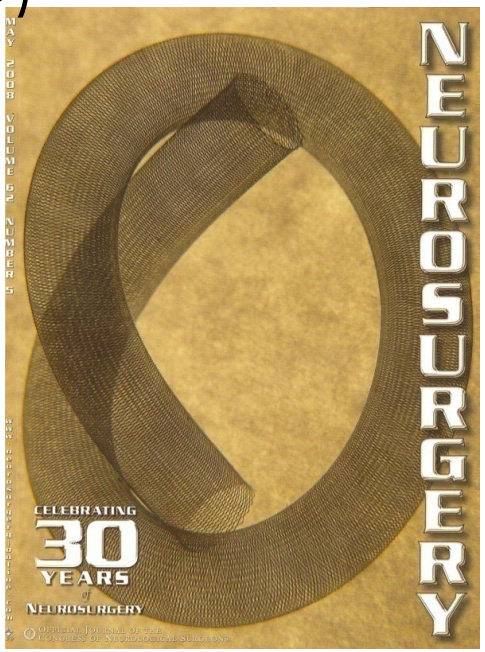
Data suggest that a stent with an overall porosity of 50–70% (30–50% metallic coverage) significantly reduces inflow rate into an aneurysm

Liou TM, Li YC. Effects of stent porosity on hemodynamics in a sidewall aneurysm model. J Biomech 2008;41:1174–83

Flow Diverters

Pipeline® Embolization Device (PED)

- **Braided mesh** cylinder
- platinum + nickel-cobalt chromium alloy
- Self-expanding, **2.5 to 5.0mm**
- Pore size is 0.02 to 0.05 mm^2
- FDA approved **petrous to the superior hypophyseal segments**.



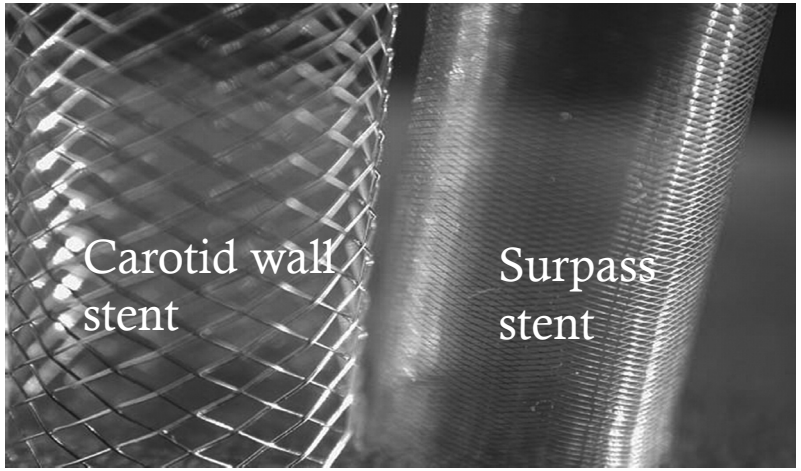
Flow Re-Direction Endoluminal Device

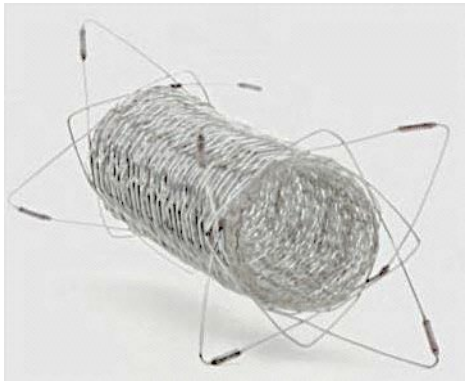
Outer layer:

- 1 mm cell size
- 16-wire weave design

Inner layer:

- 48-wire braid design
- Attached to outer layer in helix pattern





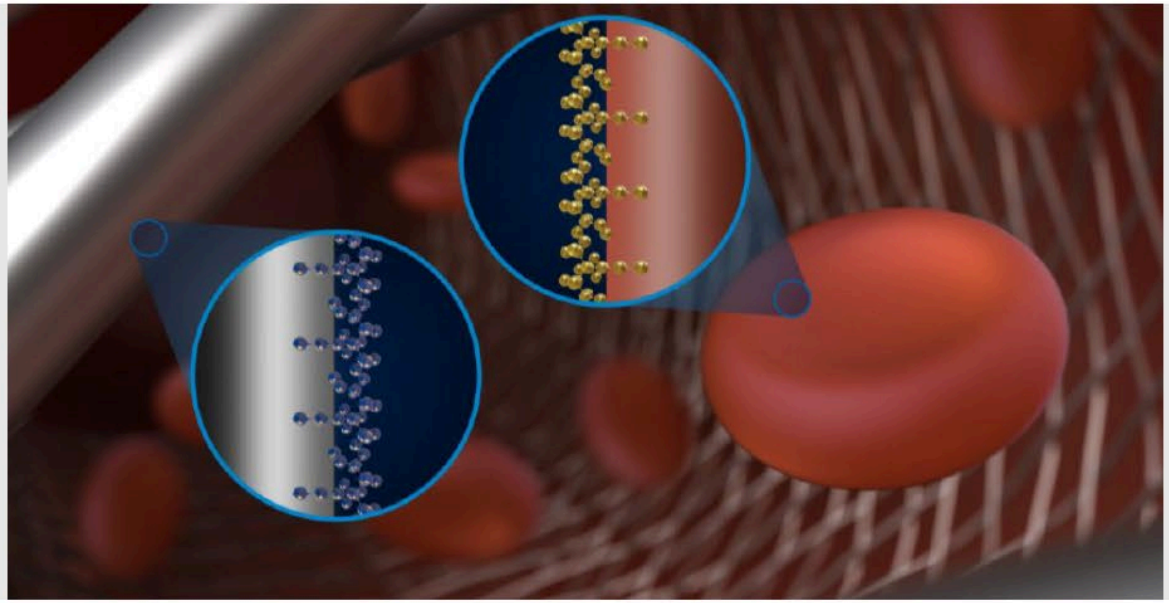
Surpass

- cobalt–chromium
- low porosity (metal surface area coverage 30%)
- **self-expanding** tubular-shaped mesh structure
- high pore density (21–32 pores/mm2)

Shield Technology

Through covalently bonding phosphorylcholine to the surface of the implant, Shield Technology™ enhances the Pipeline™ Flex embolization device to achieve a scientifically proven reduction in implant material thrombogenicity

Synthetic phosphorylcholine polymer is covalently bonded to the braid to provide a biomimetic surface modification



Phosphorylcholine is present in the outer membrane of red blood cells

Reduces Material Thrombogenicity[7,8,11*]

Shield Technology™ enhances the **Pipeline™** Flex embolization device to achieve a scientifically proven reduction in implant material thrombogenicity as shown through in-vitro studies.

94%

Reduction in platelet activation

Mean Peak Thrombin(nM)

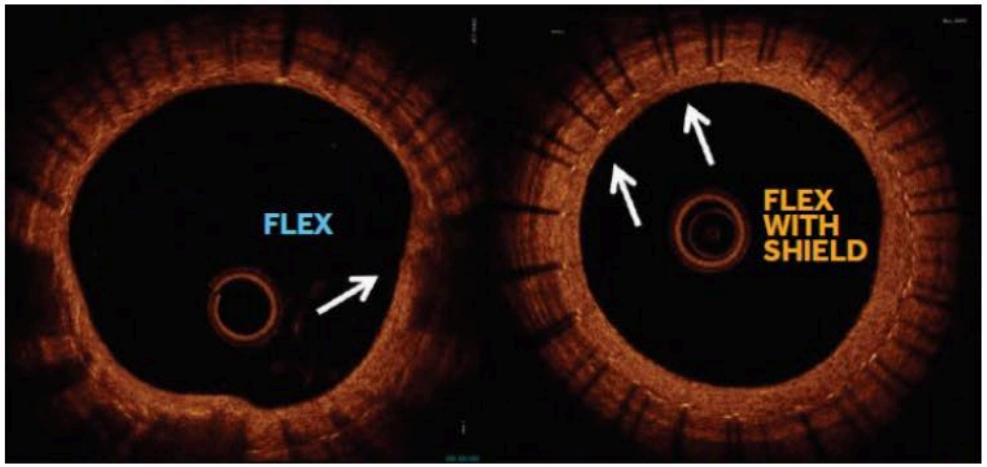
Shield Technology™ resulted in a statistically lower amount of thrombin AND a statistically higher time to peak thrombin

55%

Reduction in peak thrombin

Promotes Endothelialization[12,13*]

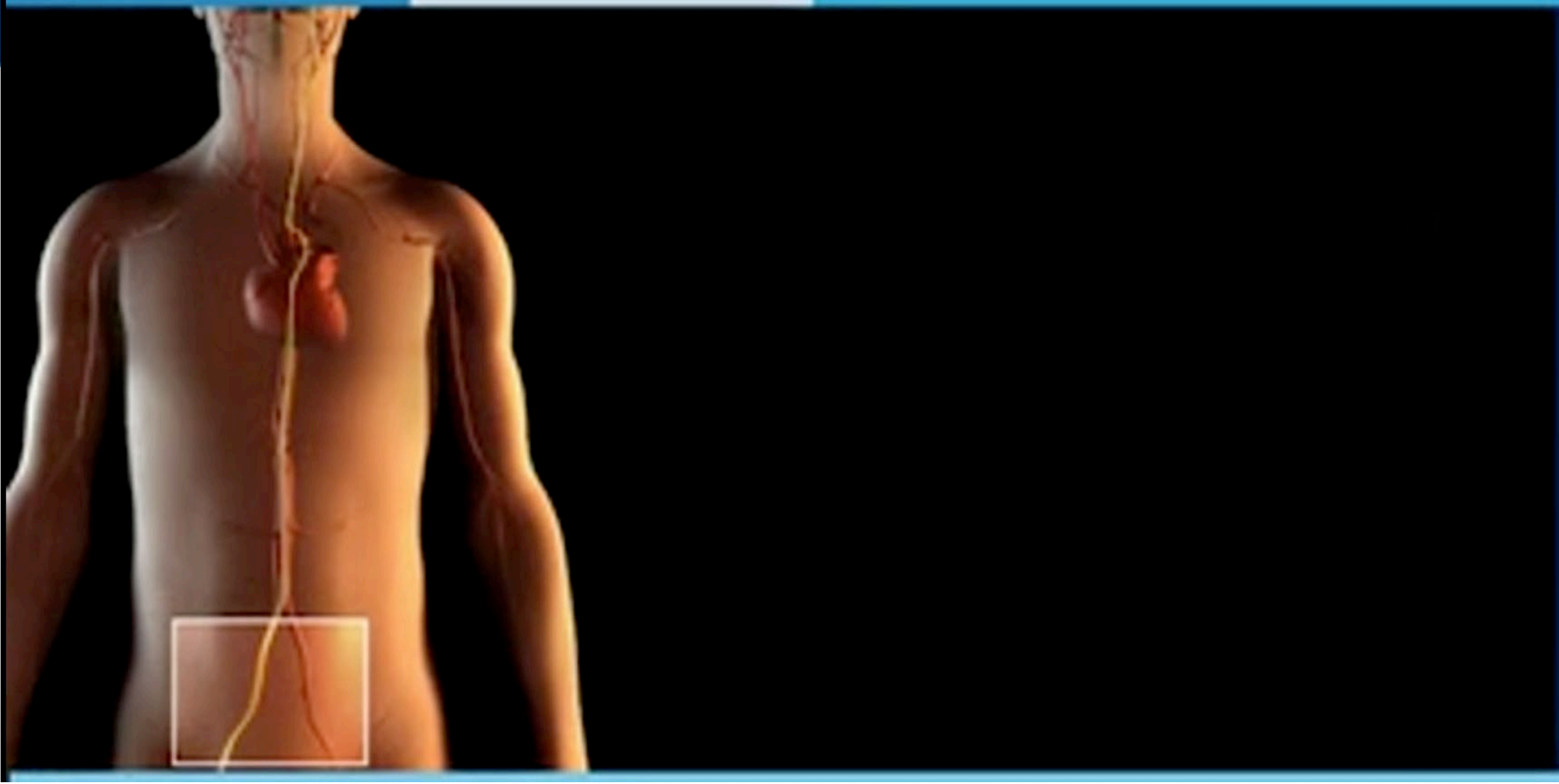
In-vivo testing shows that Shield Technology™ led to earlier and more even neointima formation with less hyperplasia and similar aneurysm occlusion rates as the Pipeline™ Flex embolization device.



Porcine models showed earlier neointimal growth at Day 7 with Shield Technology™

Porcine models also resulted in a greater thickness ratio with Shield, indicating more even growth.

Rabbit models exhibited significantly reduced neointimal hyperplasia when using Shield Technology™ with similar aneurysm occlusion.



Endosaccular vs. Endoluminal

Endosaccular

- Advantage: immediate dome protection, many neck-reconstruction options, proven technology
- Disadvantage: high recanalization rate, no good options for fusiform or blister aneurysms

vs.

Endoluminal

- Advantage: Better neck protection, lower recanalization rate, versatile for aneurysms with difficult morphology
- Disadvantage: new technology (no long-term follow), no immediate dome protection, not good at bifurcation

Complementary, not competitive techniques

New Imaging Techniques For Neurointervention

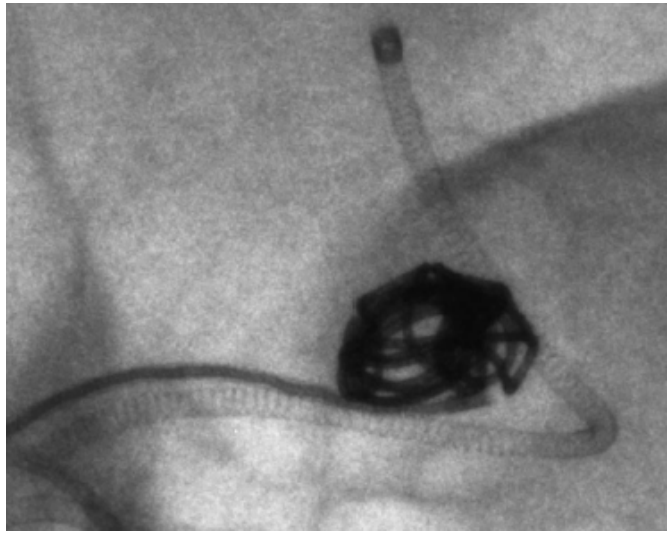
- Micro-angiographic fluoroscopy
- Rotational flat panel detector technology
- Intravascular ultrasound
- Dynamic perfusion-like (parametric) imaging

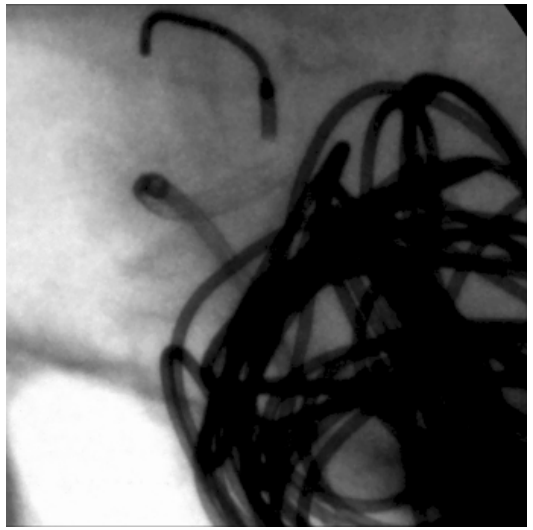
Microangio Fluoroscopy

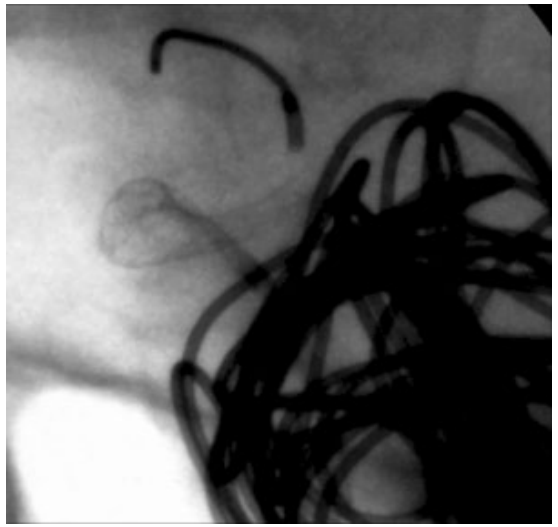
- Ultra-high intraprocedural magnification of stent struts, coils, microwires/microcatheters
- Visualization down to 60 microns

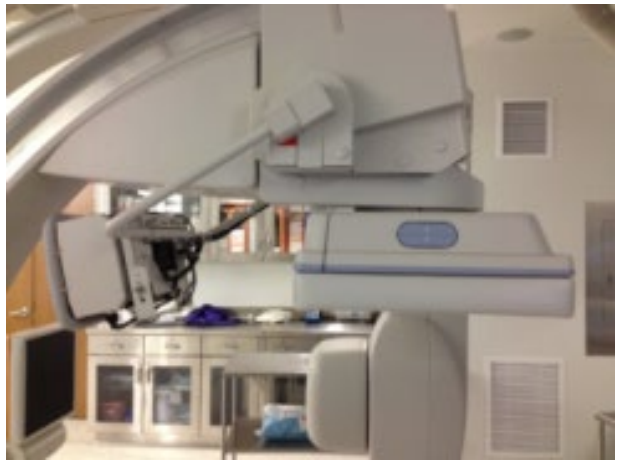
Utility of the high-definition (HiDef) zoom feature of a new x-ray detector system in the treatment of intracranial aneurysms using a Pipeline embolization device

Authors
Swetadri Vasan (first name) Setlur Nagesh (last name)*[1,3], Kunal Vakharia MD*[2,3], Vernard S. Fennell MD MSc[2,3], Gursant S. Atwal MD[2,3], Hussain Shallwani MD[2,3], Daniel R. Bednarek PhD[1,3,6], Jason M. Davies MD PhD[2,3,5,7], Kenneth V. Snyder MD PhD[2,3], Maxim Mokin MD PhD[10], Stephen Rudin PhD[1,3,4,6,8,9], Elad I. Levy MD MBA,[1-3,6] and Adnan H. Siddiqui MD PhD[1-3,6,7]









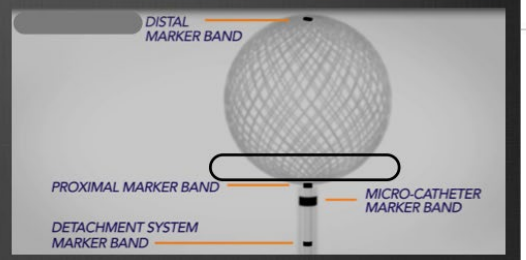
Ochsner Health System

Intrasaccular Flow Diversion: Here and On the Horizon

- Luna
- Web
- Contour
- Medina

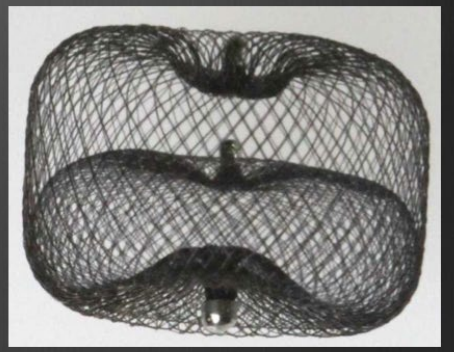
LUNA (Nfocus/Covidien) AES Concept

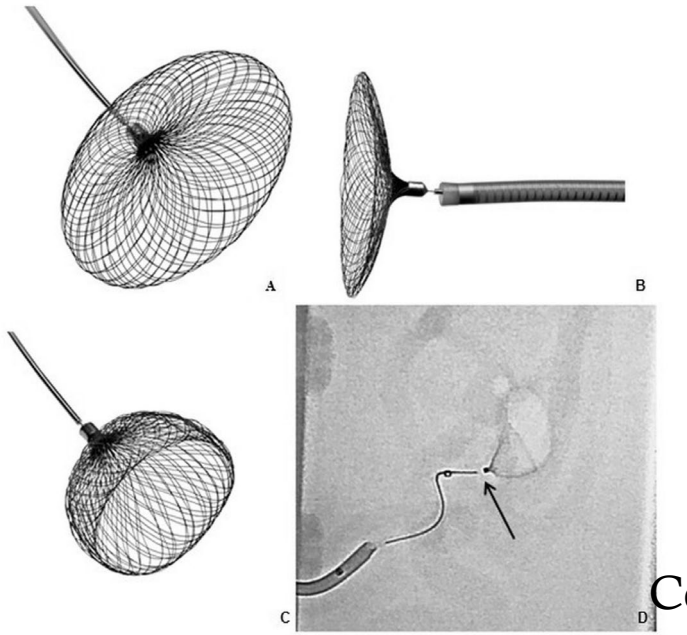
- The LUNA Aneurysm Embolization System (AES) is a self-expandable, round-ovoid implant with delivery system
- The implant is made from a double layer of 72 Nitinol wire 25µ. Mesh (144 wires) secured at both proximal and distal ends and clearly marked with radiopaque markers
- Available size 4.5mm (B) - 8.5mm (G)
- The delivery system provides for distal navigation through a commercially available (0.027 compatible) microcatheter
- Microcatheter shaft with detachment controlled by operator activation of delivery handle
- CE marked February 2011



WEB (Sequent) Concept

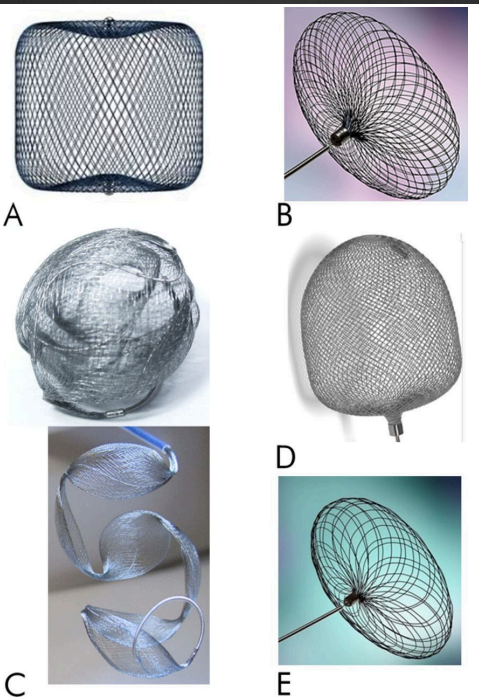
- Intrasaccular
- Microcatheters 0.027 for device ≤ 7 mm to 0.032 compatible for device > 7 mm
- Two layers of Nitinol mesh (216 or 288 wires)
- 3 platinum markers
- Retrievable and detachable
- CE marked





Countour

Medina



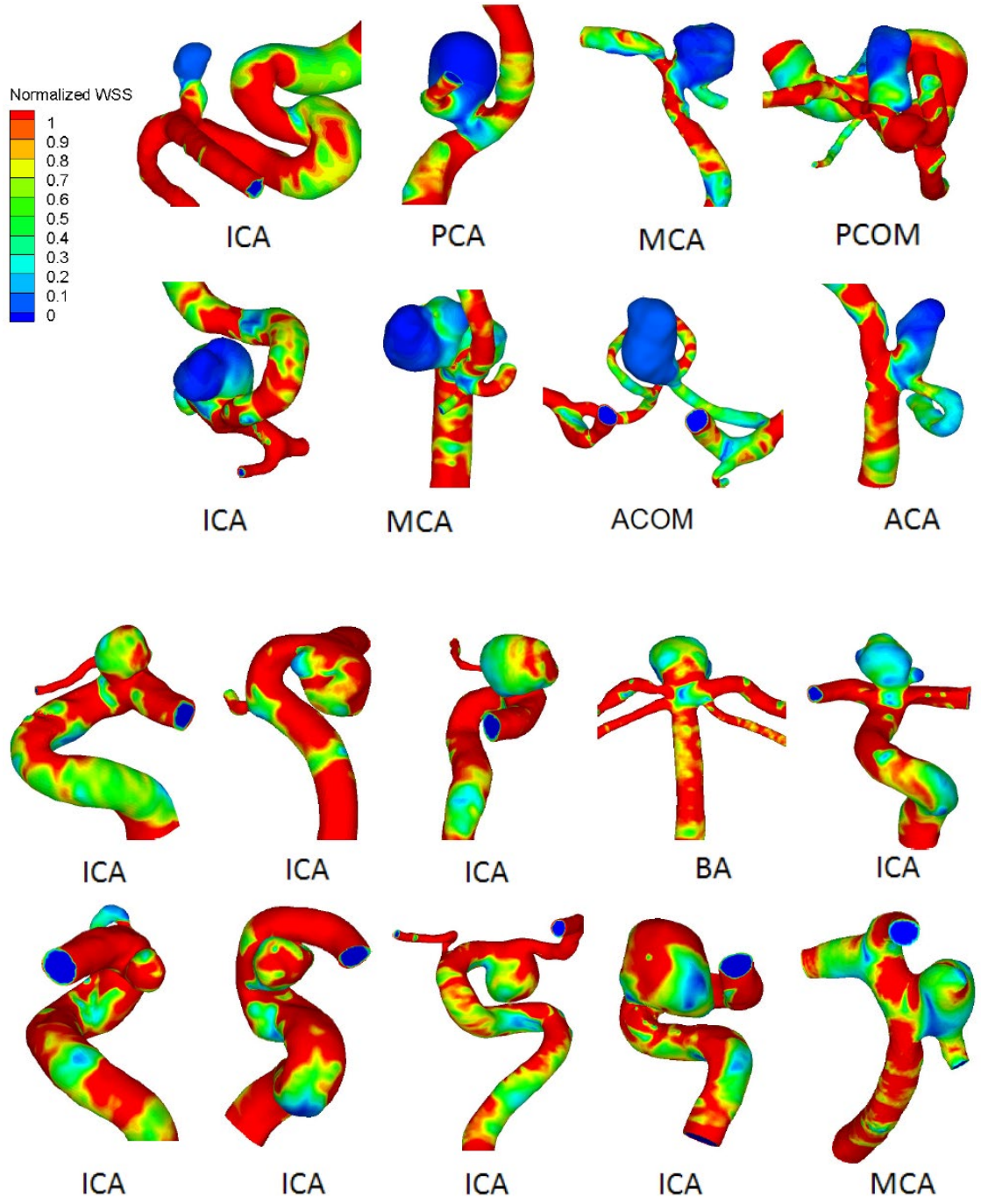
Ochsner Health System

Analysis of Aneurysm Flow Dynamics: Rupture Risk

Hemodynamics Analysis – Wall Shear Stress

Ruptured aneurysms had ***lower*** aneurysmal WSS magnitudes

… than unruptured aneurysms ($p<0.0001$)



Summary

- Endovascular treatment of aneurysms is evolving
- Open microsurgical options remain important
- Understanding the advantages and limitations of both produce optimal results

Microsurgery Innovations

Minimally invasive approaches to aneurysms of the anterior circulation: selection criteria and clinical outcomes

Sirin Gandhi [1], Claudio Cavallo [1], Xiaochun Zhao [1], Evgenii Belykh [1], Michaela Lee [1], Seungwon Yoon [1], Mohamed A Labib [1], Ali T Meybodi [1], Leandro B Moreira [1], Mark C Preul [1], Peter Nakaji [2]

Journal of Neurosurgical Sciences 2018 December;62(6):636-49

Minimally Invasive Microsurgery for Cerebral Aneurysms

Johnny Ho Yin Wong, PhD; Rachel Tymianski; Ivan Radovanovic, PhD; Michael Tymianski, MD, PhD

(*Stroke*. 2015;46:2699-2706. DOI: 10.1161/STROKEAHA.115.008221.)

Table 2. Clinical Outcomes for Aneurysm Surgery by Mini-Craniotomy Approaches

Authors and Year	No. of Patients	No. of Unruptured Aneurysm, %	Intra-Operative Rupture Rate %	Length of Stay, Days	Good Outcome, %*	Peri-Operative Complications
Supraorbital craniotomy (SOC)						
Paladino et al, 1998[11]	37	NA	3%	NA	100%	1 infection
van Lindert et al, 1998[12]	139	NA	3%	NA	NA	None
Czirják et al, 2001[13]	102	22 (22%)	2.0%	NA	96%	1 PE
Mitchell et al, 2005[14]	47	41 (87%)	4.3%	NA	96%	2 infarcts, 1 seizure, 3 postop hematomas
Reisch et al, 2005[27]	229	117 (51%)	1.7%	NA	NA†	6 infarcts†
Chen et al, 2009[25]	88	0 (0%)	26.1%	NA	89%	10 infections
Fischer et al, 2011[15]	793	319 (40%)	7.7%	NA	97%/72%‡	19 residual aneurysms, 9 infections, 9 cerebrospinal fluid leaks, 14 postop hematomas
Chalouhi et al, 2013[24]	47	0 (0%)	10.6%	NA	77%	1 post-op hematoma, 1 infection, 4 infarcts
Radovanovic et al, 2014[8]	54	30 (56%)	0%/12.5%‡	2.1/18.2‡	100%/83%‡	2 CSF leak, 1 seizure, 1 anosmia, 1 infection
Lateral supraorbital craniotomy (LSOC)						
Cha et al, 2012[29]	61	61 (100%)	NA	7.9	NA	4 post-op hematoma
Mori et al, 2014[30]	53	53 (100%)	NA	2.4	99%	1 MCA infarct
Mini-pterional craniotomy (MPTC)						
Caplan et al, 2014[20]	72	72 (100%)	NA	3.96	NA	1 MCA infarct, 2 post-op hematoma
Welling et al, 2015[28]	28	9 (32%)	14	NA	86%	2 post-op hematoma

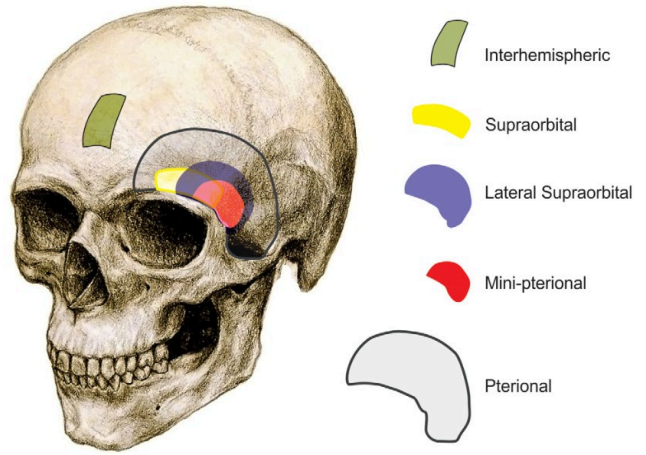
NA indicates not available.
*Good outcomes defined as mRS ≤2 or GOS ≥4.
†Outcomes and complications specific for aneurysm surgery unavailable. GOS available for entire cohort, including other pathologies.
‡Denotes results separated for unruptured cohort and ruptured cohorts, respectively.

CASE SERIES

Burr Hole Microsurgery for Middle Cerebral Artery Aneurysms: A Clinical Case Series

Levan Lepsveridze, MD, PhD, Maksim Semenov, MD, PhD, Georgy Stepanyan, MD, Sergey Abudeev, MD

VOLUME 3 | NUMBER 1 | 2022 | NEUROSURGERY OPEN



Microsurgical Treatment of Posterior Cerebral Circulation Aneurysms Via Keyhole Approaches

Qing Lan, Qing Zhu, Guowei Li

WORLD NEUROSURGERY, HTTP://DX.DOI.ORG/10.1016/J.WNEU.2015.07.046

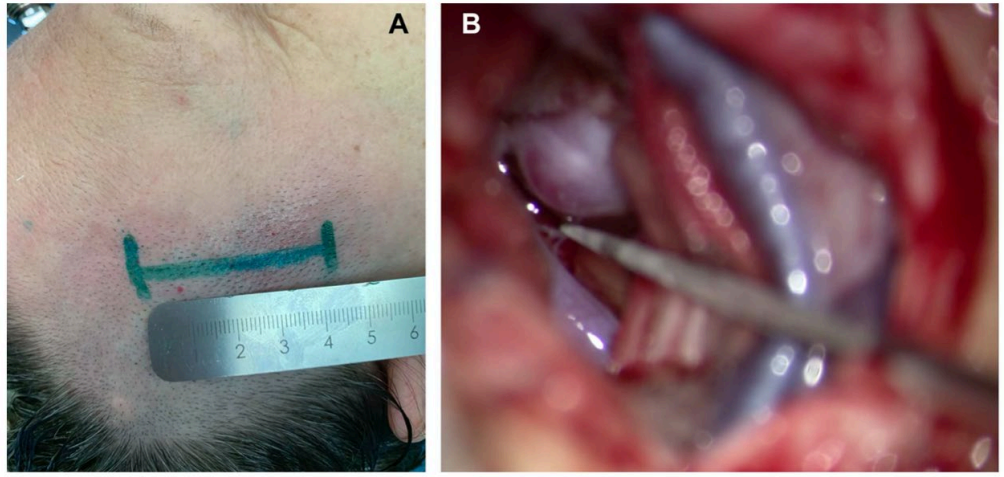
Microsurgery Innovations

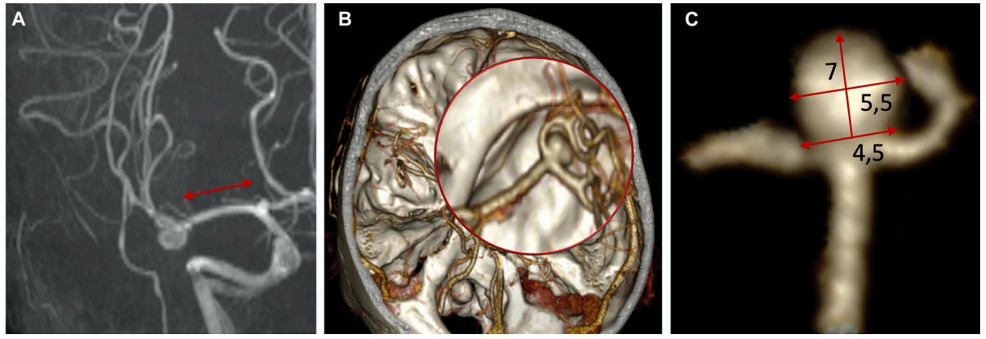
CASE SERIES

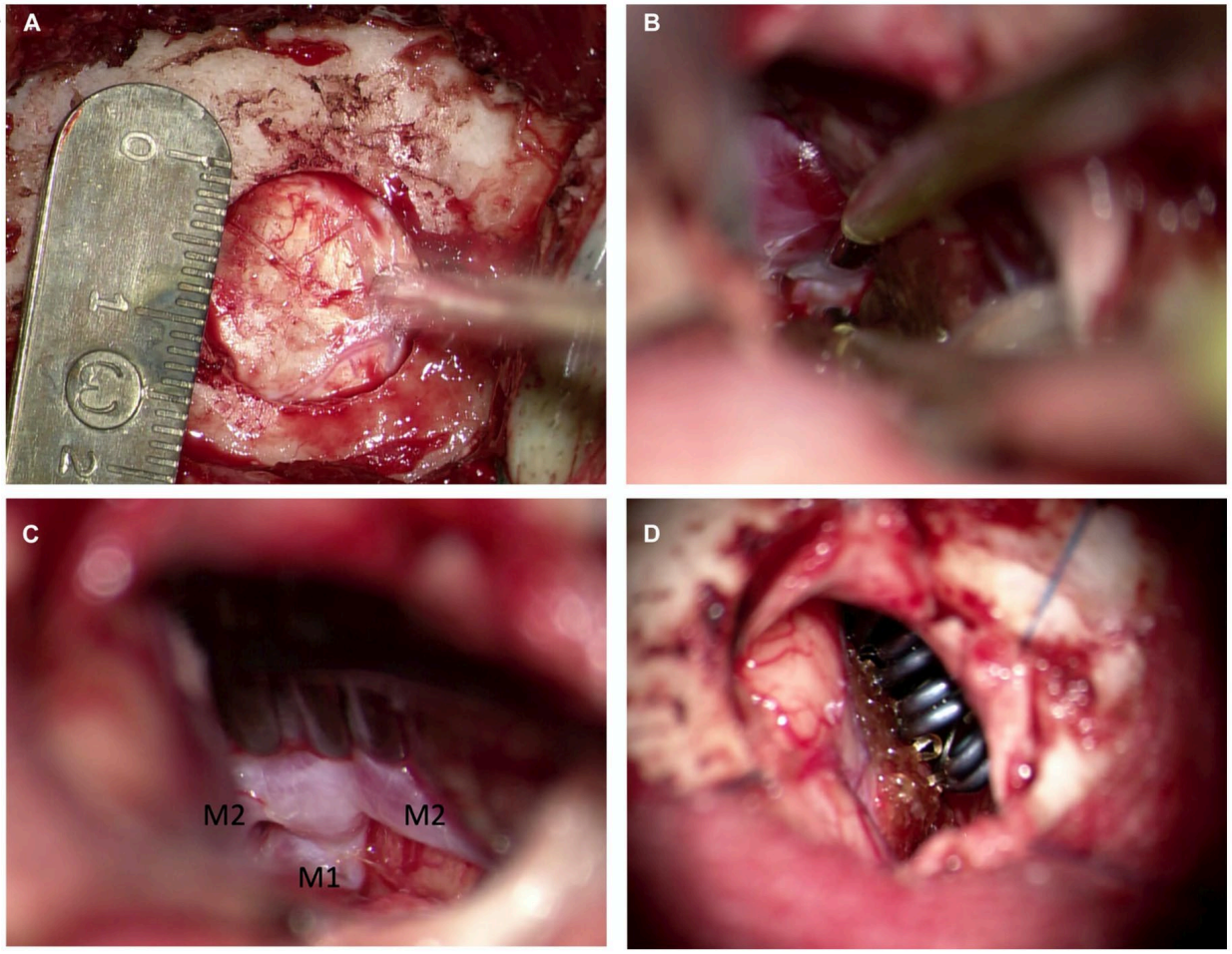
Burr Hole Microsurgery for Middle Cerebral Artery Aneurysms: A Clinical Case Series

Levan Lepsveridze, MD, PhD, Maksim Semenov, MD, PhD, Georgy Stepanyan, MD, Sergey Abudeev, MD

VOLUME 3 | NUMBER 1 | 2022 | NEUROSURGERY OPEN

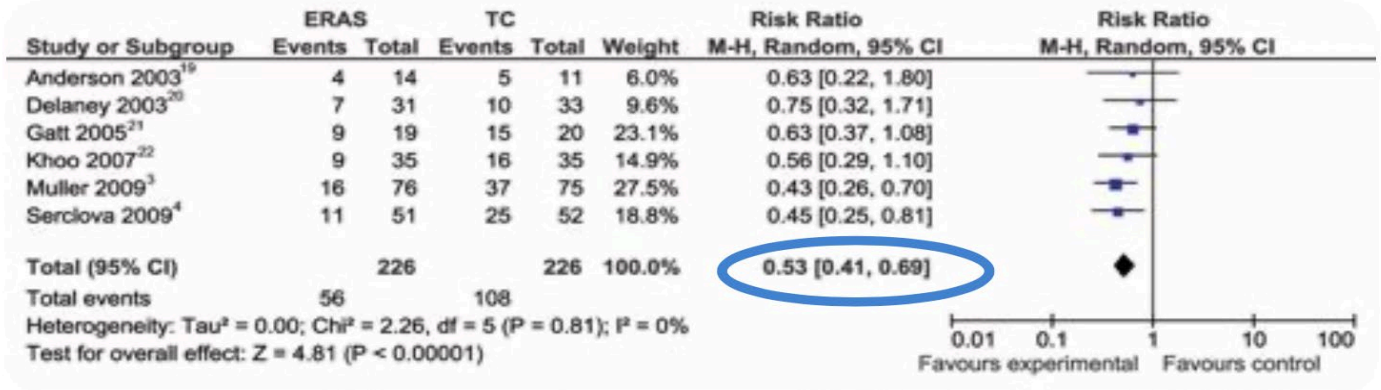






ERAS vs Traditional Care: Complications and LOS

Meta-analysis | 47% reduction in complications | 2.7 Days shorter LOS



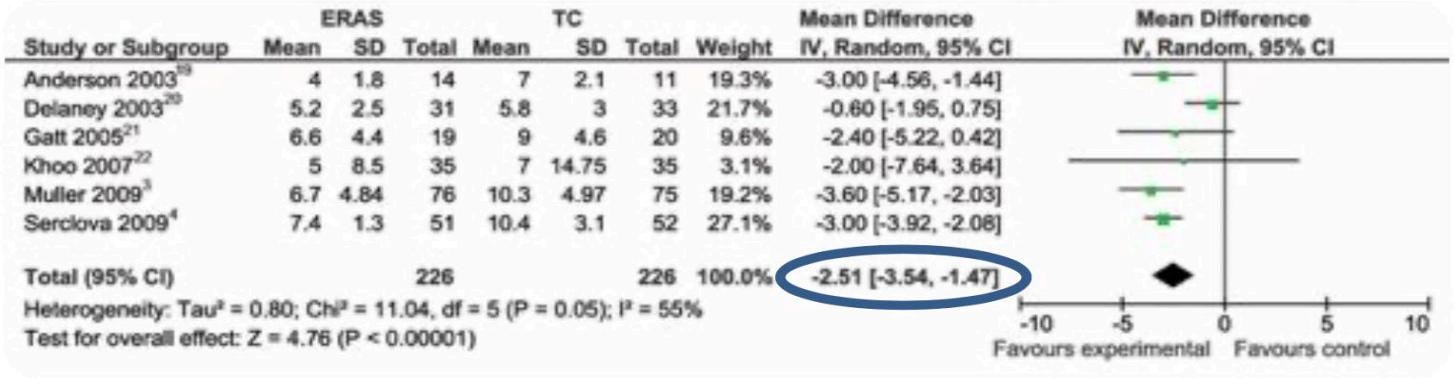


Table 3 Clinical outcomes of all patients divided into ERAS and control groups

Outcomes	Control group (n=150)	ERAS group (n=150)	P-value
Length of hospital stay, days	10 (8–12)	9 (7–11)	0.019
Readmission, n (%)	4 (2.7)	2 (1.3)	0.680
GOS at discharge, n (%)			
5	143 (95.3)	147 (98.0)	0.198
4	7 (4.7)	3 (2.0)	
MRS at discharge, n (%)			
0–1	134 (89.3)	143 (95.3)	0.148
2	9 (6.0)	4 (2.7)	
3	7 (4.7)	3 (2.0)	
GOS at follow-up, n (%)			
5	138 (92.0)	146 (97.3)	0.040
4	12 (8.0)	4 (2.7)	
MRS at follow-up, n (%)			
0–1	126 (84.0)	140 (93.3)	0.034
2	12 (8.0)	6 (4.0)	
3	12 (8.0)	4 (2.7)	

Abbreviations: ERAS, enhanced recovery after surgery; GOS, Glasgow Outcome Scale; MRS, Modified Rankin Scale.

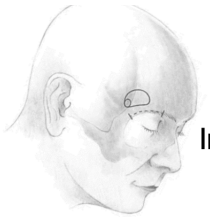
covery

Proven Recovery Neurosurgery – Multi-layer Building Block Implementation of a Universal Early Enhanced Recovery Program for Cranial and Spinal Neurosurgery at a Large Integrated Healthcare System

NeuroSafe, August 8-9, 2019, U Minnesota, Minneapolis, MN

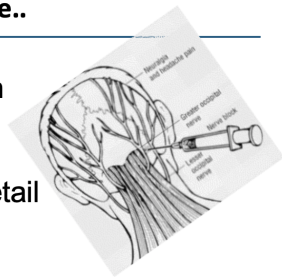
Clemens M. Schirmer, MD, PhD, FAANS, FACS, FAHA

envelope and secret (GHS) sauce..



Enhanced patient selection

Innovation and attention to detail



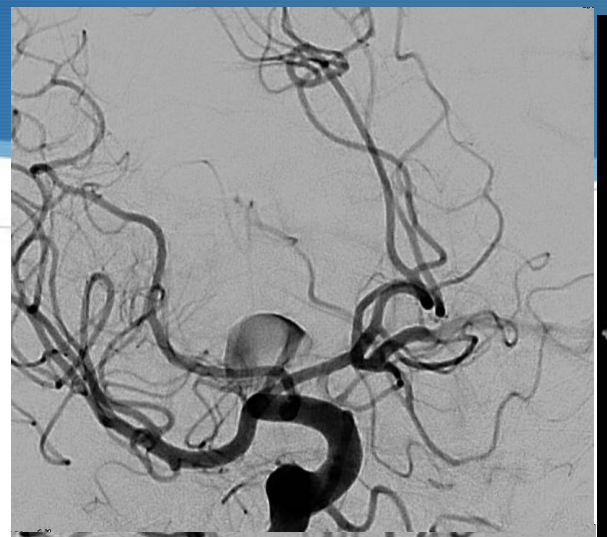
Same day craniotomy discharges for **selected** patients

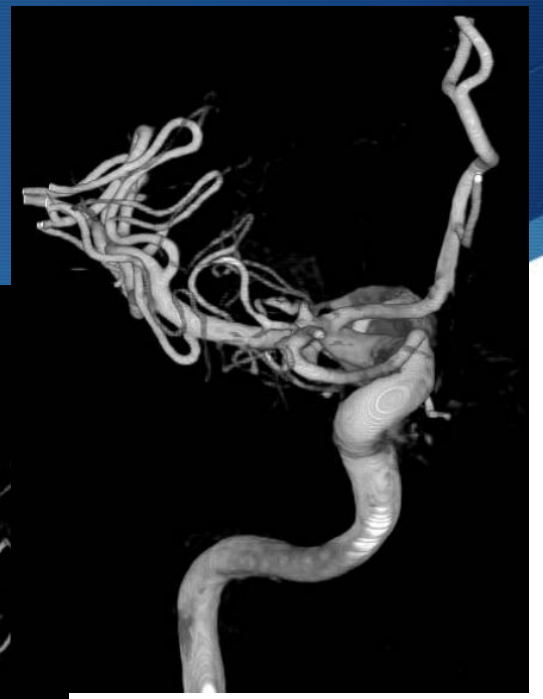
Medical Record ID	Patient ID ID	Discharge Date ID	MS-DRG (ICD-10) ID	MS-DRG (ICD-10) DESC	Principal Diagnosis - 7 Digit (ICD-10) ID	Principal Diagnosis - 7 Digit (ICD-10) DESC	Age DESC	Principal Procedure Surgeon NAME	Procedure	Principal Procedure Standard Specialty DESC	Principal Procedure - 7 Digit (ICD-10) ID	Principal Procedure - 7 Digit (ICD-10) DESC	Mortality Observed	Arith LOS Observed	Cases with Readmissions
800123	128277282	8/10/2017	27	CRANIOTMY&ENDVSC INTRCRANIALPX W/OCC/MCC	I67.1	CEREBRAL ANEURYSM, NONRUPTURED	69	SCHIRMER,CLEMENS M	Craniotomy - clipping	Neurological Surgery (NS)	03LG0CZ	OCCLUSION INTRACRANL ARTERY W/ED,OA	0.00%	1.00	0
5372925	128154655	6/22/2017	26	CRANIOTOMY&ENDOVASC INTRACRANIAL PX WCC	I67.1	CEREBRAL ANEURYSM, NONRUPTURED	35	SCHIRMER,CLEMENS M	Craniotomy - clipping	Neurological Surgery (NS)	03VG0CZ	RESTRICTN INTRACRANL ARTERY W/ED,OA	0.00%	1.00	0
9028452	128144540	6/15/2017	27	CRANIOTMY&ENDVSC INTRCRANIALPX W/OCC/MCC	I67.1	CEREBRAL ANEURYSM, NONRUPTURED	58	SCHIRMER,CLEMENS M	Craniotomy - clipping	Neurological Surgery (NS)	03VG0CZ	RESTRICTN INTRACRANL ARTERY W/ED,OA	0.00%	1.00	0

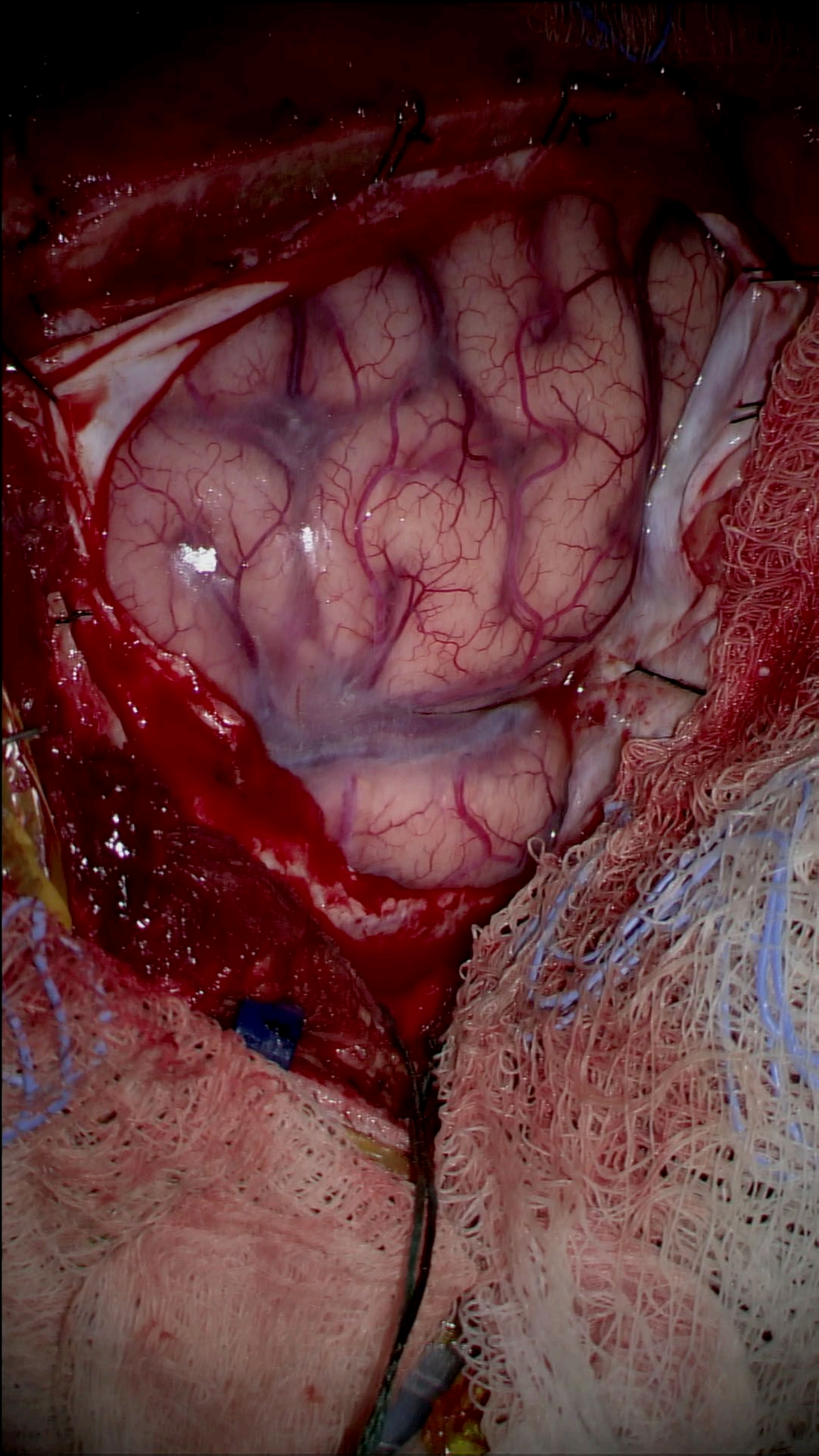
Outcomes	Baseline	1 year period ALL Craniotomies	1 year period ProvenCare Craniotomies	Running period ALL Craniotomies	Running period ProvenCare Craniotomies
Mortality	0.68%	0.61%	0.00%	0.00%	0.00%
Complications	12.24%	11.55%	11.43%	10.09%	10.77%
30-Day Readmissions (PRA v2.1)	10.31%	6.37%	4.26%	8.64%	4.26%
Hospital-Wide 30-Day Readmissions (PRA v4.0)	10.28%	8.01%	7.92%	7.77%	8.06%
All-Cause 30-Day Readmissions - All Inpatients	12.37%	9.17%	7.62%	9.26%	8.46%
Geometric LOS	2.70	2.37	2.16	2.06	2.15

When…Who…

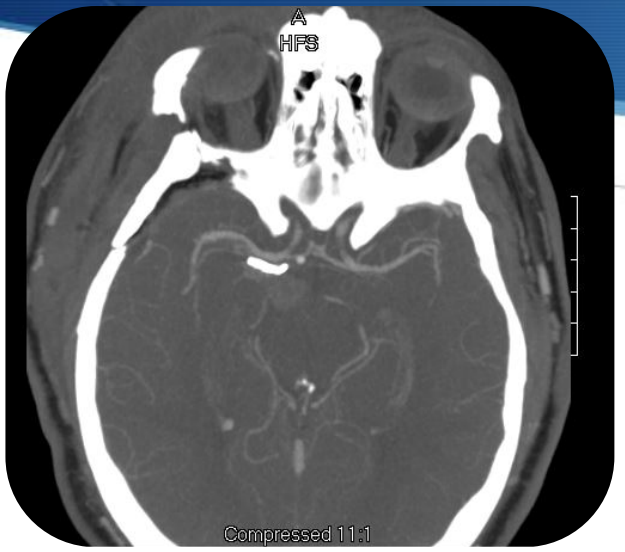
- 38m previous hx of ischemic stroke.
- Smoker, family history SAH
- Aneurysm increased in size. 5mm to 10mmx14mm
- Planned for micro surgical clip ligation



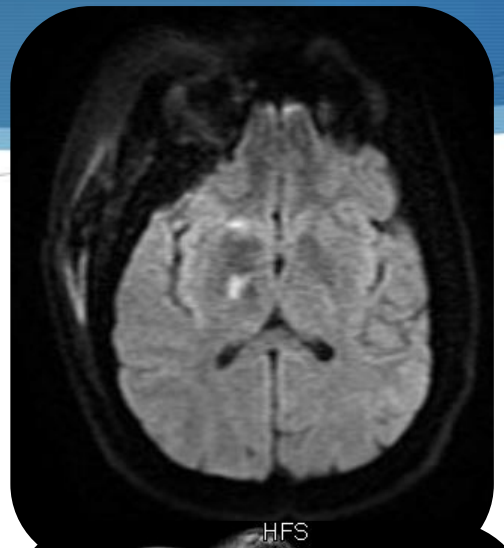


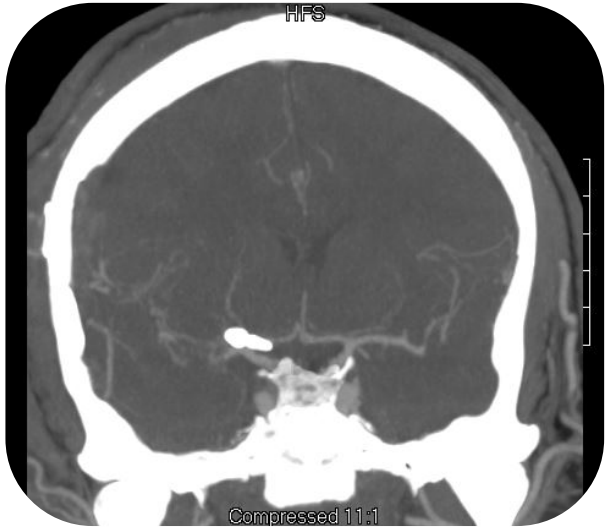


Post - op


A
HFS
Compressed 11:1

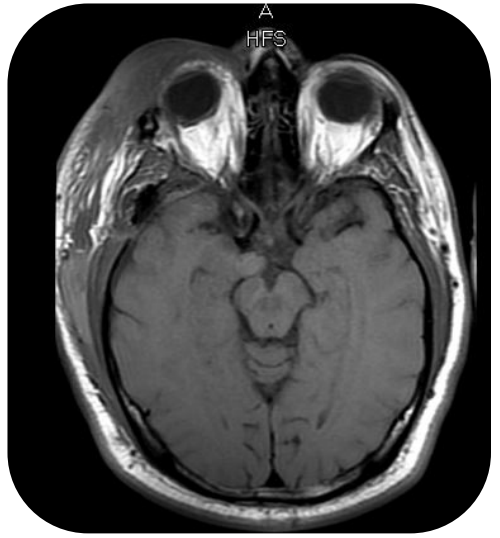

HFS
Compressed 11:1




HFS
Compressed 11:1


HFS

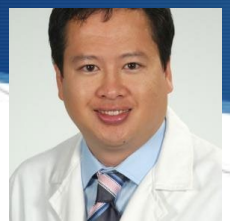

HFS


A
HFS

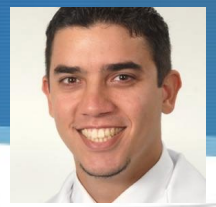
Cerebrovascular Microsurgery

Our teams

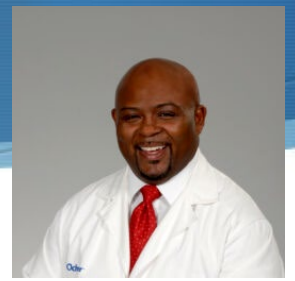
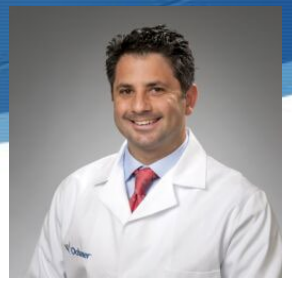
Cerebrovascular Microsurgery

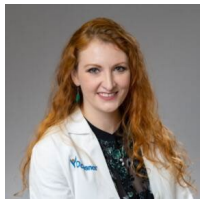

Neuro Intervention




Skullbase

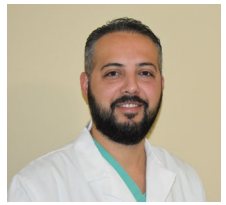




Neurocritical care









THANK YOU!!!

Ochsner™ Health System

Questions?

617-538-7327