Neurointerventional Radiology: Minimally Invasive Treatments for Neurovascular Diseases

UCSF Stroke and Aneurysm Update CME
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Disclosures

- Chief Medical Officer: ChemoFilter
- Scientific advisory: Medina
- Consulting: Stryker, Silk Road
- Data Safety and Monitoring Committee: DAWN trial
- Core Imaging Lab: MAPS trial, FRED trial
- Grant support: NIBIB, ASNR Foundation
- I will discuss off-label uses of drugs (tPA) and devices (stents, balloons, calcium channel blockers)
- Videos from vendors will be shown
- I have borrowed liberally from my colleagues and acknowledge their kind help: Christopher Dowd, MD, Joey English, MD, PhD, Daniel Cooke, MD, Peter Jun, MD, Van Halbach, MD, Randall Higashida, MD

Take Home Points

- A variety of endovascular techniques exist for treating brain aneurysms
- Cerebral vasospasm is the leading cause of mortality and morbidity in SAH patients and can be treated endovascularly

Interventional Neuroradiology

- Use of imaging for the diagnosis and treatment of disorders of the brain and spine
- Imaging modalities include:
  - X-ray fluoroscopy
  - CT
  - MRI
  - Ultrasound
What are Neurointerventional Procedures?

- Image-guided: usually x-ray fluoroscopy
- Transarterial, transvenous, percutaneous
- Diagnostic and therapeutic
- Multidisciplinary: Neurosurgery, Neurology

Scope of Practice

- Cerebrovascular disease
  - Brain aneurysms
  - Subarachnoid hemorrhage (SAH)
  - Cerebral vasospasm
  - Arteriovenous malformations (AVMs)
  - Arteriovenous fistulas (AVFs)
  - Atherosclerosis (intra/extra cranial)
  - Acute ischemic stroke

- Neuro-oncology
  - Tumors of brain, head, neck, and spine

- Peripheral vascular malformations
  - Venous and lymphatic malformations

- Neuro-endocrinology
  - Hyperparathyroidism, Cushing’s disease
  - Vertebral osteoporosis

- Neuroangiography

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- Neuroangiography
Brain Aneurysms

- Abnormal thin-walled swelling or outpouching of an artery
- 1 to 12 million Americans have potentially detectable aneurysms
- Shape and location of aneurysm influence optimal method of treatment

Location of Aneurysms

Schievink, NEJM 1997
Subarachnoid Hemorrhage

Schievink, NEJM 1997

CT X-Ray Angiography

Aneurysmal SAH

- 5% of all strokes
- 30,000 in USA annually
- Population-based mortality 45%
- Significant morbidity among survivors
- High risk of rebleeding
  - 4% day 1, 30+% first month, 3%/yr long term
- 70% mortality from rebleeding
- Goal: occlude aneurysm ASAP


Outline

- Aneurysm treatment: background and history
- Aneurysm treatment: techniques
  - Surgical clipping
  - Endovascular coiling
  - Balloon-assisted coiling
  - Stent-supported coiling
  - Vessel takedown
  - Flow diversion
- Treatment of cerebral vasospasm
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Treatment of Cerebral Aneurysms

Endovascular Timeline
• 1974: first report of balloon embolization of aneurysm (Serbenenko)
• 1982: further Soviet balloon experience reported (Romodanov, Shcheglov) - detachable and nondetachable
• 1980s: experience with silicone (Hieshima) and latex balloons; became standard endovascular alternative to surgical clipping
• 1990: limited experience with pushable fibered coils
• 1991: Guglielmi Detachable Coil (GDC) developed
Aneurysm Coiling

Endovascular Timeline

- 1995: GDC approved by FDA (high-risk aneurysms)
- 1997: Balloon-assist (“remodeling”) technique for wide necked aneurysms (Moret)
- 1997: Stent-supported coiling (Higashida and others)
- 1998: Detachable Silicone Balloon approved by FDA
- 1998: ISUIA study (retrospective)
- 2002: Other detachable aneurysm coils

ISAT (Lancet 360: 1267-1274, 2002)
International Subarachnoid Aneurysm Trial

- Coil vs. clip of ruptured aneurysms in 2143 pts.
- Pts. appropriate for both therapies randomized 1:1
- At 1 yr. f/u: 23.7% coil pts., 30.6% clip pts. dependent/dead
- Trial stopped early: “disability-free survival” at 1 yr. f/u better in coiled pts.
- Study criticisms:
  - no long-term f/u
  - many aneurysms excluded from randomization
  - rebleed rate: coil (2/1276); clip (0/1081)
ISAT Long Term Follow Up
Lancet Neurol 8:427-433, 2009

- 2143 ruptured aneurysm pts enrolled 1994-2002 at 43 centers
- Random assignment to clipping or coiling
- Annual follow-up of 2004 patients for 6 to 14 years (mean 9 y)
- 24 rebleeds at 1 or more years after index aneurysm rx
  - 13 rebleeds from index aneurysm (10 coiled, 3 clipped, p=0.06)
  - 4 rebleeds from non-index aneurysm identified at time of index rx
  - 6 rebleeds from new aneurysms
- Risk of death at 5 years: lower in coiling group (RR 0.77)
  - 11% coiled pts dead, 14% clipped pts dead (p=0.03)
- Proportion of survivors independent at 5 years: equivalent
  - 83% coiled pts independent, 82% clipped pts independent

U.S. Trends in Aneurysm Treatment

Endovascular Timeline

- 2002: ISAT study
- 2002: Neuroform Self-Expanding Stent
- 2002: Bioactive Coils Available
- 2003: ISUIA study (prospective)
- 2003: Detachable Silicone Balloons off market
- 2003: GDC approved for all aneurysm indications
- 2005: Enterprise Self-Expanding Stent
- 2011: Pipeline Flow Diverter (limited indications)
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Endovascular or Surgical Treatment of Ruptured Aneurysms

• Admit or transfer to hospital experienced in treatment of SAH
• Diagnose source of SAH as soon as possible
• Treat aneurysm (surgical clipping or endovascular coiling) within first 5 days of initial rupture
• Manage vasospasm 5 days to 2 weeks post bleed
  – Vasospasm is major source of morbidity and mortality
  – HHH therapy
  – Endovascular therapy

Endovascular Treatment of Unruptured Aneurysms

• Informed consent
• Premedication
  – ASA 81 mg PO qd x 5 days
  – Clopidogrel 75 mg PO qd x 5 days (for stents)
• Anesthesia support: MAC for dx, GA for rx
• ICU overnight after procedure
• Hospital floor bed for second night
• Home by 48 hours post procedure (now often within 36 hours)

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Factors Favoring Craniotomy

- Accessible location (e.g., MCA bifurcation)
- Ability to inspect aneurysm
- Hematoma requiring evacuation
- Experienced surgeon

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Factors Favoring Endovascular Treatment

- Anatomical
  - size
  - aneurysm neck
- Deep location
  - for example: basilar tip, low ICA, AcomA
  - fusiform dissecting vertebral aneurysms
- Concurrent vasospasm
- Older patient age
- Experienced neurointerventionalist
Left ICA Planar Angiograms

Unsubtracted Rotational Angiogram

Subtracted Rotational Angiogram

3D Angiogram Manipulation
54 yo M, GCS 15, with the second-worst headache of his life

R ICA Catheter Angiogram
Post Coiling R ICA Angiogram

Risk of Recurrent SAH

- Six-fold elevated risk of recurrent SAH in patients who have had prior aneurysmal SAH (6:10,000 per year vs 1:10,000 per year)
- Impetus for treating additional unruptured aneurysms when feasible and with low procedural risk
- Patients with prior aneurysmal SAH develop new aneurysms at 2% per year
- “Lost to follow up” is not acceptable – aneurysmal disease is a chronic condition

Schievink WI. NEJM 1997;336:28-40.

3 yo F with HA, LOC, transient paraparesis

Axial NECT

Sagittal NECT Reformat

Angiographic evaluation of SAH

- What constitutes a complete angiogram?
- Internal carotid arteries (head)
- External carotid arteries (head)
- Vertebral arteries – including cervical segments
- Assess vessel origins with common carotid and subclavian arteriograms
R costocervical DSA – late venous

Perimedullary AVF

- Type IV spinal vascular malformation
- Micro (group 1 and 2) and macro (group 3)
- Demographics (Antonietti et al., AJNR 2010)
  - Group 1: 54 y (40-65 y)
  - Group 2: 45 y (16-82 y)
  - Group 3: 17 y (2-40 y)
- Presentations: myelopathy, SAH
- Pathophysiology: venous hypertension, cord compression

3D DSA Reformats – Large Varix

Treatment Options

- Surgery – often best for micro AVF
- Embolization
  - Favorable for macro AVF or large varices
  - Favorable for young children
- Medical – alteration of coagulation or venous hypertension may temporize but not cure
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Stent-Supported Coiling - 1997

**Neuroform Stent**

pre-loaded, self-expanding nitinol stent in flexible 3F microcatheter
54 yo M hx SAH from MCA aneurysm clipped 5 yrs ago, now enlarging BTA

Options?

- Observation
- Clipping
- Primary coiling
- Balloon-assisted coiling
- Y-stenting from basilar to bilateral P1
- Stent-assisted coiling P1 to P1 across PCOMA

Vertebral angiogram post stenting

Coiling of BTA via “trapped” catheter
Coiling of BTA via “trapped” catheter

Post coiling angiogram

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11 yo M with fusiform aneurysm of cervical, petrous and cavernous segments of L ICA

Parent Vessel Occlusion

ICA Balloon Occlusion
VBJ Fusiform Aneurysm Formation After ICA Occlusion

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Flow Diversion

- Pipeline embolization device (PED)
- Lots of stent struts per unit area slow flow into aneurysm causing thrombosis
- Requires dual antiplatelet therapy long term

53 yo F with L CN VI palsy

Courtesy eV3
53 yo F with L CN VI palsy

PUFS Trial
Becske T et al. Radiology 2013; 267:858-868
• Pipeline embolization device (PED) placed in 107 of 108 patients
• Mean aneurysm size 18.2 mm
• 78/106 (74%) met primary effectiveness endpoint (complete aneurysm occlusion with <50% parent artery stenosis) at 180 days
• 6/107 (5.6%) had major ipsilateral stroke or death

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Cerebral Vasospasm: Definition
• Narrowing of intracranial arteries due to irritation by subarachnoid hemorrhage (SAH)
• Symptomatic or asymptomatic
• Reduces cerebral blood flow
  – ischemia and infarction
• Mechanism incompletely understood
  – imbalance of endothelin-mediated vasoconstriction and NO-mediated vasodilation
  – poor clinical results of aggressive clot evacuation
Cerebral Vasospasm

- Vasospasm is the single leading cause of mortality and morbidity in patients treated for aneurysmal subarachnoid hemorrhage.
- Up to 15% - 20% of patients surviving SAH experience stroke or death from vasospasm despite maximal medical therapy.
- Vasospasm can be treated medically (HHH therapy) in the ICU, and for refractory cases, endovascularly with PTA and/or IA vasodilators.

Jun et al. AJNR 2010 31:1911-1916

Don’t Let Your SAH Patients Infarct

35 yo M with gr II SAH, clipped 2 days after initial headache

DSA Pre Clipping  DSA Post Clipping

New L HP 3 days postop

CBF  CBV  MTT
Vasospasm in SAH: Risk Factors

- Amount of blood (Fisher grade)
- Clinical severity (Hunt and Hess grade)
- Age
- Gender
- Use of sympathomimetic drugs

Vasospasm in SAH: Timecourse

- Peaks on days 5 to 7 post aneurysm rupture
- Usually ends 2 weeks post rupture
- Rebleeding
  - resets the clock
  - may lengthen period of vasospasm
- SAH therapeutic strategy
  - secure ruptured aneurysm by SAH day 5
  - clinical management redirected at vasospasm

Medical Management of Vasospasm

- Hourly neurological examinations in ICU
- Prophylactic oral nimodipine
- “HHH” therapy attempts to improve CBF
  - Hypertension: phenylephrine drip
  - Hemodilution: hematocrit 30-35%
  - Hypervolemia: volume expansion
- Neurovascular intensivists manage endovascular and surgical patients

Noninvasive Diagnosis of Vasospasm

- Change in clinical neurological exam
  - New or worsening focal deficit
  - Decrease in level of consciousness
  - New or worsening confusion
- Increased TCD velocities (operator dependent)
- Problem solving
  - NECT to r/o infarction, hemorrhage, hydrocephalus
  - CTA for large vessels and proximal spasm
  - CTP for smaller vessels and distal spasm
- DSA when index of suspicion for vasospasm needing endovascular therapy is high
Vasospasm Diagnostic Algorithm

- Clinically Suspected Vasospasm
  - TCD, CTA and/or CTP -
    - Continue Medical Management
  - TCD, CTA or CTP +
    - DSA

33 yo F HH gr III SAH: Day 1 versus Day 6

CBV

MTT
33 yo F HH gr III SAH day 10
Right PCA Infarction  Bilateral ACA Infarction

Intraarterial Vasodilators: Calcium Channel Blockers
- **Verapamil**
  - extensively used in coronary interventions
  - increases CBF with mild effect on systemic BP
- **Nicardipine**
  - prolonged hypotension, pulmonary edema, renal failure limit dose usable
- **Nimodipine**
  - clinical response better than angiographic response
  - reported use in combination with magnesium sulfate

Aneurysm Coiling and Vasospasm Therapy in a Single Session
HH Grade III SAH, Day 6, Ruptured R PCoA Aneurysm  Post Coiling, Post 20 mg Verapamil IA via RICA Catheter

Intracranial Angioplasty
- First described >25 years ago (Zhubov et al)
- **Mechanism**
  - stretching artery impairs function of smooth muscle
  - causes collagen fragmentation
- **Advantages**
  - excellent, durable angiographic arterial dilatation
- **Disadvantages**
  - for large vessels (SCICA, M1, ± A1, vertebral, basilar, ± P1)
  - nonzero risk of complications
PTA: Technique

- Low compliance balloon microcatheter
- Underdilate spastic segments
- PTA before using IA vasodilators

33 yo F HH grade III SAH day 6

Pre PTA

Post PTA

PTA: Efficacy and Safety

<table>
<thead>
<tr>
<th>Series</th>
<th># patients / # segments</th>
<th>% clinical improvement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coyne et al (1994)</td>
<td>13/—</td>
<td>31</td>
</tr>
<tr>
<td>Firlik et al (1997)</td>
<td>13/—</td>
<td>92</td>
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<tr>
<td>Bejjani et al (1998)</td>
<td>31/81</td>
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<tr>
<td>Eskridge et al (1998)</td>
<td>50/170</td>
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Conclusions

- A variety of endovascular techniques exist for treating brain aneurysms
- Cerebral vasospasm is the leading cause of mortality and morbidity in SAH patients and can be treated endovascularly

Thank You

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