Endovascular Treatment of Aneurysms and Pseudoaneurysms

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
• Similar techniques can be used for treating pseudoaneurysms

What are Neurointerventional Procedures?

• Image-guided: usually x-ray fluoroscopy
• Transarterial, transvenous, percutaneous
• Diagnostic and therapeutic
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

Outline

- Aneurysm treatment: background and history
- Aneurysm treatment: techniques
  - Surgical clipping
  - Endovascular coiling
  - Balloon-assisted coiling
  - Stent-supported coiling
  - Vessel takedown
  - Flow diversion
**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**

Schievink, NEJM 1997
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

Treatment of Cerebral Aneurysms

Surgical Clipping  
Endovascular Coiling

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

Effect of ISAT and ISUIA

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  – Surgical clipping
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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

45F, SAH (I) R MCA aneurysm poor coil candidate

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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

36F, SAH (I) coil R PcomA aneurysm

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
DSA – R subclavian artery

Perimedullary AVF – early arterial
Perimedullary AVF – late venous

3D DSA Reformats – Large Varix

Coronal
Axial

Coil Embolization

Post Embolization DSA
Outline

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  - **Balloon-assisted coiling**
  - Stent-supported coiling
  - Vessel takedown
  - Flow diversion

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80 yo F with recurrent epistaxis

- NECT Soft Tissue Window
- NECT Bone Window

---

80 yo F with recurrent epistaxis

- GRE MRI
- CT Angiogram

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Balloon-Assist Technique (Moret, 1997)
Massive epistaxis before intubation

Post Emergent Intubation and Nasal Balloon Packing

Post Balloon-Assisted Coiling

Post Embolization
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Stent-Supported Coiling - 1997

Intracranial Stents to Assist Coiling

self-expanding nitinol stents in flexible microcatheters
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

Coiling of BTA via “trapped” catheter

Stent Coiling in the MAPS Trial
Hetts et al, AJNR 2014;35(4):698-705

- Clinical and angiographic impact of adjunctive stenting is poorly documented
- It is unknown whether stent assisted coiling (SAC) may result in:
  - Less aneurysm recanalization
  - More complications than coiling alone (CA)
- Evaluated outcomes of stenting and coiling alone in the prospective MAPS Trial
Baseline Demographics

All Unruptured Aneurysms (UIA)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>SAC N=137</th>
<th>CA N=224</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>N. American</td>
<td>88.3%</td>
<td>65.6%</td>
<td>0.0001</td>
</tr>
<tr>
<td>Age</td>
<td>56.5</td>
<td>56.7</td>
<td>0.90</td>
</tr>
<tr>
<td>Female</td>
<td>76.6</td>
<td>76.8</td>
<td>0.98</td>
</tr>
<tr>
<td>Coronary Disease</td>
<td>19.0%</td>
<td>13.1%</td>
<td>0.14</td>
</tr>
<tr>
<td>≥2 CV Risk Factors*</td>
<td>32.1%</td>
<td>25.9%</td>
<td>0.20</td>
</tr>
<tr>
<td>Prior CVA</td>
<td>16.9%</td>
<td>14.5%</td>
<td>0.54</td>
</tr>
<tr>
<td>Pre-Procedure mRS</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0</td>
<td>80.3%</td>
<td>84.4%</td>
<td>&gt;0.99</td>
</tr>
<tr>
<td>1</td>
<td>15.3%</td>
<td>11.6%</td>
<td>&gt;0.99</td>
</tr>
<tr>
<td>2</td>
<td>4.4%</td>
<td>3.6%</td>
<td>&gt;0.99</td>
</tr>
<tr>
<td>3</td>
<td>0.0%</td>
<td>0.4%</td>
<td>&gt;0.99</td>
</tr>
</tbody>
</table>

* CV Risk Factors = Hypertension, Hyperlipidemia, Coronary Artery Disease, Diabetes

Aneurysm Characteristics

All Unruptured Aneurysms (UIA)

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<th>SAC N=137</th>
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<tbody>
<tr>
<td>Maximum Dimension</td>
<td>7.6</td>
<td>7.8</td>
<td>0.46</td>
</tr>
<tr>
<td>Max Dim &gt; 10mm</td>
<td>19.7%</td>
<td>21.0%</td>
<td>0.77</td>
</tr>
<tr>
<td>Neck ≥4mm</td>
<td>62.0%</td>
<td>32.6%</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Average Neck</td>
<td>4.7</td>
<td>3.5</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Dome/Neck</td>
<td>4.4%</td>
<td>2.4%</td>
<td>0.39</td>
</tr>
</tbody>
</table>

Safety Results: Stroke and Other Serious Adverse Events (SAEs)

All Unruptured Aneurysms (UIA)

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</thead>
<tbody>
<tr>
<td>Peri-procedural SAE</td>
<td>6.6%</td>
<td>4.5%</td>
<td>0.19</td>
</tr>
<tr>
<td>12M Hem. stroke</td>
<td>2.9%</td>
<td>0.4%</td>
<td>0.07</td>
</tr>
<tr>
<td>12M Ischemic stroke</td>
<td>8.8%</td>
<td>2.2%</td>
<td>0.005</td>
</tr>
<tr>
<td>1 - 1 site excluded</td>
<td>6.2%</td>
<td>2.2%</td>
<td>0.11</td>
</tr>
</tbody>
</table>

Multivariate Predictors of Stroke at 1 Year and 2 Years

<table>
<thead>
<tr>
<th>Parameter</th>
<th>1 Year OR (95% CI)</th>
<th>1 Year P-value</th>
<th>2 Year OR (95% CI)</th>
<th>2 Year P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Prior Cerebrovascular Accident</td>
<td>3.84 (1.29-11.4)</td>
<td>0.0159</td>
<td>4.71 (1.47-15.0)</td>
<td>0.0089</td>
</tr>
<tr>
<td>Aneurysm Neck Size ≥4mm vs &lt;4mm</td>
<td>3.70 (1.09-12.5)</td>
<td>0.0359</td>
<td>4.51 (1.27-16.0)</td>
<td>0.0196</td>
</tr>
<tr>
<td>Stent Used</td>
<td>1.85 (0.61-5.59)</td>
<td>0.2732</td>
<td>1.05 (0.34-3.27)</td>
<td>0.9351</td>
</tr>
</tbody>
</table>

1 - 1 site in the trial accounted for 5/12 ischemic stroke subjects in UIA SAC subset. All ischemic strokes at that site occurred ≥ 7 days post procedure.
Efficacy – 1 Year Angiographic

All Unruptured Aneurysms (UIA)

<table>
<thead>
<tr>
<th></th>
<th>SAC N=114</th>
<th>CA N=180</th>
<th>p</th>
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</thead>
<tbody>
<tr>
<td>Core Lab Occlusion</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Assessment</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Raymond 1</td>
<td>51.8%</td>
<td>44.4%</td>
<td>0.22</td>
</tr>
<tr>
<td>Raymond 2</td>
<td>21.1%</td>
<td>33.9%</td>
<td>0.57</td>
</tr>
<tr>
<td>Raymond 3</td>
<td>27.2%</td>
<td>31.7%</td>
<td>0.41</td>
</tr>
<tr>
<td>Core Lab Change</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Assessment</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Better</td>
<td>51.8%</td>
<td>31.1%</td>
<td>0.0004</td>
</tr>
<tr>
<td>Same</td>
<td>31.6%</td>
<td>35.6%</td>
<td>0.48</td>
</tr>
<tr>
<td>Worse</td>
<td>16.7%</td>
<td>33.3%</td>
<td>0.002</td>
</tr>
</tbody>
</table>

81% of UIA had assessable angiograms for Core Lab evaluation at 1 year follow up.

Angiographic Improvement: Residual Aneurysm to Neck Remnant

Post Coiling

Follow Up

Angiographic Worsening: From Complete Occlusion Immediately Post Coiling to Residual Aneurysm on Follow Up

Recanalization = Worse (Post vs. FUP)

Clinical Outcomes

1 Year – All UIA

<table>
<thead>
<tr>
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<th>SAC N=137</th>
<th>CA N=224</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>TAR</td>
<td>8.8%</td>
<td>8.5%</td>
<td>0.93</td>
</tr>
<tr>
<td>Delayed Bleed</td>
<td>0.0%</td>
<td>0.4%</td>
<td>&gt;0.99</td>
</tr>
<tr>
<td>Retreatment</td>
<td>8.8%</td>
<td>8.5%</td>
<td>0.93</td>
</tr>
</tbody>
</table>

2 Years – All UIA

<table>
<thead>
<tr>
<th></th>
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<th>CA N=224</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>TAR</td>
<td>8.5%</td>
<td>9.8%</td>
<td>0.92</td>
</tr>
<tr>
<td>Delayed Bleed</td>
<td>0.0%</td>
<td>0.4%</td>
<td>&gt;0.99</td>
</tr>
<tr>
<td>Retreatment</td>
<td>9.5%</td>
<td>9.8%</td>
<td>0.92</td>
</tr>
</tbody>
</table>
### Multivariate Predictors of TAR at 1 Year and 2 Years

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<th>Parameter</th>
<th>1 Year OR (95% CI)</th>
<th>1 Year P-value</th>
<th>2 Year OR (95% CI)</th>
<th>2 Year P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aneurysm Dome Size ≥10mm vs &lt;10mm</td>
<td>10.1 (4.06-24.9)</td>
<td>&lt;0.0001</td>
<td>9.94 (4.12-24.0)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Aneurysm Neck Size ≥4mm vs &lt;4mm</td>
<td>2.34 (0.94-5.81)</td>
<td>0.0664</td>
<td>2.17 (0.93-5.06)</td>
<td>0.0729</td>
</tr>
<tr>
<td>Stent Used</td>
<td>0.89 (0.38-2.10)</td>
<td>0.7855</td>
<td>0.83 (0.36-1.88)</td>
<td>0.6505</td>
</tr>
</tbody>
</table>

### Outline

- Aneurysm treatment: background and history
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### 18 yo F with headache

![NECT](image1.png)  ![CTA](image2.png)  

![L vert DSA AP Early](image3.png)  ![L vert DSA AP Mid](image4.png)
18 yo F with headache

R PCA Branch AP
R PCA Branch Lateral

n-BCA Cast Post Embo
4 Years Later – Progressive AVM Nidus

Progressive AVM Nidus with AV Shunting

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

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

53 yo F with L CN VI palsy

PUFS Trial
Becske T et al. Radiology 2013; 267:858-868

L ICA DSA AP Pretreatment  L ICA DSA Lat Pretreatment
PUFS Trial

- 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

Endovascular Treatment of Aneurysms
Naggara et al. *Radiology* 2012; 263:828-835

- 7172 patients (26 studies)
- Outcomes analysis of endovascular treatment of unruptured aneurysms
- Coiling-based techniques have become progressively safer over the past 2 decades
- Data on stents is mixed, but also improving
- Data on flow diverters is sparse
- Large aneurysms have worse treatment outcomes than small aneurysms
Conclusions

- A variety of endovascular techniques exist for treating brain aneurysms
- Similar techniques can be used for the treatment of pseudoaneurysms

Thank You

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