# Treatment of Carotid Artery Disease

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## Objectives

- Stroke Epidemiology and risk factors  
- Review indications for carotid revascularization  
- Choosing between endarterectomy and stenting: outcomes  
- Timing of revascularization
Stroke

- Ranks third as leading cause of death behind heart disease and cancer
- Annual stroke occurrence in the United States around 795,000
- Current American Heart Association data suggest that every 40 seconds someone in the United States is having a stroke


Stroke Epidemiology

- Significant gender and racial differences
- Strokes occur in 55,000 more women than men
- African-Americans have almost twice the stroke risk of whites
- Mexican Americans have also been shown to have an increased incidence of stroke

Stroke Sequelae

- 70% of stroke survivors do regain functional independence
- 15% to 30% become permanently disabled
- 3 months after stroke, up to 20% will continue to require long-term care


Stroke Sequelae

- Among ischemic strokes at 6 months after the initial insult for patients who are ≥ 65 years old the following deficits exist:
  - 50% had some hemiparesis
  - 30% required some assistance with walking
  - 26% could not perform activities of daily living independently
  - 19% had aphasia
  - 26% were institutionalized

### Cost

- In 2007, the total cost of stroke exceeded 40 billion dollars in U.S.
- projections of future costs of stroke from 2005 to 2050
  - $1.52 trillion for whites
  - $313 billion for Hispanics
  - $379 billion for African-Americans


### Risk Factors

- Modifiable risk factors for stroke mimic those for cardiovascular disease in general
- Smoking, diabetes and hypertension
- Atrial fibrillation independently increases the risk for stroke by a factor of 5

Risk Factors

• Age
• Gender
  – women aged 45-84 have a lower risk than men
  – women aged greater than 85 have higher risk than men
• Race


Risk Factors

• Hypercholesterolemia?
• Statin drugs decrease stroke risk even in patients without hypercholesterolemia

### Risk Factors

- **TIA**
  - 3% to 10% risk of stroke at 2 days following TIA
  - 9% to 17% risk of stroke at 90 days after TIA
  - TIA related mortality at 1 year is up to 25%


### Carotid Stenosis

- Stroke risk is directly related to the degree of carotid disease
- 1115 patients from the Asymptomatic Carotid Stenosis and Risk of Stroke (ACSRS) group
- Asymptomatic internal carotid artery stenosis greater than 50% followed for a mean of 37 months
- Linear relationship between stroke and degree of carotid stenosis

Carotid Stenosis

- 296 carotid arteries in 293 patients were followed for an average of 46 months
- Either less than 75% stenosis or greater than 75% stenosis
- Patients with greater than 75% stenosis were found to have higher risk of both TIA and stroke
- Plaque morphology


Carotid Artery Disease

20 to 30% of strokes are caused by atherosclerotic carotid artery disease

- Carotid artery disease increases the risk for stroke:
  - by plaque or clot breaking off from the carotid arteries and blocking a smaller artery in the brain
  - by narrowing of the carotid arteries due to plaque build-up
  - by a blood clot becoming wedged in a carotid artery narrowed by plaque

Treatment Modalities

- Medical therapy
- Carotid endarterectomy
- Carotid artery stenting

Medical Treatment

- **Advantages**
  - Good option for those with short life expectancy (i.e. benefits of endovascular or surgical therapy does not outweigh the risks)
  - Does not require hospitalization

- **Disadvantages**
  - Risk of stroke may be higher
  - Risk of hemorrhage
  - Regular lab monitoring
Natural History of Asymptomatic Carotid Disease

- Asymptomatic Carotid Atherosclerosis Study (ACAS)
- European Asymptomatic Carotid Surgery Trial (ACST)
- Overall stroke risk in medically managed asymptomatic patients is about 2% per year

Results of Asymptomatic Trials

<table>
<thead>
<tr>
<th></th>
<th>Medical (%)</th>
<th>Surgical (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>ACAS (ipsilateral stroke risk)</td>
<td>11</td>
<td>5.1</td>
</tr>
<tr>
<td>ACST (any stroke risk)</td>
<td>11.8</td>
<td>6.4</td>
</tr>
</tbody>
</table>
## Indications

- Largely independent of method of revascularization
- Symptomatic disease
- Asymptomatic disease
- Vertebral or posterior fossa disease
- External carotid disease
- 3% rule (ACAS 2.3% stroke/death)

## Asymptomatic Disease

- > 60%
- ACAS 5 year follow up
  - 11% stroke risk in medical arm
  - 5.1% stroke risk in surgical arm
  - lesser benefit in women
- Consider limiting to men, > 80%, contralateral occlusion or high grade stenosis, ulcerated lesions
- No increased benefit with increasing degrees of stenosis
### Symptomatic Disease

- **70 – 99%**
- **NASCET 2 year follow up**
  - 26% stroke risk in medical arm
  - 9% stroke risk in surgical arm
  - especially benefits males > 75

### Symptomatic Disease

- **50 – 69%**
- **NASCET 5 year follow up**
  - 22.7% stroke risk in medical arm
  - 15.7% stroke risk in surgical arm
<table>
<thead>
<tr>
<th><strong>Vertebral Disease</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>• Carotid reconstruction first if there is concomitant carotid and vertebral disease in the presence of posterior fossa symptoms</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>External Carotid Disease</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>• Ipsilateral hemispheric TIA (not amaurosis) in the setting of ipsilateral ICA occlusion and contralateral ICA stenosis – contralateral ICA revascularization</td>
</tr>
<tr>
<td>• Ipsilateral amaurosis in the setting of ipsilateral ICA occlusion and ipsilateral ECA stenosis – ipsilateral ECA revascularization</td>
</tr>
<tr>
<td>• Ipsilateral TIA in the setting of patent contralateral carotid system, ipsilateral ICA occlusion, and ipsilateral ECA stenosis – ipsilateral ECA revascularization</td>
</tr>
</tbody>
</table>
### Endarterectomy vs. Stenting

- High risk for endarterectomy – CMS criteria
- Endarterectomy outcomes
- Stenting outcomes

### High Risk for Endarterectomy

- NYHA III or IV CHF
- EF < 30%
- Unstable angina
- Recent MI
- Contralateral occlusion
- Recurrent stenosis
- Radiation
### High Risk for Endarterectomy

- COPD
- Anatomically inaccessible lesion
- Cervical immobility
- Prior neck dissection
- Tracheostomy
- Contralateral cranial nerve injury

### Endarterectomy Outcomes

- Symptomatic
  - 0.6 – 1% death
  - 5 – 7% stroke/death
- Asymptomatic
  - 2.3% stroke/death
## Endarterectomy Outcomes

- Cranial nerve injury: 4 – 7%
- Hemorrhage: 3%
- MI: 1 – 2.6%
- Hyperperfusion syndrome/intracranial hemorrhage: 1%
- Restenosis: 3 - 6%
- Infection: 0.3 – 0.8%

## Stenting Outcomes

- Randomized trials plagued by
  - bias
  - operator inexperience
  - aberrant CEA outcomes
  - Non-standardized EPD
  - angioplasty without stent
## Stenting Outcomes

<table>
<thead>
<tr>
<th>Trial</th>
<th>CEA Stroke/death</th>
<th>CAS stroke/death</th>
<th>CEA restenosis</th>
<th>CAS restenosis</th>
</tr>
</thead>
<tbody>
<tr>
<td>CAVATAS 2001</td>
<td>9.9%</td>
<td>10%</td>
<td>10.5%</td>
<td>30.7%</td>
</tr>
<tr>
<td>SAPPHIRE 2004</td>
<td>20.1%</td>
<td>12.2%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>EVA-3S 2006</td>
<td>3.9%</td>
<td>9.6%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>SPACE 2006</td>
<td>6.3%</td>
<td>6.8%</td>
<td>4.6%</td>
<td>10.7%</td>
</tr>
</tbody>
</table>

### ICSS (n = 1,713)

<table>
<thead>
<tr>
<th></th>
<th>Stroke</th>
<th>Stroke/death/MI</th>
</tr>
</thead>
<tbody>
<tr>
<td>CEA</td>
<td>4.1%</td>
<td>5.2%</td>
</tr>
<tr>
<td>CAS</td>
<td>7.7%</td>
<td>8.5%</td>
</tr>
</tbody>
</table>
Carotid Revascularization Endarterectomy versus Stenting Trial (CREST)

- Only NIH sponsored, prospective, randomized, controlled, multi-center trial; normal risk patients
- Long enrollment period
- Rigorous operator training and credentialing
- Best medical therapy regimen used
- Independent neurologist evaluation
- Crossovers discouraged
- New devices now

CREST

- 2502 patients
- Symptomatic disease ≥50% by angiography, >70% by ultrasound, CTA or MRA,
- Asymptomatic ≥60% stenosis by angiography, or >70% by ultrasound or >80% by CTA of MRA
CREST

- Primary endpoint of any stroke, MI or death during the periprocedural period or ipsilateral stroke for up to 4 years occurred in 7.2% of CAS patients and 6.8% of CEA patients
- Better outcomes were seen with patients aged ≤ 70 who underwent CAS
- Patients aged > 70 did better with CEA

CREST sub analysis of MI and stroke

<table>
<thead>
<tr>
<th></th>
<th>CEA</th>
<th>CAS</th>
</tr>
</thead>
<tbody>
<tr>
<td>MI</td>
<td>2.3%</td>
<td>1.1%</td>
</tr>
<tr>
<td>Stroke</td>
<td>2.3%</td>
<td>4.1%</td>
</tr>
</tbody>
</table>
• Postprocedure analysis demonstrated greater impact on the patients who had suffered a stroke rather than an MI

Post-Procedure Stroke

• If patient awakens with neurologic deficit – return to OR
• Neurologic deficit within 24 hours – return to OR
• Neurologic deficit after 24 hours – head CT to rule out hemorrhage first
### Timing of Revascularization

<table>
<thead>
<tr>
<th>Duration</th>
<th>Fixed Deficit</th>
<th>Infarct Volume</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 2 weeks</td>
<td>mild fixed deficit or no fixed deficit</td>
<td>small or undetectable infarct volume</td>
</tr>
<tr>
<td>4 weeks</td>
<td>moderate fixed deficit</td>
<td>moderate infarct volume</td>
</tr>
<tr>
<td>6 weeks</td>
<td>significant fixed deficit</td>
<td>large infarct volume</td>
</tr>
<tr>
<td>Emergent</td>
<td>immediate thrombosis after CEA or CAS</td>
<td></td>
</tr>
<tr>
<td>Urgent</td>
<td>crescendo TIA</td>
<td>stroke in evolution</td>
</tr>
</tbody>
</table>
Carotid Artery Disease

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Stent or Endarterectomy?

High Surgical Risk
Symptomatic high-grade stenosis
– Stent
Asymptomatic high-grade stenosis
– Stent (through a trial)
– Continued Medical Management
### Standard Risk Patients

**Age < 70**

CAS or CEA with equivalent composite stroke/MI/death rates

- CAS: ↑ stroke risk ↓ MI risk
- CEA: ↑ MI risk ↓ stroke risk

### Standard Risk Patients

**Age > 70**

CEA (lower periprocedural stroke risk)

Medical management

1. Antiplatelet therapy
2. Statin
3. Management of hypertension
4. Smoking Cessation
National Coverage Determination for PTA (20.7)

- ONLY High-Risk, Symptomatic, >70% stenosis
- Otherwise has to be part of a trial
- Not covered if embolic protection not used
- Not covered if facility not Medicare approved

https://www.cms.gov/MedicareApprovedFacilitie/CASF/list.asp
### Cardiac Complications

- MI is responsible for 25% to 50% of perioperative deaths
- Late deaths are due to myocardial infarction
- Surgically correctable CAD was identified in 20%

### Preoperative Management

Eagle or Goldman / Detsky index used to determine need for further workup. Minor predictors do not warrant cardiac testing.

No further workup:
- Recent coronary revascularization within 5 years
- Negative coronary angiography or cardiac stress testing within 2 years.
Anesthetic Choice

<table>
<thead>
<tr>
<th>Anesthetic Choice</th>
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</thead>
<tbody>
<tr>
<td><strong>General</strong></td>
</tr>
<tr>
<td>– Need to have monitoring of brain activity</td>
</tr>
<tr>
<td>– Routinely shunt</td>
</tr>
<tr>
<td><strong>Local cervical block</strong></td>
</tr>
</tbody>
</table>

![Image of surgical site](image_url)
CN Injury

Hypoglossal Nerve
• Tongue weakness and deviation to the affected side
• Unilateral hypoglossal nerve injury is rarely serious

Hewett R M, Stewart G E J Neurol Neurosurg Psychiatry 2011;82:376-377
### CN Injury

**Vagus Nerve**
- Recurrent laryngeal branch - Paralysis of the ipsilateral vocal cord
- Hoarseness and loss of an effective cough mechanism
- *Superior Laryngeal Nerve* - loss of tensioning of the ipsilateral vocal cord

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**Facial Nerve: Marginal Mandibular Branch**
- Drooping of the ipsilateral lower lip
- Injury is usually due to excessive stretch
**CN Injury**

*Glossopharyngeal and Spinal Accessory Nerves*

- Exceedingly rare
- Glossopharyngeal - mild dysphasia to recurrent aspiration
- Spinal accessory nerve - shoulder droop, scapular winging, and difficulty abducting the shoulder
### Hyperperfusion

- Related to loss of cerebral autoregulation
- Usually acute but may present delayed
- Risks:
  - Hypertension and recent contralateral carotid
  - Very tight stenosis preop

Headaches and Hypertension
  - May result in cerebral hemorrhage / death

### Recurrent Stenosis

- Meta-analysis - 6% to 14%
- 10% within the first year, 3% in the second, and 2% in the third year
- Usually from intimal hyperplasia
- Some regress over time
- Closure with a patch reduces recurrent stenosis
## Follow-Up Schedule for Duplex

<table>
<thead>
<tr>
<th>Percentage Range</th>
<th>Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>20-49%</td>
<td>An annual study</td>
</tr>
<tr>
<td>50-79%</td>
<td>Every six months</td>
</tr>
<tr>
<td>80-99%</td>
<td>Every 6 months if surgery not performed</td>
</tr>
</tbody>
</table>

### After carotid endarterectomy

- **Ipsilateral/unilateral examinations**
  - At six weeks
  - Six months
  - One year

- **Bilateral study**
  - Symptoms or previously disease in the contralateral carotid
Filter Wires

- Set wires and catheters
- Cross lesion before protected

Flow Reversal

- Closer to how it is done in CEA
- Can use different wire and catheters
- “Belt and Suspenders” with filter in ICA
## Complications

<table>
<thead>
<tr>
<th>Complications</th>
</tr>
</thead>
</table>
| **• Hyperperfusion syndrome**  
  Headache and hypertension  
  Focal motor seizures and intracerebral hemorrhage  
  1.1% incident |
| **• Myocardial infarction**  
  1 to 4% |

<table>
<thead>
<tr>
<th>Complications</th>
</tr>
</thead>
</table>
| **• Renal dysfunction**  
  Contrast-induced nephropathy  
  Atheroemboli  
  Hypoperfusion  
  Risk greatest in moderate to severe renal insufficiency and diabetes |
## Complications

<table>
<thead>
<tr>
<th>Access-related complications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hematoma</td>
</tr>
<tr>
<td>Bleeding</td>
</tr>
<tr>
<td>Pseudoaneurysm</td>
</tr>
<tr>
<td>Atheroembolization</td>
</tr>
<tr>
<td>Purple discoloration of the toes or gangrene</td>
</tr>
<tr>
<td>Marbled pattern (livedo reticularis)</td>
</tr>
<tr>
<td>Extremely Painful</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Carotid restenosis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acute thrombosis in 0.5 to 2 %</td>
</tr>
<tr>
<td>Early restenosis due to neointimal hyperplasia, 6 % 1 year</td>
</tr>
<tr>
<td>Stent fracture</td>
</tr>
<tr>
<td>As high as 29 percent</td>
</tr>
<tr>
<td>Clinical significance unknown as of yet</td>
</tr>
</tbody>
</table>
### Follow Up

- Dual Antiplatelet Therapy
  - Aspirin 325mg for life
  - Plavix 75mg 6 weeks or longer
- Statin
- Smoking Cessation
- BP control

### Carotid Duplex

- Normal criteria probably overestimate degree of stenosis
- Related to decreased compliance from stent
- Those in trials will have defined follow up
- Otherwise similar to CEA for ultrasound