Carotid Artery Disease

1. **Prevalence and ethiopathogeny of stroke**
2. Imaging techniques
3. Medical treatment
4. Carotid endarterectomy: randomised trials
5. Carotid endarterectomy: surgical technique
6. Carotid artery stenting

**Introduction**

- Prevalence of > 50% carotid artery stenosis
  - 50 - 59 y: 0.5%
  - > 80 y: 10%
- PAOD: 20%
- Stroke is the 3rd cause of death
- Stroke and TIA are heterogenous conditions with various etiologies and difficult to classify
- Subsequent stroke risk after TIA = 7% per year
- Annual risk of unheralded stroke for an asymptomatic > 80% stenosis = < 3% per year
- 20% of subsequent strokes in the territory of a symptomatic ICA are unrelated to the ICA stenosis

**Appropriate Carotid Surgery**

The leading cause of stroke in carotid artery disease is **atheroembolism** rather than flow-reduction.

**Abstract:**

Carotid artery disease (CAD) becomes a commonly seen disease in general medical practice, due to the general population aging. Stroke, one of the most frequent complications of CAD represents the third cause of death in Western countries. The leading cause of stroke in CAD is atheroembolism rather than flow-reduction. This paper reviewed imaging techniques, medical treatment and especially carotid endarterectomy (from point of view of indications, surgical technique and results) and carotid artery stenting for the correct management of CAD.

**Key Words:** Carotid Artery Disease, Stroke, Carotid Endarterectomy, Carotid Stenting

**APPROPRIATE CAROTID SURGERY**

The leading cause of stroke in carotid artery disease is **atheroembolism** rather than flow-reduction.
Diagram of plaque with intraplaque hemorrhage. Intraplaque hemorrhage broken through the surface, allowing egress of the hemorrhage material up the internal carotid artery to the brain.

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**correlation between flow velocity and % stenosis**

<table>
<thead>
<tr>
<th>% stenosis</th>
<th>peak systolic velocity</th>
<th>end diastolic velocity</th>
<th>PSV ICA ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 - 40%</td>
<td>25 - 100 cm/sec</td>
<td>&lt; 40 cm/sec</td>
<td>&lt; 1.5</td>
</tr>
<tr>
<td>40 - 60%</td>
<td>100 - 120 cm/sec</td>
<td>&lt; 40 cm/sec</td>
<td>&lt; 1.8</td>
</tr>
<tr>
<td>60 - 80%</td>
<td>&gt; 130 cm/sec</td>
<td>&gt; 40 cm/sec</td>
<td>&gt; 1.8</td>
</tr>
<tr>
<td>80 - 99%</td>
<td>&gt; 250 cm/sec</td>
<td>&gt; 80 cm/sec</td>
<td>&gt; 4.0</td>
</tr>
</tbody>
</table>

Velocity measurements: an **indirect** method for stenosis evaluation.

**diameter and surface area stenosis**

- *Aliasing*
- *Turbulent flow*
advantages:
- analysis of plaque structure
- analyses of flow disturbances

limitations:
- limited to cervical portion of carotid artery
- operator dependent
- interference with cardiac disease
- obscuring calcified lesions

the surgeon as “clinician-sonographer”

carotid angiography
- neurologic morbidity: AVC 0.1%
- mortality: 0.02%
- renal toxicity
- puncture site complications: 0.5 to 1%
784 carotid angiograms with intracranial views
- 6% siphon stenosis
- 2% intracranial aneurysm
- 0.01% cerebral tumor

1000 carotid angiograms with aortic arch view
- 0.6% intrathoracic stenosis
- 0.3% tandem lesions

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Best medical treatment for carotid artery disease
- anti-platelet drugs: aspirine 100 mg, clopidogrel 75 mg
- lipid lowering drugs: statins
- anti-hypertensive drugs: ACE-inhibitors

Triple therapy allows to stabilise and heal the atheromatous plaque

* SPARCL (Stroke Prevention by Aggressive Reduction Cholesterol Levels) NEJM 2006;355:549-559
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The marginal benefit of CEA for stroke prevention by carotid TEA for a recently symptomatic ICA stenosis is nullified once perioperative stroke-death rate exceeds 3%.

<table>
<thead>
<tr>
<th>% of stenosis</th>
<th>ARR (5 y)</th>
<th>NNT (5 y)</th>
</tr>
</thead>
<tbody>
<tr>
<td>50-69%</td>
<td>10.3%</td>
<td>35</td>
</tr>
<tr>
<td>70-99%</td>
<td>16.5%</td>
<td>25</td>
</tr>
</tbody>
</table>

Meta analysis of pooled data of NASCET, ECST and VA, Lancet 2004; 363: 915-924

Benefit of carotid endarterectomy in function of time delay between CEA and presenting symptom

<table>
<thead>
<tr>
<th>Presenting symptom</th>
<th>ARR (5 y)</th>
<th>NNT (5 y)</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 2 weeks</td>
<td>15.9%</td>
<td>20.0</td>
</tr>
<tr>
<td>2-4 weeks</td>
<td>13.5%</td>
<td>12.0</td>
</tr>
<tr>
<td>4-12 weeks</td>
<td>10.3%</td>
<td>15.0</td>
</tr>
<tr>
<td>&gt; 12 weeks</td>
<td>9.0%</td>
<td>20.0</td>
</tr>
</tbody>
</table>

Benefit of CEA for symptomatic ICA stenosis

<table>
<thead>
<tr>
<th>Treatment effect modifiers</th>
<th>AR (5 y)</th>
<th>NNT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time since last ischemic event</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>8.6%</td>
<td>22</td>
</tr>
<tr>
<td>Female</td>
<td>5.0%</td>
<td>37</td>
</tr>
<tr>
<td>Age</td>
<td></td>
<td></td>
</tr>
<tr>
<td>65-74 y</td>
<td>10.0%</td>
<td>10.0</td>
</tr>
<tr>
<td>&gt;75 y</td>
<td>12.0%</td>
<td>8.0</td>
</tr>
<tr>
<td>Other</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Plaque surface</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Smooth</td>
<td>10.0%</td>
<td>10.0</td>
</tr>
<tr>
<td>Ulcerated</td>
<td>15.0%</td>
<td>7.0</td>
</tr>
<tr>
<td>Degree of stenosis</td>
<td></td>
<td></td>
</tr>
<tr>
<td>50-69%</td>
<td>12.0%</td>
<td>10.0</td>
</tr>
<tr>
<td>70-99%</td>
<td>15.0%</td>
<td>7.0</td>
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Rothwell, Pooled data of NASCET, VA and ECST Trials, Lancet 2003; 363: 915-924
benefit of CEA in elderly

natural history of a 70-99% symptomatic stenosis:
- > 75 y: 36.5% ipsilateral stroke risk at 2 y
- < 75 y: 20.0% ipsilateral stroke risk at 2 y

number needed to treat to prevent one ipsilateral stroke at 5 years:
- < 65 years: NNT = 10
- 65 - 75 years: NNT = 7
- > 75 years: NNT = 3

pooled NASCET/ECST data

benefit of CEA for asymptomatic carotid stenosis (60-99%)

prevention of ipsilateral stroke at 5 years follow-up

<table>
<thead>
<tr>
<th></th>
<th>absolute risk reduction</th>
<th>N.N.T.</th>
</tr>
</thead>
<tbody>
<tr>
<td>ACAS</td>
<td>5.5%</td>
<td>17</td>
</tr>
<tr>
<td>ACST</td>
<td>5.4%</td>
<td>18</td>
</tr>
</tbody>
</table>

ACAS, JAMA 1995;273:1421-1428
ACST, Lancet 2004;363:1491-1502

benefit of surgery in terms of prevention of ipsilateral stroke in patients with an asymptomatic > 60% stenosis (ACST - Trial)

- limited benefit for 60 - 99% stenosis (RRR = 53%, ARR = 5.9% at 5 y)
- less benefit for retinal event (AF)
- no benefit for women (1.7% RRR vs 66% for men)
- no benefit if controlateral occlusion
- no benefit for octogenarians
- no benefit for near occlusion
- linear relation between degree of stenosis and stroke risk (1.8% for 70-80%, 3.5% for > 80% stenosis)

Rigorous selection of patients and low (<3%) peri-operative stroke-death rate are required to justify carotid TEA for asymptomatic stenosis.

Operative outcome of CEA

- for symptomatic stenosis (*)
  - 30-day mortality: 1.1%
  - 30-day stroke-death rate: 7.1%

- for asymptomatic stenosis (**) (ACST - Trial)
  - 30-day stroke-death rate: 2.9%

(*) from Rothwell - Pooled data of NASCET, BEST and VA-309, Lancet 2003;361:107-116
(**) from Chambers - CEA for asymptomatic carotid stenosis, COCHRANE data base 2005, (CD 00 1923)

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open carotid endarterectomy (CEA) : operative technique

inlay shunt (Javid)

<kinking> of ICA.
carotid endarterectomy

5 controversial points:
- open CEA vs eversion
- shunt or no shunt
- patch or no patch
- cerebral monitoring
- general vs local anaesthesia

►► patch closure: 4.0% restenosis (> 50%) rate at 1 year
0.5% early thrombosis

►► direct closure: 17% restenosis rate at 1 year
(24% in women)
3% early thrombosis
- < 0.1% risk of venous patch "blow out"
- < 0.5% risk of prosthetic patch infection


carotid endarterectomy

routine shunt or no shunt or elective shunt?
- almost all patients tolerate a 20 to 30 min period of carotid clamping
- selection of shunting, based on trans-cranial doppler or intra-operative EEG is questionable
- routine shunting is safest and gives the best exposure of the distal ICA

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CAS (Carotid Artery Stenting)

catheter based intervention is
- trendy
- industry pushed
- attractive, less invasive

Endovascular angioplasty:
Controlled injury
Carotid Stent

Angio before and after stenting

Different stenting strategies

Carotid Wallstent:
- For treating carotid bifurcation lesions
- For treating long and/or soft, dishomogeneous lesions

Nitinol stents:
- For treating short and/or hard-calcified lesions
- For maintaining original anatomy

“Free cell area” based analysis

- Comparison of free cell area

- closed cell

- open cell
**Distal cerebral protection**

- Embolic protection device (filter)

- 30-day TIA: 3.1%
- 30-day minor stroke: 2.1%
- 30-day major stroke: 1.2%
- 30-day mortality: 0.6%
- 30-day stroke death rate: 4.7%

Global Carotid Artery Stent Registry (12392 CAS procedures, 1997-2002)

from Wholey, Catheter Cardiovasc Interv 2003;60:259-266

**Cerebral Protection Strategies**

- CAS (Carotid Artery Stenting)
- Global Carotid Artery Stent Registry (12392 CAS procedures, 1997-2002)
- 30-day TIA: 3.1%
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- 30-day mortality: 0.6%
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from Wholey, Catheter Cardiovasc Interv 2003;60:259-266

**CAS (Carotid Artery Stenting)**

- Stroke-death rate: overall 4.7%, with EPD (filter) 2.9%, without EPD (filter) 6.2%
- Stroke-death rate in symptomatic pts: 4.9%, in asymptomatic pts: 2.9%
- Restenosis rate at 3 y: 2.5%
- Ipsilateral stroke rate at 1 y: 1.2%

from Wholey, Catheter Cardiovasc Interv 2003;60:259-266

**CAS (Carotid Artery Stenting)**

- Randomised controlled trials (low risk, symptomatic > 60% stenoses)

<table>
<thead>
<tr>
<th>Trial</th>
<th>Nb of procedures</th>
<th>30-day stroke-death rate CAS</th>
<th>CEA</th>
</tr>
</thead>
<tbody>
<tr>
<td>SPACE* (Germany-2006)</td>
<td>1183</td>
<td>6.8%</td>
<td>6.3% (unilateral) 3.9% (any)</td>
</tr>
<tr>
<td>EVA 3S** (France-2006)</td>
<td>527</td>
<td>9.6%</td>
<td></td>
</tr>
</tbody>
</table>

* Lancet 2006;368:1315-6
CAS (Carotid Artery Stenting)

- Always embolic protection device
- Complete coverage of the plaque (from disease free distal CCA to disease free proximal ICA)
- Self-expanding nitinol stent (superior conformability and resistance to deformation)
- Predilatation with a 2 mm balloon for tight stenoses
- 4 days Aspirin + Clopidogrel prior to CAS
- 30 days Aspirin + Clopidogrel following CAS

WHO ARE performing CAROTID STENTING?

- Vascular Surgeon
- Radiologist
- Cardiologist

BASED ON THE 40 SURVEY CENTERS

International Carotid Angioplasty Registry

M.H. Wholey. GET-Montecarlo 16-19 May 2003

Human and technical limits

Cost-estimation of CAS

2007 Guidelines of American Heart Association

- CEA is justified for symptomatic 50-99% stenosis if the risk of perioperative stroke or death is less than 6%
- CEA is justified for asymptomatic 80-99% stenosis if the risk of perioperative stroke or death is less than 3%
- CAS (carotid artery stenting) is still a procedure under investigation (only justified in controlled trials)

Carotid endarterectomy

greatest benefit
- for symptomatic stenosis
- for TIA
- within 2 weeks after TIA
- for elderly
- for men
- for severe (> 80%) stenoses