EC – IC bypass indications and techniques
## History of revascularization

<table>
<thead>
<tr>
<th>Author (year)</th>
<th>Event</th>
</tr>
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<tbody>
<tr>
<td>Kredel, 1942</td>
<td>EDAMS</td>
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<tr>
<td>Woringer &amp; Kunlin, 1963</td>
<td>CCA-ICA bypass with saphenous vein graft</td>
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<tr>
<td>Donaghy &amp; Yasargil, 1968</td>
<td>STA – MCA bypass</td>
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<tr>
<td>Loughheed 1971</td>
<td>CCA- ICA bypass</td>
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<tr>
<td>Kikuchini &amp; Karasawa, 1973</td>
<td>EC-IC bypass for moyamoya</td>
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<tr>
<td>Karasawa, 1977</td>
<td>Encephalomyosynangiosis for moyamoya</td>
</tr>
<tr>
<td>Story, 1978</td>
<td>ICA-MCA bypass, saphenous vein graft</td>
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<tr>
<td>Sundt, 1982</td>
<td>Saphenous vein graft for posterior circulation</td>
</tr>
<tr>
<td>EC/IC bypass study group, 1985</td>
<td>No benefit of STA-MCA bypass in reducing ischemic events compared to best medical therapy</td>
</tr>
<tr>
<td>COSS, 2010</td>
<td>Study stopped for futility</td>
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Revascularization

- **Indirect**:  
  - Promote new capillary network formation  
  - Revascularization with time  
  - Flow augmentation, smaller volume of flow  
  - Recipient vessel size not important  
  - Ischemic brain unable to accommodate a higher flow

- **Direct**:  
  - Vessel to vessel anastamosis  
  - Immediate revascularization  
  - Flow augmentation/replacement  
  - Recipient vessel size > 1mm (ideally > 1.5 mm)
Indirect revascularization

- EMS (encephalomyosynangiosis)
- EDAS (encephaloduroarteriosynangiosis)
- EDAMS (encephaloduroarteriomyosynangiosis)
- Omental graft
- Multiple burr holes
Direct revascularization

- STA
  - STA – MCA anastamososis
- Arterial / venous graft
  - PETROUS ICA – SUPRACLINOID ICA
  - CERVICAL ECA/ICA – MCA
  - CERVICAL ECA/ICA – SUPRACLINOID ICA
  - Bonnet graft (opposite STA – Saphenous graft- MCA)
Revascularization

- Decision about direct/indirect
- Decide on donor vessel
- Decide on conduit
- Decide on recipient
- Technique of anastomosis
Revascularization

<table>
<thead>
<tr>
<th>Direct</th>
<th>Indirect</th>
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</thead>
<tbody>
<tr>
<td>• Immediate flow required (vessel sacrifice)</td>
<td>• Immediate flow not required (3-4 months to mature)</td>
</tr>
<tr>
<td>• The brain can handle the high flow rates</td>
<td>• Collaterals may not develop in 40–50% adults</td>
</tr>
<tr>
<td>• Availability of acceptable recipient vessel</td>
<td>• Mass effect of muscle (aphasia)</td>
</tr>
<tr>
<td></td>
<td>• Revascularized area dependent on craniotomy size and site (only local revascularization)</td>
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<tr>
<td></td>
<td>• No acceptable recipient</td>
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</table>
Donor vessel

- STA (superficial temporal artery)
- MMA (middle meningeal artery)
- ECA (external carotid artery)
- ICA (internal carotid artery)
- OA (occipital artery)
- VA (vertebral artery V3 segment)
Conduit

- Pedicled grafts
  - STA ≥ 1mm
  - OA
  - MMA
- Free arterial graft
  - Radial ≥ 2.4mm
  - Other arteries
- Free venous graft
  - GSV ≥ 3mm

J Neurosurg 102:116–131, 2005
Flow characteristics of grafts

- Low resistance circulation, vein grafts not a disadvantage
- Low flow vessels
  - STA, OA, MMA
  - < 50ml/min flow at time of anastamosis
- High flow grafts
  - Radial artery
    - 50-150 ml/min at anastamosis
  - Saphenous vein graft
    - 100-250 ml/min at anastamosis
### Vein Vs arterial graft

<table>
<thead>
<tr>
<th>Arterial graft</th>
<th>Venous graft</th>
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<tbody>
<tr>
<td>Better suited to high pressure flow</td>
<td>Larger diameter, higher flow rates</td>
</tr>
<tr>
<td>Short term patency rates are better (98% at 6 W)</td>
<td>Lower short term patency rates (93% at 6 W)</td>
</tr>
<tr>
<td>Length is a limitation</td>
<td>Length is not a limitation</td>
</tr>
<tr>
<td>No valves</td>
<td>Almost always available</td>
</tr>
<tr>
<td>Lumen approximates that of recipient</td>
<td>Valves present</td>
</tr>
<tr>
<td>May not always be available (incomplete palmar arch)</td>
<td>Lumen larger than recipient</td>
</tr>
<tr>
<td>Recipient ≥ 2 mm</td>
<td>Higher procedure related complications</td>
</tr>
<tr>
<td></td>
<td>Children &lt; 12 years</td>
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<tr>
<td></td>
<td>Recipient ≥ 2.5 mm</td>
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</tbody>
</table>

Graft flow characteristics

**High flow > 50 ml/min**
- Proximal vessel sacrifice
- Flow replacement
- Large area to be revascularized

**Low flow (< 50 ml/min)**
- No vessel sacrifice
- Flow augmentation
- Small area to be revascularized
- Brain can not handle high flows
Recipient vessel

- M1 tolerates temporary occlusion poorly (lenticulostriate perforators)
- Implant into a bifurcation
- Implant into a 2.5 mm vessel MCA
- If M1 segment short, MCA unsuitable recipient, use supraclinoid ICA if aneurysm infraclinoid
- If supraclinoid ICA used as recipient collateral from ACA essential (temp PCA occlusion required)
- Suturing started at the heel end
Anastamotic technique

- Hand sewn (commonest)
  - Require proximal and distal clamping of the recipient
- Non occlusive anastamosis
  - Expensive, learning curve, larger recipient vessel size, patency rates comparable, similar complication rates
    - ELNA (Excimer Laser assisted Non occlusive Anastamosis)
    - C-Port xA Distal Anastomosis System
STA – MCA bypass

- STA
  - Parietal branch preferred (frontal has collaterals with ophthalmic)
  - Location of craniotomy
    - Junction of the anterior 2/3 and posterior 1/3 of a line joining lateral canthus to ipsilateral tragus
    - A line perpendicular to this
    - Craniotomy 3-5 cm in diameter 6 cm above this line
  - Anastomose to temporal M4 branches
    - Avoid ischemia to frontal branches during occlusion
    - Good collaterals with PCA
    - More consistent good M4 branches

Radial artery harvest

- Radial artery graft
  - Allen’s test
  - Expose at wrist between FCR and brachioradialis tendon
  - Follow upwards between Pronator Teres and brachioradialis

J Neurosurg 102:116–131, 2005
GSV harvest

- Expose at ankle 1 cm anterior and cranial to medial malleolus
- Follow upwards to medial aspect of leg
- Harvest appropriate length
- Can also be harvested in the thigh (drains into CFV 3 cm below inguinal ligament)

J Neurosurg 102:116–131, 2005
Anastomosis

- Meticulous haemostasis (heparin administration)
- Distension of graft to prevent spasm
- Vein graft *not reversed*
- Intracranial anastomosis performed first
- Arterial graft retro/ preauricular route
- Venous graft retroauricular route
- Deliver graft without torsion
Hand sewn anastomosis

• Fish mouthing of graft end before anastomosis
• Teardrop arteriotomy of recipient
• Ensure no air in graft (back bleeding/flushing)
• Verify flow through graft (Doppler/angiography)
• Bone flap placed without compromising graft
Indications for bypass

- Cerebral ischemia
- Moyamoya disease
- Aneurysms
- Skull base tumors
Bypass after major vessel sacrifice

- Selective approach: only if test occlusion is positive
  - 22% risk of TIA, infarcts
  - TIA 10%, stroke rate of 5% and mortality of 5% after ICA occlusion following test occlusion
    - Neurosurgery 36:26–30, 1995
- A high flow bypass if fails test occlusion, low flow if passes
- Universal approach: irrespective of test occlusion results
Moyamoya disease

- **Rational for surgery**
  - Augment blood flow
  - Improvement in CBF has been demonstrated
  - Reduction in further ischaemic events
  - Reduction in hemorrhagic events

- **Indications for surgery**
  - History of infarct/ haemorrhage

- **Regions to be addressed**
  - MCA territory: EDAS, EDAMS, STA – MCA bypass
  - ACA territory: multiple burr holes, STA – ACA bypass, vascularized dural flap
Moyamoya disease

- **Indirect revascularization**
  - Encephalo – galeo – synangiosis
  - Multiple burr holes
  - Omental graft

- **Direct revascularization**
  - STA – MCA bypass
  - STA – ACA bypass (technically difficult, poor results)
  - A higher incidence of symptomatic hyperperfusion with direct revascularization as compared to atherosclerotic disease
Aneurysms

- Only level III evidence available
- Sacrifice of parent vessel or a major branch
- As a temporary measure during prolonged temporary clipping of complex aneurysm
- Aneurysms requiring bypass
  - Giant / blister aneurysms
  - Absence of a neck (fusiform or saccular-fusiform aneurysms
  - Severe atherosclerosis or calcification in the neck
  - Extensive thrombosis
  - Critical branch origin from neck or sac
  - Symptomatic dissecting aneurysm
  - Blister aneurysm
Cranial base tumors

- Facilitates tumor removal with better patient outcome and tumor removal
- Allows surgeon to focus on cranial nerve preservation
- High morbidity and mortality
- Performed by few centers
- Being used less frequently (GKRS)
Cerebral ischemia
(occlusive cerebrovascular disease not amenable to carotid endarterectomy)

- EC – IC bypass study 1985
- Not effective preventing ischemia
- Reduction in bypass
- Criticism
  - Only half of the patients received antiplatelet agents at entry into study
  - No evaluation preop for cerebrovascular hemodynamic status.
  - Both the patient and the therapist were not blinded
  - Randomization-to-treatment bias could have occurred
  - No angiographic determinants for entry.
  - A large percentage of patients had no symptoms between the angiographic demonstration of ICA occlusion and randomization.
  - Large number of patients underwent surgery outside the study.
  - A high percentage of patients had tandem lesions
COSS study

• Inclusion criteria
  • Complete occlusion of an ICA
  • TIA or ischemic stroke in the hemispheric territory of an occluded internal carotid artery in the preceding 120 days

• Outcome measures
  • Surgery arm
    • Death or stroke 30 days from surgery
    • Ipsilateral stroke within 2 years
  • Medical arm
    • Death or stroke 30 days from randomization
    • Ipsilateral stroke within 2 years

• Results
  • Study stopped on 24 June 2010 for futility
Present status of revascularization

- **Cerebral ischemia:**
  - most RCT have shown no benefit

- **Moyamoya disease:**
  - only class III evidence of benefit

- **Complex aneurysms:**
  - class III data. Evidence of benefit
  - IC – IC bypass, lower morbidity, comparable patency rates

- **Skull base tumors:**
  - class III evidence of benefit
  - alternative strategies for treatment of residual disease,