Carotid endarterectomy (CEA) appears to be an intuitively logical operation which probably accounts for the incredible growth in its popularity since it was introduced in 1954. Between 1971 and 1985, the number of carotid endarterectomies performed increased from 15,000 to 107,000 cases per year in the USA. Between 1985 and 1990, the number of endarterectomies declined due to concerns voiced by prominent individuals about the paucity of evidence supporting its efficacy and safety given the reported wide variations in morbidity and mortality rates. As a result, a number of well-designed prospective, randomized trials were initiated comparing best available medical therapy versus best available medical therapy combined with endarterectomy. The salient results of some of the more important trials are shown in Table 1. Confirmation of the efficacy of the procedure, at least among selected patients, resulted in a rapid increase in the use of endarterectomy to > 140,000 annually in the United States.

**Who Should Have the Operation?**

Several prospective, randomized studies have shown significantly improved outcomes for medically stable patients with symptomatic, high grade stenosis (70-99%) following carotid endarterectomy combined with best medical therapy compared to medical therapy alone. Similarly, but to a lesser extent, symptomatic patients with 50-69% stenosis also benefit from combining surgery with medical therapy (Table 1).

Controversy, however, continues to surround the role of carotid endarterectomy for asymptomatic patients. The Asymptomatic Carotid Atherosclerosis Study (ACAS) reported that asymptomatic males with >60% stenosis benefited from endarterectomy provided they were done at centers with a perioperative morbidity and mortality of less than 3% (the participating centers had a rate of 2.3% when angiography related morbidity was excluded). The American Heart Association, in its consensus statement, has endorsed the procedure provided that perioperative morbidity and mortality rates are low (<3%). Conversely, the Canadian Neurosurgical Society has taken the position that the current evidence is insufficient.

These outcome studies evaluating the efficacy of carotid endarterectomy have been based on the recruitment of medically stable patients. Despite these restrictions, cardiac complications represented the most common cause of postoperative non-stroke related morbidity and mortality. A history of myocardial infarction or angina and a history of hypertension were identified as independent risk factors for postoperative complications following CEA, suggesting that patients with co-existing medical conditions should be optimized prior to surgery.

AHA recommendations advocate a 30-day risk of perioperative stroke or death of 3% for asymptomatic patients, 5% for patients with a history of transient ischemic attacks, 7% for patients with a previous stroke and 10% for those undergoing surgery for recurrent stenosis. The overall risk of perioperative death from all causes should be 2% or less.
Where Should the Operation Be Done?

Carotid endarterectomy is usually performed as an open surgical procedure in the operating room. However, there continues to be growing interest in the use of endovascular approaches for the treatment of carotid atherosclerotic disease. Proponents of the endovascular approach cite lower hospital costs, lower patient morbidity and an expanded target patient population as potential benefits. However, there are concerns about embolization during the procedure and the overall morbidity and durability of the procedure are still unknown. The majority of the published experience are non-randomized personal series. A number of large prospective, randomized multi-center studies are completed (CAVATAS, SAPPHIRE), or in progress (CREST, ACT1).

From the anesthesia perspective, the challenges usually associated with the radiology suite pertain. These include isolation from the main operating rooms, staff that may not be familiar with our needs and limited patient access during the procedure. We typically provide intravenously administered analgesia (fentanyl or remifentanil) and minimal sedation (midazolam or propofol) to patients undergoing these procedures. Embolization can occur before, during or after the angioplasty and patients should be appropriately monitored. At the time of balloon distention of the carotid artery, profound bradycardia may occur in some patients. Appropriate drugs and external pacing pads should be immediately available.

How Should The Anesthesia Be Done?
CEA can be performed safely under general anesthesia or regional anesthesia (including local anesthetic infiltration). Experienced centers report similar morbidity and mortality, and available evidence is insufficient to definitively establish the superiority of either technique. A recent meta-analysis found a benefit in favor of regional anesthesia when uncontrolled trials were compared, but no difference when randomized trials were compared. A recent Cochrane review using essentially the same data came to the same conclusion and called for a randomized trial. Such a randomized trial, the GALA trial, is indeed underway in Europe and has recruited about 2,000 patients. The principle investigators for the trial are a vascular surgeon and a neurologist, which is a sad indictment of the anesthesiology community.

Regional Anesthesia

Superficial and deep cervical plexus blocks are the most common regional anesthetic techniques for CEA. Superficial cervical plexus block combined with local anesthetic infiltration by the surgeon has been reported to provide equally effective anesthesia.

Carefully titrated sedation using either small, repeated intravenous doses of fentanyl (10-25 µg) and/or midazolam (0.5-2 mg) or a low dose remifentanil infusion (0.01-0.05 µg/kg/min) should ensure a comfortable and cooperative patient during the operation. Propofol is a reasonable alternative administered as a low dose continuous infusion (25-75 micrograms/kg/min). Provisions should be immediately available to convert to a general anesthetic if intraoperative conditions warrant.

Advantages of regional anesthesia include: (1) Superior neurologic monitoring associated with an awake patient with the potential to minimize interventions such as shunt insertion based on symptoms at cross-clamping; (2) Less expensive; (3) Reports of more rapid recovery and shorter hospitalization.

Disadvantages of regional anesthesia include: (1) Requires an OR staff committed to working with patients under regional anesthesia, i.e., patience, gentle technique, re-enforcement of block as needed; (2) Lack of airway and ventilatory control; (3) Potential need to deal with complications in an awake patient, e.g., cerebral ischemia, airway obstruction, hypoventilation, confusion, agitation, angina; (4) Complications associated with cervical plexus blocks.

General Anesthesia

General anesthesia represents the most common anesthetic technique for CEA. There is no convincing evidence that the actual choice of general anesthetic agent significantly alters clinical outcome.

Advantages of general anesthesia include: (1) It may be more comfortable for patients and operating room staff; (2) It facilitates intraoperative control of ventilation, airway, and sympathetic responses; (3) It may facilitate management of complications such as cerebral ischemia, e.g., induced hypertension, pharmacologic suppression of EEG activity.

Disadvantages of general anesthesia include: (1) The (possible) need for an alternate method for monitoring cerebral function since it is possible that some remediable complications may not be detected prior to irreversible neuronal injury (e.g., cross-clamp intolerance, kink in carotid shunt, etc.); (2) Prolonged emergence may confuse postoperative evaluation; (3) It is more expensive.

Intra-operative Monitoring

A topic of great debate continues to be the necessity and value of intra-operative monitoring, in an attempt to recognize cerebral ischemia. If patients suffering ischemic insults could be identified, alterations in surgical and anesthetic technique may offer neuroprotective benefit. However, the value of one
monitoring technique versus another has not been ascertained and different physicians use a wide range of monitoring modalities including not using one at all. The latter group bases its view on the fact that the perioperative stroke rate is not much different between those who monitor and those who do not thus making the major benefit of monitoring physician comfort and medico-legal protection.

Common monitoring techniques include EEG, SSEP and TCD. Unfortunately there are no randomized, prospective, blinded evaluations of any of these monitors.

The EEG is the most commonly used. There have been a few blinded cohort studies which found that the EEG is well correlated with CBF but only the most severe EEG changes are likely to be associated with poorer outcome. The inability of intra-operative EEG to detect all patients at risk is four-fold. Firstly, false negative rates may be higher in patients with existing neurological deficit due to increased difficulty of interpretation. Secondly, EEG cannot prevent delayed strokes or those attributable to embolic events, which account for the majority of strokes. Also, subcortical or small cortical ischemia may not be appreciated. Thus, the greatest value of the EEG may be to spare patients of the possible complications of unproven neuroprotective techniques. In addition to the above limitations, it entails additional costs, equipment, training and personnel.

Somatosensory Evoked Potentials (SSEP) has been even less well studied but is preferred by some because interpretation of prolonged latency and reduced amplitude are easier to identify and less subjective and they are only minimally altered by thiopental or propofol given to produce burst suppression.

Transcranial Doppler (TCD) can be used on its own or in conjunction with electrophysiological monitors. TCD measures flow velocity as a surrogate of blood flow usually in the middle cerebral artery. Its major benefit is probably in identifying emboli during dissection and (un)clamping and thrombosis at the endarterectomy site which then results in a reduction in flow.

Summary

Several large, prospective trials have now clearly defined an important role for CEA in the prevention of stroke among selected patients. As a result, the procedure has experienced a resurgence in popularity and recommendations have been established with respect to the appropriate selection of patients and acceptable risk. Currently, considerable interest is focused on the use of carotid angioplasty and stenting as an alternative to CEA. Several prospective trials designed to evaluate the efficacy and safety of these procedures are in progress. Controversy continues to surround the most appropriate choice of anesthetic technique for CEA. Current evidence is inadequate to definitively establish regional or general anesthesia as a superior technique. However, based on reported experience, satisfactory results can be achieved using either technique with respect to current recommendations concerning acceptable perioperative morbidity and mortality.

Bibliography:

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Endovascular versus surgical treatment in patients with carotid stenosis in the Carotid and Vertebral Artery Transluminal Angioplasty Study (CAVATAS): a randomised trial. Lancet 2001 Jun 2;357(9270):1729-37

European Carotid Surgery Trialists’ Collaborative Group. MRC European Carotid Surgery Trial: Interim results for symptomatic patients with severe (70-99%) or with mild (0-29%) carotid stenosis. Lancet 1991;337:1235-43.


Some currently recruiting trials:


HOBSON RW et al. Carotid Revascularization Endarterectomy versus Stenting Trial (CREST) Funded by NINDS.


GOUGH M. General anaesthetic versus local anaesthetic for carotid surgery (GALA). Funded by The Health Foundation, European Society for Vascular Surgery.
Table 1
Randomized prospective trials in patients with carotid stenosis

<table>
<thead>
<tr>
<th>TRIAL</th>
<th>SIZE</th>
<th>ENTRY</th>
<th>BENEFIT</th>
<th>COMMENT</th>
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<tbody>
<tr>
<td>Joint Study</td>
<td>316</td>
<td>TIA</td>
<td>Yes</td>
<td>Excluded patients with in-hospital death or stroke</td>
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<tr>
<td>1970</td>
<td>S-169</td>
<td>Uni/Bilateral</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>M-147</td>
<td>Carotid &amp; Vertebral Disease</td>
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<tr>
<td>NASCET</td>
<td>659</td>
<td>TIA</td>
<td>Yes</td>
<td>Risk of stroke reduced by 17% at 2 years.</td>
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<td>1991</td>
<td>S-331</td>
<td>&gt;70% Ipsilateral Stenosis</td>
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<td>TIA’s not included as endpoint</td>
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<td>M-328</td>
<td>&gt;70% Stenosis</td>
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<td>778</td>
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<td>VA</td>
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<td>Men only benefit only if TIA’s included, in outcome</td>
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<td>ECST</td>
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<td>M-1118</td>
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<td>ACAS</td>
<td>1659</td>
<td>Asymptomatic, &gt;50% Reduction in Diameter</td>
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<td>Benefit if male &amp; periop morbidity &amp; mortality &lt;3%</td>
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