REVIEW ARTICLE

Carotid Endarterectomy; Local or General Anaesthesia?

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Objectives: to review the evidence for theoretical and clinical benefits of local or general anaesthesia for carotid endarterectomy.

Methods: literature review.

Results: animal studies suggest cerebral protection by a variety of general anaesthetic agents but clinical evidence is lacking. There is some clinical evidence that normal cerebral protective reflexes are preserved with local anaesthesia. Shunt insertion is the most widely used method of providing cerebral protection with awake testing the most reliable monitoring technique for the identification of ischaemia. There are therefore theoretical arguments for a reduced risk of perioperative stroke when local anaesthesia is used and this is supported by a meta-analysis of non-randomised studies. Intraoperative blood pressure is always higher with local anaesthesia but the incidence of postoperative haemodynamic instability seems to be independent of anaesthetic technique. There is little evidence that myocardial ischaemia is more common with either anaesthetic technique but meta-analysis of non-randomised again suggests fewer cardiac complications with local anaesthesia. Cranial nerve injury and haematoma formation may be less common with local anaesthesia but the evidence is weak. There is no evidence that surgery is more difficult with local anaesthesia or that it is poorly tolerated by the patients.

Conclusions: there are theoretical arguments and clinical evidence that the outcome from carotid endarterectomy may be better when local anaesthesia is used with no significant disadvantages. An appropriately designed randomised trial is required to confirm this.

Key Words: Local anaesthesia; General anaesthesia; Carotid endarterectomy.

Introduction

Since the benefit of carotid endarterectomy (CEA) in appropriate patients was confirmed by the ECST\(^1\) and NASCET\(^2\) trials, attention has focussed on the technical aspects of surgery with a view to increasing safety. Of all the variables examined the strongest evidence is in favour of routine patching following conventional endarterectomy.\(^3\)\(^4\) However, there is no convincing evidence as to the superiority of either eversion or conventional CEA\(^5\) and whilst routine shunting may confer a small advantage,\(^6\) selective shunting presents the problem of accurately identifying those patients who develop significant post clamping cerebral ischaemia. Finally, although quality control by means of angiography, angioscopy or duplex scanning at completion of CEA appears attractive, its benefits have not been established.\(^7\)\(^8\)

The possibility that the choice of anaesthetic technique may influence the outcome of surgery has also been raised, particularly since loco-regional anaesthesia may be associated with a reduction in neurological and non-neurological morbidity and mortality.\(^9\) Other factors which have encouraged the wider use of this technique include the desire to calibrate sophisticated monitoring techniques against awake testing in order to derive criteria for shunt insertion, the “threat” posed by the endovascular treatment of carotid disease, which avoids general anaesthesia, and the possibility that loco-regional anaesthesia may offer cost savings.\(^10\)

In this paper the theoretical, practical and clinical benefits of loco-regional anaesthesia are compared with those of general anaesthesia.

History of Anaesthesia for Carotid Endarterectomy

Although Eastcott performed his carotid reconstruction for symptomatic internal carotid artery...
stenosis in 1954 under general anaesthesia,\textsuperscript{12} regional or local anaesthesia was preferred by most of the pioneers of carotid endarterectomy. However, there was concern about intraoperative cerebral ischaemia and after Wells\textsuperscript{13} published his series in 1963 suggesting that general anaesthesia may confer a cerebral protective effect, this technique was widely adopted. Interest in loco-regional anaesthesia was subsequently revived by surgeons who believed that awake testing was the only reliable method of monitoring cerebral oxygenation. Nevertheless most surgeons continued to operate under general anaesthesia. Ultimately a generation of vascular surgeons and anaesthetists were trained to perform carotid endarterectomy under general anaesthesia utilising a wide variety of imperfect monitoring techniques.

**Neurological Outcome**

**Potential benefits of general anaesthesia**

Wells\textsuperscript{13} appeared to demonstrate that thiopental offered a degree of cerebral protection during CEA, but also stressed the value of being able to maintain hypercarbia, hypertension and an inspired \(O_2\) content of 70–80\% when using general anaesthesia. Cerebral protection has also been claimed for various other anaesthetic agents.

**Pharmacological cerebral protection by general anaesthetic agents (Table 1)**

A protective effect against cerebral ischaemia is suggested by the ability of barbiturates to reduce oxygen metabolism (cerebral metabolic rate for oxygen, CMRO\(_2\)) and thus oxygen demand, by reducing electrical activity.\textsuperscript{14} However, loss of electrical activity precedes irreversible cellular damage.\textsuperscript{15} As barbiturates do not affect the critical cerebral blood flow at which cellular integrity is threatened, merely reducing electrical activity cannot offer protection from severe ischaemia.\textsuperscript{16} Although animal studies have demonstrated other possible mechanisms of protection (redistribution of regional cerebral blood flow,\textsuperscript{17} reduction in intracranial pressure, prevention of oedema\textsuperscript{18} and inhibition of \(Ca^{++}\) influx\textsuperscript{19}) these effects are only achieved at doses\textsuperscript{20} associated with unacceptable cardiovascular and respiratory complications in man.\textsuperscript{21} At smaller doses only one prospective study of patients undergoing normothermic open-heart surgery has demonstrated a clinical benefit.\textsuperscript{21}

Etomidate and propofol may also provide cerebral protection by similar mechanisms (reduction in CMRO\(_2\), redistribution of cerebral blood flow, inhibition of free fatty acid liberation) without the cardiovascular side effects of the barbiturates.\textsuperscript{22} However, etomidate must be given as an infusion due to its short half life and there is evidence that this may produce significant adrenocortical suppression and myoclonic movements.\textsuperscript{23} Similarly there are case reports of propofol induced seizures, myoclonus and opisthotonus which would be detrimental in the setting of cerebral ischaemia.\textsuperscript{24} Although propofol has been used for anaesthesia during cerebrovascular surgery\textsuperscript{25} there are no prospective, controlled, clinical studies to support any theoretical benefit for either agent.

General anaesthesia for carotid endarterectomy is most commonly achieved using volatile anaesthetic agents such as isoflurane, desflurane or sevoflurane, which are capable of reducing neuronal activity and CMRO\(_2\) at doses that produce anaesthesia without hypotension.\textsuperscript{26} As with barbiturates, animal studies have suggested that other mechanisms including suppression of sympathetic activity and a decrease in glutamate receptors thus reducing the cytotoxic \(Ca^{++}\) influx\textsuperscript{27} are important. In patients undergoing CEA, isoflurane reduces the critical blood flow at which EEG changes of ischaemia occur in comparison to halothane and enflurane\textsuperscript{28} but there is no evidence that isoflurane improves clinical outcome. In contrast, nitrous oxide increases CMRO\(_2\) by stimulating the sympathetic nervous system but its use has not been shown to be detrimental to neurological outcome.

Thus, although there is a wealth of experimental data suggesting that various anaesthetic agents provide a degree of cerebral protection, there is no convincing evidence of benefit in the clinical setting of carotid endarterectomy.

**Blood pressure manipulation**

The blood vessels within an ischaemic area of brain are maximally dilated and therefore blood flow is directly dependent on perfusion pressure. Animal studies have confirmed that neurological outcome can be improved by moderate hypertension\textsuperscript{31} and raising systemic pressure can elevate stump pressure.\textsuperscript{32} Although the value of an increase in stump pressure is not proven, at least anecdotally, pharmacological manipulation of the blood pressure can reverse neurological deterioration during cross clamping in patients undergoing CEA with local anaesthesia. However, patients with cerebrovascular disease often have ischaemic heart disease such that perioperative cardiac events are as common as neurological deficits in patients undergoing CEA.\textsuperscript{12} Thus, whilst systemic hypertension may improve cerebral perfusion it may
Table 1. Cerebral protection by anaesthetic agents. CMRO₂ (cerebral metabolic rate for oxygen), CBF (cerebral blood flow).

<table>
<thead>
<tr>
<th>Mechanism of cerebral protection</th>
<th>Evidence</th>
<th>Drawbacks</th>
<th>Clinical usage</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Barbiturates</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Electrical activity ↓</td>
<td>Animal studies</td>
<td>Large doses required producing: (i) Cardiovascular depression (ii) Respiratory depression</td>
<td>Often used in small doses during neurosurgery, cardiopulmonary bypass and CEA</td>
</tr>
<tr>
<td>CMRO₂↓</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Redistribution of CBF</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Intracranial pressure ↓</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ca²⁺ influx↓</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Volatile anaesthetics</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Electrical activity ↓</td>
<td>Animal studies</td>
<td>Hypotension</td>
<td>Isoflurane agent of choice in most centres</td>
</tr>
<tr>
<td>CMRO₂↓</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sympathetic activity ↓ (nitrous oxide has opposite effect)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ca²⁺ influx↓</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Propofol</strong></td>
<td>Conflicting animal studies</td>
<td>Seizures Myoclonus Opisthotonus</td>
<td>Rarely used</td>
</tr>
<tr>
<td>Electrical activity ↓</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CMRO₂↓</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Etomidate</strong></td>
<td>Animal studies</td>
<td>Must be used as continuous infusion with potential for: (i) Adrenocortical suppression (ii) Myoclonic movements</td>
<td>Infusion used in research only</td>
</tr>
<tr>
<td>Electrical activity ↓</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CMRO₂↓</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Redistribution of CBF</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Free fatty acid release↓</td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>

also have a detrimental effect on myocardial oxygen requirements.

When CEA is performed under loco-regional anaesthesia the systemic blood pressure is usually higher than normal and it is often argued that, although cerebral perfusion is maintained, the risk of cardiac morbidity is increased. On the other hand, episodes of hypotension, when both cerebral and myocardial perfusion may be compromised, are common during general anaesthesia and the subsequent administration of pressor agents increases myocardial work and the risk of infarction. There are certainly no convincing arguments that general anaesthesia is essential to optimise blood pressure.

*pCO₂* manipulation

Hypercarbia causes cerebral vasodilatation and thus hypoventilation was initially perceived as a method of maximising cerebral blood flow. However, stimulating vasodilatation in normal brain while increasing total cerebral blood flow may divert blood flow away from the ischaemic area. Conversely, hypocarbia may cause a reduction in total cerebral blood flow while increasing flow to the ischaemic area, a phenomenon known as reverse steal. The results from animal studies are conflicting and to date there is no clinical evidence that manipulating *pCO₂* is of any benefit. Thus most anaesthetists aim to maintain *pCO₂* at normal levels and from this point of view there is no theoretical benefit from general as opposed to loco-regional anaesthesia.

Potential benefits of loco-regional anaesthesia

Identification of patients requiring shunts

The risk of a major or minor neurological deficit following CEA is in the order of 5%. Approximately two-thirds occur intraoperatively with the majority being embolic in nature. While it is estimated that only 20% are due to hypoperfusion it is difficult to determine the cause of neurological deficit with certainty and furthermore an embolus on a background of hypoperfusion may be more significant than an embolus to well perfused brain. Zampella reported a series of 369 patients who were not shunted but in whom cerebral blood flow was measured using Xenon-122 (Xe₁₂₂). Patients with the lowest cerebral blood flow were no more likely to suffer a neurological deficit than those with the highest blood flow. Nevertheless the majority of surgeons attempt to avoid hypoperfusion if possible and this can be achieved by placement of an intraluminal shunt.

The use of a shunt may not be without risk, however, with the potential for intimal damage resulting in early thrombosis or late stenosis, the risk of platelet and air embolisation from the shunt or of atheroma from...
Table 2. Cerebral monitoring and criteria for shunting. False positives and negatives are derived from studies in which monitoring has been compared with awake testing.

<table>
<thead>
<tr>
<th>Criteria for shunt</th>
<th>False positive</th>
<th>False negative</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Awake testing</td>
<td>Hesitancy in response</td>
<td>Gold standard</td>
<td>Gold standard</td>
</tr>
<tr>
<td></td>
<td>Loss of consciousness</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stump pressure</td>
<td>&lt;50 mmHg (&lt;25 mmHg and &lt;35 mmHg also used but high false negative rate)</td>
<td>20–40%</td>
<td>0–23%</td>
</tr>
<tr>
<td>Stump pressure index: stump pressure × 100 / systemic pressure</td>
<td>&lt;33</td>
<td>40%</td>
<td>0</td>
</tr>
<tr>
<td>Transcranial doppler (TCD)</td>
<td>MCAV fall by 60–70%</td>
<td>4–45%</td>
<td>Up to 17% if &gt;70% fall used</td>
</tr>
<tr>
<td>Cerebral blood flow (Xe133 washout)</td>
<td>&lt;18 ml/100 g/min</td>
<td>Unknown</td>
<td>Unknown</td>
</tr>
<tr>
<td>EEG</td>
<td>≥50% reduction in α or β activity Increase in δ activity Asymmetry</td>
<td>5–13%</td>
<td>5–25%</td>
</tr>
<tr>
<td>Somatosensory evoked potentials (SSEPs)</td>
<td>Prolongation of conduction time &gt;1 ms Reduction in amplitude &gt;50%</td>
<td>Unknown</td>
<td>Unknown</td>
</tr>
<tr>
<td>Near infrared spectroscopy</td>
<td>Cerebral O2 saturation (fall of &gt;5%) Caa3 concentration (no criteria yet)</td>
<td>Unknown</td>
<td>Unknown</td>
</tr>
<tr>
<td>Continuous jugular venous oximetry</td>
<td>SvO2 &lt;50%</td>
<td>Unknown</td>
<td>Unknown</td>
</tr>
</tbody>
</table>

The common carotid artery. In addition the shunt may compromise surgical exposure thus requiring more extensive dissection, which may increase the risk of cranial nerve injury.39 For these reasons shunting remains controversial. The results from numerous series in which shunts are used routinely are similar to those in which shunts are used either selectively or not at all, although some authors have suggested that the use of a shunt increases the risk of complications.40,41,45

Two randomised trials comparing obligatory shunting with non-shunting have been analysed by The Cochrane Stroke Review Group.56–47 In 590 randomised patients there was a non-significant trend suggesting a benefit for routine shunting, although the total number of outcome events was small (4.6% risk of stroke at 30 days). It is possible that the benefit of shunting in those patients with an inadequate collateral circulation was cancelled out by the embolic complications of shunting in patients in whom a shunt was unnecessary. Therefore a selective shunting policy would seem to be more logical. Although there are no randomised trials to support this view, Plestis48 reported an improvement in his results when he adopted a selective shunting policy instead of non-shunting and in a retrospective series of 305 patients Salviant found a major stroke rate of 4.4% in a routinely shunted group compared to only 0.5% in the selectively shunted group. For those who choose a selective shunting policy the challenge is to ensure that all patients who are at risk of hypoperfusion are shunted whilst the minimum number of shunts are inserted unnecessarily in patients with adequate collateral circulation.

Various techniques have been employed to identify
hypooperation (Table 2) and depend upon the measurement of haemodynamic parameters and parameters of cerebral oxygenation or cerebral function following cross clamping.

(i) Haemodynamic parameters. Measurement of the "stump pressure" in the internal carotid artery after clamping is arguably the most widely used methods of assessing the need for a shunt. However, sensitivity and specificity have been found wanting and this method only provides an assessment of perfusion at a single instant in time.50,53

Transcranial Doppler ultrasound (TCD)52 can be used to measure the middle cerebral artery velocity (MCAV) throughout surgery and into the postoperative period but considerable expertise is required to obtain a reliable signal which is not technically possible in approximately 10–15% of patients due to an inadequate sonic window in the temporal bone. Nevertheless TCD provides reassurance that cerebral blood flow is maintained throughout the endarterectomy with or without a shunt and can also be used to predict those patients at risk of postoperative hyperperfusion.51 Detection of emboli62 also provides feedback to the surgeon during dissection of the carotid arteries41 and may give advance warning of imminent postoperative thrombosis.54

Intraoperative measurement of cerebral perfusion using the Xe133 washout method is well described40,55 but requires specialist equipment and technical skills as well as posing a potential radiation hazard. Furthermore, the technique is oversensitive to the superficial layers of the cortex at the expense of deeper structures.56 Whilst being of limited clinical value, Xe133 washout may be a useful research tool.

(ii) Cerebral oxygenation. In measuring haemodynamic parameters it is assumed that a given blood flow provides adequate oxygen to the brain. An alternative approach is to assess cerebral oxygenation either directly or indirectly. It is possible to continuously measure the oxygen content of the venous blood draining into the jugular bulb (SjvO2) using near infrared technology.57 This technique is often used to monitor patients with severe head injury but is too dependent on a stable catheter position to provide useful clinical information during carotid endarterectomy.58

Near infrared spectroscopy provides a direct assessment of cerebral oxygenation.59 In principle this technique should be ideal with its only flaw being the relatively small volume of brain sampled. In practice the technology has yet to overcome some fundamental problems that enable quantification of oxygen saturation and the deletion of contaminating signals from the scalp and cranium. Thus, for the present its role appears to be that of a research tool.58

(iii) Cerebral function. As cerebral blood flow falls neurological function is lost before irreversible neuronal damage occurs.15 Electroencephalography (EEG)66 and the measurement of somatosensory evoked potentials (SSEPs)66 are used to detect loss of neurological function so that a shunt can be inserted before ischaemic injury occurs. Both techniques require a neurophysiologist or neurologist and are further complicated by the influences of various anaesthetic agents,40 hypotension,62 arterial pCO2, previous stroke63 and the use of diathermy.62 Sensitivity and specificity are also issues of concern.

(iv) Awake testing. The most reliable and easiest way to test neurological function is to perform surgery under local anaesthesia. Ischaemia most commonly results in deterioration of conscious level but a focal deficit or fit may also ensue. Higher cortical function is tested by mini mental state type questions and motor function by asking the patient to squeeze a squeaky toy held in the contralateral hand. Hesitancy in the performance of simple tasks requiring higher function (e.g. counting, orientation in time and place) is a sign of imminent loss of consciousness and is often accompanied by a marked rise in systemic blood pressure.

It is important that awake testing continues throughout the period of cross clamping as neurological deterioration can occur as late as 45 min after clamping of the internal carotid artery.50 However, clear communication with the surgeon or anaesthetist is essential and thus not all patients are suitable for awake testing. This includes patients who have residual motor weakness, dysarthria or receptive or expressive dysphasia following a previous stroke and patients who are deaf or who do not speak the same language as the surgeon or anaesthetist.

Shunts are required less often than with other monitoring techniques. Only 5–21% of patients require a shunt when awake testing is used40,53,58,64–66 compared to 15–30% with EEG monitoring,63 50% using Xe133 washout,63 20% when MCAV measured by TCD falls of 60–70%,68 and up to 60% with stump pressures less than 50 mmHg.58 This data indicates that all other monitoring methods are over-sensitive. More importantly, however, in every series where they have been compared to local anaesthesia there have been a significant number of patients who developed a deficit despite normal monitoring.65,66,69 Thus patients who do not need a shunt will be exposed to the risks of shunting because of inadequate specificity whilst
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others will be exposed to the risks of hypoperfusion because of inadequate sensitivity.

Thus loco-regional anaesthesia ensures that shunts are used in all patients with significant hypoperfusion while the potential risks of a shunt are avoided in all patients who have adequate cerebral perfusion.

Preservation of normal cerebrovascular reflexes with local anaesthesia

Although the difference in shunt usage between general and local anaesthesia is usually attributed to the deficiencies in the various monitoring techniques, there is also evidence that physiological protective mechanisms may be preserved when local anaesthesia is used. Using a combination of near infrared spectroscopy and continuous jugular venous oximetry McCleary et al. demonstrated that cerebral oxygenation is maintained following application of the carotid clamps during loco-regional anaesthesia. This phenomenon appears to depend on a reflex rise in blood pressure that is not seen in general anaesthetic patients. This finding that local anaesthesia preserves cerebral oxygenation is also supported by data from Wellman who showed that ischaemic EEG changes were less common with local anaesthesia (6.3% vs 15.7%).

Hypotension and hypoxia are detected by the carotid sinus and the carotid body respectively resulting in a systemic pressor response. Whilst the baroreflex is known to be impaired by volatile anaesthetic agents, the nerve to the carotid sinus was infiltrated with local anaesthetic in all patients in McCleary’s study and therefore a different mechanism must be responsible for the post-clamping reflex hypertension in regional anaesthesia patients. It is also well recognised, although under-investigated, that a transient rise in blood pressure is often observed in acute stroke. These rises in blood pressure appear to be mediated by the sympathetic nervous system, which is known to be depressed by volatile anaesthetic agents such as isoflurane. This effect seems to be “dose dependent” and thus it is possible that the reflex may be preserved with “light general anaesthesia” as advocated by Roizen, explaining the finding by McCleary that it was preserved in a few of the general anaesthetic patients. Furthermore, a portion of the reticular activating system in the medulla appears to be sensitive to hypoxia, especially in the presence of hypotension, stimulating an increase in systemic blood pressure. Of course the medulla is supplied by the posterior cerebral artery but other similar centres within the internal carotid artery territory may exist.

In addition to the differences in cerebrovascular physiology and cerebral oxygenation observed following carotid artery cross clamping further differences occur during reperfusion. Transiently increased middle cerebral artery velocities (MCAV) are commonly observed on reperfusion and these have been interpreted as representing failure of autoregulation. Certainly this seems to be the case during general anaesthesia but when loco-regional anaesthesia is used the link between oxygen supply and demand (assessed using NIRS and SjvO2) is preserved (McCleary, unpublished data).

The preservation of normal cerebrovascular physiology during loco-regional anaesthesia may prevent cerebral injury during carotid endarterectomy. Data from Calvey et al. who measured concentrations of S100 (a protein released by glial cells following cerebral injury) in jugular venous blood and performed detailed psychometric tests on patients undergoing carotid endarterectomy, support this hypothesis. They found that S100 levels were higher and postoperative cognitive performance worse in general anaesthetic patients compared to local anaesthesia patients.

Cranial nerve injury and haematoma formation

Although most series fail to report the incidence of cranial nerve injuries, they occur in up to 5% of CEA. Although they may be more common with the use of shunts there is no evidence to suggest an association between cranial nerve injuries and the type of anaesthetic. Similarly, although well recognised as a complication of carotid surgery, haematoma formation is rarely mentioned in published series. However, in Forsell’s randomised study, re-exploration for wound haematoma was less common in the general anaesthetic group (1.8% vs 10.9%, OR 0.22, CI 0.05–0.99). One possible explanation for this finding is that, as the blood pressure at the time of wound closure is generally higher with local anaesthesia, bleeding points may be more readily recognised and dealt with.

Cardiac Outcome

Patients with cerebrovascular disease have a high incidence of ischaemic heart disease and concerns have been raised that the higher systemic blood pressures during carotid endarterectomy performed under regional anaesthesia may increase the risk of myocardial ischaemia and infarction. Berlatsky et al. reported a series of 140 patients undergoing vascular
reconstruction (82 carotid endarterectomies) under regional anaesthesia. Serial ECGs, perioperative ST segment analysis with a 12 lead Holter monitor and levels of cardiac enzymes were recorded and indicated that 46% of patients suffered at least one episode of significant myocardial ischaemia and 5% had a myocardial infarction. Despite these findings, there is no convincing evidence suggesting that cardiac morbidity is more likely with local anaesthesia while there are numerous retrospective series suggesting the contrary. Furthermore a meta-analysis of local vs general anaesthesia for carotid endarterectomy (randomised and non-randomised studies) calculated a significantly lower incidence of MI with local anaesthesia (0.6% vs 1.3%, OR 0.34, 95% CI 0.18–0.63, p<0.001).

In an attempt to explain a reduction in the cardiac morbidity observed with the use of local anaesthesia in their own practice, Sbarigia et al. randomised 107 patients to local or general anaesthesia, carefully recorded intraoperative haemodynamic parameters and used Holter monitoring to detect perioperative myocardial ischaemia. They found that LA patients were more likely to have episodes of hypertension while GA patients were more likely to have episodes of hypotension although there was no significant difference in the frequency of myocardial ischaemia (GA 23% vs LA 18%). Four patients in the GA group suffered postoperative cardiac events as opposed to two in the LA group. Unfortunately the relationships between intraoperative haemodynamic events, myocardial ischaemia and cardiac events were not reported.

Thus there would appear to be a reduction in cardiac morbidity with local anaesthesia but the reasons remain unclear. While hypertension may increase myocardial oxygen consumption, hypotension reduces coronary artery perfusion and is often overcorrected with use of vasoactive drugs, which in turn increase myocardial oxygen consumption. Furthermore it has also been suggested that in the presence of ischaemic heart disease volatile anaesthetic agents may produce a steal phenomenon that would precipitate myocardial ischaemia. Interestingly Sbarigia’s finding that myocardial ischaemia was only more likely with a general anaesthetic than with a local anaesthetic, in patients with a history of ischaemic heart disease, is consistent with this.

**Haemodynamic instability**

Several authors have addressed the question of postoperative haemodynamic instability. While there is general agreement that intraoperative blood pressure tends to be higher with local anaesthesia the results of studies that have investigated postoperative haemodynamic instability are conflicting. The reasons for haemodynamic instability in the postoperative period are unclear but may involve altered sensitivity of the carotid sinus, recovery of function in the carotid sinus nerve blocked with local anaesthetic intraoperatively, and the volume of fluid given intraoperatively.

Postoperative hypertension is associated with an increased incidence of neurological deficit with Bove reporting postoperative hypertension in 19% of his patients of whom 10% had a permanent neurological complication. However, since cerebral ischaemia is known to cause an increase in blood pressure these results do not prove that hypertension causes neurological deficits. Similarly there is no evidence that haemodynamic instability results in myocardial infarction or early thrombosis of the internal carotid artery despite the theoretical possibilities.

**Comparison of clinical outcome**

There are theoretical arguments in favour of both general and local anaesthesia but outcome measures of changes in perioperative blood pressure, shunt usage, cerebral or myocardial ischaemia are only relevant if they translate into clinical benefit. To date only three randomised trials of local vs general anaesthesia have been published, two of which were designed to study postoperative haemodynamic changes rather than clinical outcome. Tangkanakul performed a meta-analysis on the 143 patients and found no significant difference in the main clinical outcomes of neurological and cardiac morbidity. Clearly the number of patients was too small to detect differences in rare adverse outcomes. When 17 non-randomised studies (5970 patients) were also subjected to metaanalysis there was a 50% reduction in the relative odds of perioperative stroke or death with local anaesthesia (Table 3).

This is consistent with our series of 200 consecutive CEA performed by one surgeon. Outcome was significantly better in the local anaesthesia patients (n = 97) than in the general anaesthesia patients (n = 103). Although non-randomised (anaesthetic technique according to patient preference), the indications for surgery and risk factors were the same in both groups. The 30-day stroke rates were 0% (LA) vs 3.9% (GA), myocardial infarction rates 1.1% (LA) vs 2.9% (GA) and combined 30-day stroke and death rates 1.1% (LA) vs 5.8% (GA). These data would support the hypothesis.
Table 3. Selected results from Tangkanakul’s systematic review. \textsuperscript{10} \textit{p} values are given for results considered to be significant by the authors.

<table>
<thead>
<tr>
<th></th>
<th>Local anaesthesia</th>
<th>General anaesthesia</th>
<th>Odds ratio</th>
<th>95% confidence intervals</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Randomised</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>\textit{n}=154 (operations)</td>
<td>Any CVA or death</td>
<td>5%</td>
<td>5%</td>
<td>0.98</td>
</tr>
<tr>
<td></td>
<td>MI</td>
<td>2.7%</td>
<td>1.3%</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Pulmonary complications</td>
<td>Not reported</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Haematoma</td>
<td>1.8%</td>
<td>10.9%</td>
<td>0.22</td>
</tr>
<tr>
<td></td>
<td>Shunts</td>
<td>8.9%</td>
<td>45.5%</td>
<td>0.16</td>
</tr>
<tr>
<td><strong>Non-randomised</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>\textit{n}=5517 (operations)</td>
<td>Any CVA or death</td>
<td>2.2%</td>
<td>6.1%</td>
<td>0.47</td>
</tr>
<tr>
<td></td>
<td>MI</td>
<td>0.6%</td>
<td>1.3%</td>
<td>0.34</td>
</tr>
<tr>
<td></td>
<td>Haematoma</td>
<td>2.4%</td>
<td>2.9%</td>
<td>0.95</td>
</tr>
<tr>
<td></td>
<td>Pulmonary complications</td>
<td>0.7%</td>
<td>0.9%</td>
<td>0.36</td>
</tr>
<tr>
<td></td>
<td>Shunts</td>
<td>10.8%</td>
<td>44.3%</td>
<td>0.12</td>
</tr>
</tbody>
</table>

NB: Every outcome measure was not available from every study.

that local anaesthesia is safer but suffer from the usual potential biases to which non-randomised series are susceptible. In particular it is possible that surgeons may avoid local anaesthesia in those patients in whom they expect to require a shunt. Such patients, with a history of previous stroke or contralateral occlusion, appear to carry a higher risk of neurological deficit. Similarly, in the belief that higher intraoperative blood pressures increase the risk of myocardial infarction, patients with known ischaemic heart disease may be directed towards general anaesthesia. Clearly the issue can only be resolved by an appropriately designed randomised controlled trial.

**Feasibility and acceptability to surgeon and patient**

A proportion of patients are unsuitable for local anaesthesia because communication with the patient to allow accurate awake testing would not be possible. Furthermore up to 10% of patients may refuse local anaesthesia.\textsuperscript{79} However, although local anaesthesia is often avoided in patients with short fat necks, there is no reason why an adequate block cannot be achieved in all patients, albeit with some supplementary local infiltration intraoperatively. It is generally assumed that both surgeon and patient anxiety is increased by the use of local anaesthesia. but surgeons with experience of local anaesthesia find it reassuring to know that the patient is neurologically intact both during surgery and in the immediate postoperative period. This knowledge also allows for an unhurried and precise endarterectomy usually without the added technical difficulties associated with shunt usage. Fears that dissection of the distal internal carotid artery may prove to be difficult with local anaesthesia are also unfounded, although supplementary local anaesthesia injected into the carotid sheath may be required. There are also fears of the need to convert from local to general anaesthesia during the operation because of loss of consciousness or seizures. However, conversion rates are low (1–3%\textsuperscript{85–87}) and the advent of the laryngeal mask has allowed the airway to be secured with minimal difficulty.

There is little doubt that patients may find it difficult to remain still for an operation that can last 2 h. It is possible to improve their comfort by minor adjustments to the operating theatre procedures. For instance, the use of an opaque plastic drape instead of conventional towels to form a tent over the head and a small electric fan mounted nearby to provide adequate ventilation are useful. The literature is devoid of studies that formally assess patient satisfaction, although several series report patients agreeing to have local anaesthesia for a second carotid endarterectomy.\textsuperscript{84} This aspect of local anaesthesia for carotid surgery is included as part of the GALA trial (see below).

**Complications specific to local anaesthesia**

Four different techniques for providing local anaesthesia are described; cervical epidural, local infiltration, superficial cervical plexus block, superficial and deep cervical plexus block. Cervical epidural is rarely used because of the potential for major complications; hypotension, bradycardia, respiratory failure requiring intubation in 1%, dural puncture in 0.5%, bloody tap in 2%.\textsuperscript{85} Local infiltration is uncomfortable for the patient and is time consuming for the surgeon while superficial plexus block does not provide anaesthesia to deeper tissues or neuromuscular blockade.
of sternomastoid. A combination of deep and superficial plexus block is the most commonly used technique but may also be accompanied by significant complications. Inadvertent injection of local anaesthetic into the vertebral artery, although very rare, can produce immediate loss of consciousness or fitting\(^9\) while the phrenic, recurrent laryngeal and pharyngeal branches of the glossopharyngeal nerves can all be blocked temporarily.\(^9\) Care must also be taken not to exceed the toxic dose of whichever local anaesthetic is used. However, significant complications attributable to local anaesthesia are very rare.

**Health economics**

Papers from North America,\(^1\) Australia\(^8\) and Europe\(^9\) have described strategies to reduce the costs of carotid endarterectomy, which have all included the use of local anaesthesia. Svrk\(^1\) estimated savings of US$6000 (1999) per patient, although it is not clear whether this was entirely due to the use of local anaesthesia. Certainly expensive neurological monitoring can be avoided (EEG monitoring has been estimated at US$500 per case), although other potential strategies for cost reduction (avoidance of angiography, early discharge, avoidance of intensive or high dependency care) may also be applicable to general anaesthesia. At present there is no strong evidence that local anaesthesia is more cost effective than general anaesthesia, although this subject is also being addressed within the GALA trial.

**GALA Trial**

The GALA (general anaesthetic vs local anaesthetic) Trial is currently randomising patients to either general or local anaesthesia for CEA. Assuming a 50% reduction in the relative odds of perioperative stroke or death, as found in Tangkanakul’s systematic review, a trial of 2000 patients would have a 90% chance of detecting a difference with a 5% significance level. Although the principle end points are stroke and death other outcomes including length of stay, requirement for high dependency/intensive care, cardiac complications, patient satisfaction and treatment costs are also being assessed. Once completed this trial should clarify many of the uncertainties described above.

**Conclusion**

There is some evidence to suggest that local anaesthesia may be safer than general anaesthesia in terms of both neurological and cardiac outcome, although this still requires confirmation in a randomised trial. It could be argued that this should be performed before local anaesthetic techniques are widely adopted, a move that could be potentially detrimental if the benefits are not proven. Despite this, the hypothesis that neurological outcome may be improved by preservation of normal cerebrovascular physiological responses to cerebral ischaemia is attractive. This also reduces shunt usage, which may confer additional benefits. Unfortunately differences in cerebral physiology between the two anaesthetic techniques also invalidate the translation of criteria for shunt usage derived from comparisons with awake testing to patients who have a general anaesthetic. The reasons for a possible reduction in the incidence of myocardial infarction are unclear but may include the avoidance of intraoperative hypotension.

At present there is no convincing evidence that using local anaesthesia reduces the total cost of carotid endarterectomy and there is little information regarding patient tolerance of a relatively long and potentially uncomfortable procedure.

The complication rate of carotid endarterectomy is low regardless of variations in anaesthetic and surgical technique and as a result it is difficult to prove an advantage of one technique over another. Nevertheless, in addition to the obvious benefit to the patients concerned, a reduction in the complication rate would alter the risk/benefit ratio and may thus extend the indications for carotid endarterectomy. It is therefore important that all of the variations in technique are systematically investigated.

**References**


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