Intraoperative Duplex Imaging of Carotid Endarterectomy

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Improved outcome following carotid endarterectomy is dependent upon low surgical morbidity and mortality rates. Guidelines for performing carotid endarterectomy recommend that surgeons should have a documented complication rate of <7% for symptomatic and <3% for asymptomatic patients.1 Efforts to ensure a low stroke rate have stimulated scrutiny of factors such as presenting symptoms, experience amongst individual surgeons, and operative technique. However, it is recognised that intraoperative defects, that result in either cerebral embolisation or a reduction in cerebral blood flow, are the most common cause of perioperative stroke. Such defects can also stimulate rapid intimal hyperplasia and have been identified as the causal factor for early restenosis.2 Diagnosis of such defects is dependent upon the detection of the intraluminal abnormality and/or compromised flow. Surgeons have relied upon a plethora of intraoperative monitoring and completion imaging methods to achieve this goal.3 Methods range from simple, digital palpation of the artery, through non-invasive methods such as duplex ultrasound to more invasive procedures, such as angiography and angioscopy.

The optimum quality-control method should provide rapid and accurate information on both the haemodynamic and anatomical state of the endarterectomy site. Criteria for re-exploration should be well defined, as the extended clamp time and possibility of reperfusion injury will increase the operative risk. Preoperatively, duplex ultrasound has already replaced arteriography in many centres, and it is now becoming the favoured technique for completion imaging, because it provides both anatomical and haemodynamic information without increasing the risk of the procedure.4

Early duplex studies used conventional transcutaneous scan heads, which were unable to fully examine the distal extent of the endarterectomy in every case.5 Improvements in ultrasound transducer design and image technology over the last few years have enabled superior imaging along the full extent of the endarterectomised segment, providing detail down to suture level. Spectral Doppler information alone has been used to identify residual haemodynamic stenosis.6 The relationship between residual stenosis and focal defects such as intimal flaps, platelet aggregation, vessel kinks, and intramural thrombosis is well described.4,7 Particularly, intimal flaps are recognised as an important cause of early thrombus formation.5 However, subsequent studies have failed to demonstrate a convincing link between intraoperative defects and the development of perioperative or early postoperative neurological events. Furthermore, many defects appear to be benign, resolving within a month after surgery without intervention.8 The exact features detected intraoperatively which justify re-exploration therefore remain contentious, as does the role of completion imaging.

Successful intraoperative duplex imaging requires a high-resolution transducer (~10MHz) with a small footprint. Completion imaging should be performed as soon as blood flow is restored to the endarterectomised vessel. This allows defects and associated compromised flow to be identified at the earliest possible time, so that corrective measures can be implemented immediately. We do not advocate delaying duplex

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scanning until the patient is in the recovery room, as this gives time for thrombus to form. Different flow characteristics and vessel diameters prevail at the proximal and distal extents of the endarterectomy, and influence the type of problems encountered. Thus, problems in the distal internal carotid artery are more likely to cause internal carotid occlusion, compared with those in the proximal common carotid artery.

Normal vessels have an intimal-media thickness (IMT) of less than 1 mm. Intraoperatively an IMT of more than 1.5 mm indicates a residual intimal shelf. A residual shelf or intimal flap at the proximal extent of the endarterectomy will tend to be approximated against the arterial wall by the blood flow. Thus, defects at this level are relatively benign, but can be avoided by accurately identifying the proximal extent of the plaque, using preoperative duplex scanning. In addition, we have found that sharp dissection of the plaque with scissors immediately adjacent to the arterial wall prevents detachment of the proximal IMT complex and abolishes the possibility of a flap. At the distal extent of the endarterectomy a similar intimal flap or shelf will have more serious consequences. A 2- or 3-mm flap in the small calibre distal internal carotid artery can cause a stenosis of more than 50% of the luminal diameter. Furthermore, there will be a tendency for blood flow to encourage a dissection of the intimal flap, causing it to protrude intraluminally, restrict flow and thereby cause thrombosis.

Flow disturbance occurs in regions of vessel tortuosity or dilatation, the latter being seen in patched vessels, while turbulence is noted at or distal to localised vessel constrictions. Haemodynamically significant stenoses are identified by conventional duplex criteria and vessels can be differentiated into moderate stenoses (50–69%) or severe stenoses (70–99%). It should be noted that the accuracy of stenosis grading might be affected by the prevailing haemodynamic conditions, which may include a contralateral occlusion, arrhythmia and general anaesthesia. It would seem logical that, having performed surgery to remove a 70–99% stenosis, then detection of a residual stenosis of this degree should justify immediate re-exploration. However, a severe stenosis may resolve without surgical intervention. In some instances stenoses are associated with kinking of the vessel, and for some surgeons this would be an indication for intervention, either with patch angioplasty or by plication and resection of redundant arterial wall. However, untreated kinks often resolve and are not associated with neurological events. This may be because endothelial resurfacing normalises the compliance mismatch created between the endarterectomised and non-endarterectomised segments.

There is no doubt that high-resolution, intraoperative duplex imaging has revealed new information regarding the state of the endarterectomised vessel. Sub-millimetre, residual intimal fronds are clearly visualised and can be significantly reduced by meticulous attention to removing such debris from the endarterectomised surface. Other important information includes wall damage caused by the arterial clamps. The use of Fluoropassiv™ (Sulzer Vascutek Limited, Renfrewshire, Scotland) patches has resolved the problem of ultrasound passage through synthetic material, and excellent duplex images can be obtained. Other polyester and polytetrafluoroethylene patches completely attenuate the ultrasound signal.

It is generally accepted that training and experience are required to obtain low perioperative complication rates. While it is acknowledged that comprehensive training can be given without influencing operative risk, the acquisition of technical excellence is not well documented. We have found that more technical problems are encountered in operations performed by trainees compared to those by the consultant, and therefore duplex imaging offers a means of auditing technical competence.

If a thrombosed internal carotid artery is detected perioperatively, immediate re-exploration, correction of any technical defect and restoration of blood flow is essential. However, the decision to re-explore defects that are subtle, or not necessarily associated with significant stenosis, remains controversial. While re-exploration may increase the risk of the procedure, correction of defects has the potential advantage of preventing perioperative stroke and reducing the incidence of restenosis. The key questions are: which defects require correction and how does this impact on the morbidity and mortality associated with carotid endarterectomy? As yet there is no convincing evidence that completion imaging improves clinical outcome, and so many surgeons continue to operate without any form of completion imaging. The only reliable approach to assess the influence of intraoperative completion imaging is by direct comparison in a randomised, controlled trial. However, it is probably now unethical to perform this trial, as it would be difficult to withhold intervention in patients in whom a large, flow-limiting technical defect is demonstrated.

The benefit of carotid endarterectomy is dependent upon achieving low perioperative morbidity and mortality rates. The role of completion imaging in reducing these is difficult to establish, as is the relationship between recurrent stenosis and ipsilateral stroke. In many centres the role of intraoperative duplex lies
mainly in the modification of surgical technique to eradicate technical imperfection and to perform continuous audit of both trainee and consultant surgeons in order to maintain high technical excellence.

References


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