Intraoperative Duplex Scanning as a Means of Quality Control During Carotid Endarterectomy

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Objectives: To identify correctable technical errors following carotid endarterectomy using intraoperative colour Duplex sonography (ATL, UM9, HDI). Results were compared with intraoperative flow measurements using an operative flow meter and with middle cerebral artery velocity measured by trans-cranial Doppler (TCD).

Design: Prospective study.

Materials and Methods: 50 consecutive patients undergoing carotid endarterectomy were investigated. Follow-up was performed at 6 weeks using Duplex scanning and clinical evaluation.

Results: Significant intraoperative technical errors were detected in three patients and were re-explored. Two scans demonstrated kinking or pinching at the distal endarterectomy site requiring patch-plasty and the third revealed a large mass of intramural thrombus. A further 18 endarterectomies yielded 21 additional minor abnormalities.

Conclusions: Duplex sonography provides a sensitive intraoperative technique for detecting thrombus and technical errors. It yields both anatomic and hemodynamic details and is superior to intraoperative flow measurements and transcranial Doppler.

Key Words: Carotid endarterectomy; Ultrasonography; Vascular surgery.

Introduction

A number of techniques are currently available for intraoperative quality control during and after carotid endarterectomy (CE). These include continuous wave Doppler (CWD),1 transcranial doppler (TCD),2,3 intraoperative flow measurements,4 intraoperative angiography (IOA)5,6 and angioscopy.7 Technical errors remain a major cause of perioperative thrombosis and embolisation and have been identified in 2.4 to 26% of patients studied using these imaging modalities.3-5,7 Intimal flaps, kinks, emboli and residual thrombus or plaque account for the majority of identifiable defects during the procedure and relate directly to clinical outcome. Recent work has also confirmed a lower morbidity and mortality when surgeons utilise these assessment methods.8

It is generally still agreed that the ‘gold standard’ for technical quality assurance in theatre is on-table arteriography, but it is invasive, time-consuming, not always readily available and provides no haemodynamic information.

Overview of current techniques for CE quality control

Continuous wave Doppler (CWD) can provide a qualitative overview of the haemodynamics within the endarterectomy. Areas of high velocity or turbulence can be identified but the technique is operator dependant and will not quantify the degree of stenosis.

Trans-cranial Doppler (TCD) allows continuous monitoring of the ipsilateral middle cerebral artery mean blood flow velocity (Vmca) during CE.3 If Vmca is maintained on clamping of the common and external carotid arteries then studies have shown that the operation can be performed without the need for shunting.9 Effective monitoring of shunt function is also possible. At completion of the endarterectomy Vmca would be expected to increase or at least return to the preoperative value. Vmca is however directly related to blood pressure and this must be borne in mind when making comparative readings.

Intraoperative flow: a Doppler operative flow meter (Scimed Op-Dop, Bristol, U.K.) can measure flow directly from a graft or native vessel. ICA flow in ml/min can be measured pre- and postoperatively to assess operative improvement in cerebral supply.3
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Criteria for re-exploration based on these measurements are however not well defined.

Intraoperative colour Duplex (ATL, HDI UM9) can be used to assess the technical adequacy of CE.10-14 This study compares the use of intraoperative Duplex scanning with other quality assurance measures of $V_{\text{mea}}$ and ICA flow.

Patients and Methods

A prospective study of 50 consecutive patients was carried out between May 1992 and November 1994. There were 39 men and 11 women, median age 69 years (range 50-90 years). Presenting symptoms and associated risk factors are shown in Table 1. Only three of the patients with drop attacks or vertigo had isolated symptoms of this nature. All the other patients in this group had additional classic symptoms. The degree of stenoses are demonstrated in Table 2. All patients had pre- and postoperative ICA flow measurements using a Doppler flow meter (Scimed Op-Dop, Bristol, U.K.) as well as transcranial monitoring during of surgery. Intraoperative colour Duplex sonography (ATL, UM9, HDI) was performed prior to skin closure to examine the operative site for technically correctable defects. Routine follow-up Duplex scanning was performed at 6 weeks in the vascular studies unit. All transcranial Doppler measurements and Duplex scans were performed by a single experienced vascular technologist.

Operative technique

Under general anaesthesia all patients were positioned with placement of a head box to protect the transcranial Doppler transducer.15 After dissection of the carotid bifurcation the sinus nerve was blocked with 2ml local anaesthetic (0.5% marcaine with adrenaline 1:200,000) to reduce haemodynamic instability. Preoperative ICA flow was measured. TCD was used primarily for assessment of shunt requirement and function as well as for detection of intraoperative emboli. If $V_{\text{mea}}$ fell by 50% on clamping a Javid shunt was used. Endarterectomy was performed using a standard technique. Patch angioplasty was only performed where the artery was small. Following the removal of the clamps the postoperative ICA flow was measured and intraoperative Duplex scan performed.

Intraoperative Duplex scanning

An ATL Ultramark 9 HDI colour Duplex scanner with an L10-5 wideband 7.5MHz linear array transducer in a sterile drape (Aldon intestinal bag, Rusch U.K. Ltd, High Wycombe, U.K.) was used for intraoperative scanning. The exposed transducer cable was protected by operative drapes. The wound was instilled with Hartmann's solution as a stand-off medium allowing the endarterectomy and distal vessels to be imaged without touching the vessels. Vessel patency and flow distribution was then assessed by obtaining colour-flow images and appropriate Doppler signals.

The entire length of each endarterectomy was assessed with B-mode, pulsed-wave and colour Doppler and hard copies of the waveforms and images were obtained in all cases (Table 3). The result of the endarterectomy was assessed in both the ICA and ECA. Additional waveforms and images were

Table 1. Patient symptoms and risk factors

<table>
<thead>
<tr>
<th>Symptoms</th>
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<tbody>
<tr>
<td>Amaurosis/Fugax</td>
<td>20</td>
</tr>
<tr>
<td>Transient weakness</td>
<td>34</td>
</tr>
<tr>
<td>Dysphasia</td>
<td>12</td>
</tr>
<tr>
<td>Drop Attacks/Vertigo</td>
<td>10</td>
</tr>
<tr>
<td>Asymptomatic (ACST)</td>
<td>2</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Risk Factors</th>
<th></th>
</tr>
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<tbody>
<tr>
<td>Diabetes</td>
<td>15</td>
</tr>
<tr>
<td>Hypertension</td>
<td>24</td>
</tr>
<tr>
<td>Smoking</td>
<td>15 current (+26 past history)</td>
</tr>
</tbody>
</table>

25 patients experienced a combination of multiple symptoms. 17 patients had a combination of multiple risk factors).

Table 2. Degree of ICA stenosis of operative side

<table>
<thead>
<tr>
<th>Degree of stenosis</th>
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<tbody>
<tr>
<td>&lt;50%</td>
<td>1</td>
</tr>
<tr>
<td>≥50%</td>
<td>3</td>
</tr>
<tr>
<td>≥75%</td>
<td>26</td>
</tr>
<tr>
<td>≥90%</td>
<td>20</td>
</tr>
</tbody>
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1. CCA Doppler waveform (record peak systolic frequency (psf) at 60° or peak systolic velocity (psv) at 160°)
2. ICA Doppler waveform (record psf or psv)
3. ECA Doppler waveform (record psf or psv)
4. Colour image of site of endarterectomy (at least one view)
5. B-mode image of site of endarterectomy (at least one view)

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recorded as required, together with full documentation of any enhanced frequencies or other abnormalities. The technique added little to the operative time and provided more information than conventional Doppler flow measurements.

Results

Of the 50 patients, 29 had normal intraoperative scans. Twenty-one had abnormal initial scans. For the purposes of this study, potential correctable defects were defined as those causing a ≥75% stenosis and/or those where a visible filling defect or constriction of the ICA lumen was detected and/or those where the technical appearance of the endarterectomy closure was deemed to be suboptimal. Three endarterectomies warranted re-exploration and re-fashioning and this resulted in a normal intraoperative scan in all three cases. Eighteen other patients had 21 minor abnormalities on intraoperative scanning but these did not require operative correction.

Operative mortality in this study was 2% with one patient death as a result of a perioperative stroke. This patient had a normal intraoperative Duplex scan. There was no additional morbidity associated with this patient population.

Normal

Twenty-nine patients had normal intraoperative scans. All remained normal at 6 weeks.

Abnormal— not re-explored

A total of 21 abnormalities were detected. At follow up 10 abnormalities had returned to within normal limits and 11 abnormalities persisted. None of these remaining abnormalities were deemed to be clinically significant.

Turbulence. Seven patients had scans which exhibited turbulence only with no enhanced velocities. At 6 weeks, four of these patients had a normal scan, two patients had mild residual turbulence and one patient had mildly enhanced ICA frequencies (4.5kHz) suggestive of mild intimal hyperplasia (≥50% stenosis).

ECA stenosis. Ten patients had residual ECA stenosis on the intraoperative scan. Three of these had resolved at 6 weeks. Seven had persistent ECA velocity enhancement at 6 weeks. Two of the patients had additional turbulence in the ICA which resolved at follow-up.

ICA stenoses. Four patients had enhanced intraoperative frequencies in the internal carotid artery. One of these had additional high frequencies in the ECA. In three of the four cases ICA frequencies were only mildly enhanced suggestive of >50% stenosis but these had reverted to normal at 6 weeks. In the fourth case a >75% stenosis was recorded in the ICA which was felt to be associated with kinking distal to the endarterectomy. Gentle caudal traction of the ICA resulted in a reduction of the peak systolic frequency recorded at the site of kinking (>50% stenosis). Re-exploration of this lesion was not performed as the significance was uncertain and the access difficult. Some residual turbulence distal to the endarterectomy was still present at 6 weeks but peak systolic frequencies were within the normal range.

Re-explorations

Three patients underwent re-exploration and re-fashioning of the endarterectomy on the basis of an abnormal Duplex scan.

Patient A. This patient had a >50% stenosis of the ICA implicated by colour aliasing and enhanced Doppler frequencies. A small kink was visible at the site of frequency enhancement which could not be eliminated by gentle caudal traction of the ICA. The endarterectomy was re-opened, re-fashioned and a normal Duplex scan resulted. Six week follow-up was normal.

Patient B. This patient had a >75% stenosis of the ICA and there was also incomplete colour filling at the distal endarterectomy. The site was re-opened, thrombus removed and a patch inserted. A repeat Duplex scan was normal. Six week follow-up was also normal.

Patient C. This patient had a >75% stenosis of the ICA. This was due to kinking or pinching at the distal end of the endarterectomy. The site was re-opened and a patch inserted. A repeat Duplex revealed that a functional >75% stenosis still remained this time accompanied by a visible filling defect on the posterior wall of the distal endarterectomy. The endarter-
ectomy was again re-opened and the patch and endarterectomy extended distally. A third Duplex scan yielded a normal result. The postoperative recovery was uneventful and 6 week follow-up was normal.

ICA flow and $V_{mca}$ measurements

In all cases intraoperative flow increased following carotid endarterectomy. The average increase in those patients exhibiting normal intraoperative Duplex was 340ml/min ranging from 150–754ml/min. In the abnormal group the average increase was 311ml/min ranging from 39ml/min to 1071 ml/min. There was no statistical significance between the two groups (Mann Whitney U-test). $V_{mca}$ increased or remained constant after the procedure in all cases. None of the Duplex abnormalities could be detected using TCD criteria.

Discussion

Results of this study would indicate that neither ICA flow measurements or $V_{mca}$ are sensitive predictors of correctable defects associated with CE. In general, quantitative assessment of $V_{mca}$ is used only for shunting criteria and not for postoperative evaluation purposes. Duplex results suggest that turbulence alone during an intraoperative scan may be a normal phenomenon. Similar turbulence has been noted in Duplex scanning in the lower limb immediately post-angioplasty. This may be associated with local trauma, and usually resolves by the time the patients are scanned again at 6 weeks.

Those patients with high frequencies during intraoperative colour Duplex scanning are a grey area and exact criteria for re-exploration are as yet unclear. There is currently insufficient data to objectively compare the risks of surgical imperfections with the risks of extended anaesthesia and further surgery — but it is interesting to note that there were no neurological deficits in any of the patients who had intraoperative abnormalities.

The results of this study suggest that where significantly enhanced frequencies/velocities indicating a functional stenosis are accompanied by a visible filling defect or constriction of the internal carotid lumen there may be a need for re-exploration of the endarterectomy.

It can be concluded that intraoperative colour Duplex appears to be a useful means of quality assurance for carotid endarterectomy supplying detailed anatomical and haemodynamic information about the operative site in real time. A randomised trial including all other current quality assurance techniques together with detailed pre- and postoperative psychometric testing would be a move towards more closely defining quantitative interpretation of results in terms of operative outcome. This trial must include a non-intervention group in order to be able to define which defects indicate a significant risk to the patient.

References


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