Variation in Surgical and Anaesthetic Technique and Associations with Operative Risk in the European Carotid Surgery Trial: Implications for Trials of Ancillary Techniques

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Objectives: several ancillary surgical techniques, such as shunting and patching, are used in association with carotid endarterectomy. However, the balance of risks and benefits of these techniques is uncertain because of the lack of large randomised controlled trials (RCTs). To assess the potential for further trials, we studied the variation in use of these techniques by surgeon and by country in the European Carotid Surgery Trial (ECST).

Methods: use of each ancillary technique was assessed by surgeon and by country. For each technique, the relationships between the use of the technique and baseline patient characteristics, use of other techniques, and the 30-day operative risk of stroke and death were determined.

Results: there was considerable variation between surgeons in the use of ancillary operative techniques both within (p<0.001 for shunting and patching), and between countries (p<0.001 for shunting and patching). Some surgeons used techniques selectively, and so the characteristics of patients differed depending on which techniques were used. Use of each technique was also significantly associated with the use of other techniques. Multiple regression analysis, taking into account all these factors, found no statistically significant associations between operative risk and the use of shunting, patching, intra-operative EEG monitoring, or type of anaesthetic. The only surgical technique significantly associated with an increased operative risk was not using intra-operative anticoagulation (hazard ratio = 2.33, 95% CI = 1.4–4.2). Other factors associated with an increased risk were an operation time of less than 1 h, or greater than 1.5 h, and the surgeons’ subjective assessment that the operation was difficult.

Conclusions: in the ECST, operative risk was more closely related to patient characteristics, length of surgery, and the surgeons’ perception of the difficulty of the operation, than to the use of particular ancillary operative techniques. The considerable variation between surgeons, and between countries, in the use of ancillary techniques is in keeping with the lack of convincing data from RCTs, and suggests that there should be sufficient uncertainty to make large pragmatic trials possible.

Key Words: Carotid endarterectomy; Risk factors; Complications.

Introduction

Certain baseline clinical and angiographic characteristics are associated with an increased risk of death or major stroke within 30 days of carotid endarterectomy.1–4 Many baseline risk factors, such as age and gender, are not open to modification and are consequently of limited help to clinicians once the decision to operate has been made. One important aspect of quality control is the identification of factors that can be modified, such as surgical and anaesthetic technique, and to assess their influence on surgical outcome.

When performing a carotid endarterectomy, surgeons may use a number of ancillary techniques, such as local anaesthetic, shunting, patching or anticoagulation. Randomised controlled trials have been performed to try and assess the effect of these techniques,5–10 but the relatively low risks of stroke and death due to carotid endarterectomy mean that very large patient sample sizes are required to get reliable results.7 Currently, there are no completed trials of adequate size for any of the ancillary techniques.8–10 Most of the evidence for or against techniques such
as shunting, patching and different types of anaesthesia, originates from retrospective case series, or routinely collected data, such as Medicare beneficiary databases. However, these studies are of limited value since they are non-randomised, and they rarely correct for the multiple potential confounding factors, such as case-mix and associations with the use of other ancillary techniques. Moreover, the decision to use any one technique is rarely made in isolation and is likely to affect the decision to use another. The different techniques may be used selectively, according to set criteria, or rigidly (e.g. always or never). The reasons and thresholds for selecting a particular technique may differ between individual surgeons.

To determine the potential viability and design of large multi-centre randomised controlled trials, it is useful to study clinical practice across a large number of centres, and across different countries if international trials are planned. Several important issues can then be addressed. Firstly, it is important to document the variation in use of the various ancillary surgical techniques. If clinical practice is highly consistent, despite the lack of trial data, then large trials may not be viable. Secondly, it is important to determine the inter-relations between use of the different techniques. To what extent might randomisation to the use of one technique (e.g. shunting) influence the use of other ancillary techniques (e.g. patching)? Thirdly, it is important to assess to what extent particular techniques are used in particular types of patients. Fourthly, in the absence of reliable estimates of treatment effects from RCTs, detailed individual patient data from cohort studies can be used to estimate the likely effect of techniques on operative risk and thereby inform sample size calculations. Ideally, these analyses should be done in a cohort of patients that was established prospectively and in which the decision to analyse and report the results was not data-dependent. The European Carotid Surgery Trial (ECST) surgery patients are such a group. They are the largest published cohort of patients with symptomatic carotid stenosis in which the complications of endarterectomy were assessed by both a neurologist and a surgeon.

**Patients and Methods**

The methods of the ECST have been published in detail previously. Briefly, patients were randomised if they had suffered a carotid distribution transient ischaemic attack, minor ischaemic stroke, non-disabling major ischaemic stroke, or a retinal infection in the last 6 months, and if, after a carotid angiogram, the neurologist and surgeon were uncertain whether to recommend carotid endarterectomy. Patients were randomised to “immediate surgery” (60%) or to “avoid immediate surgery” (40%). At randomisation, certain baseline clinical data were recorded and sent to the main trial centre along with the pre-randomisation carotid angiogram and a pre-randomisation computed tomographic (CT) brain scan, if abnormal. The degree of stenosis at the bifurcation of both carotid arteries was measured by two observers (PMR and CPW) on the angiogram by the ECST method, and the average of the two measurements considered to be the “true” stenosis.

It was strongly recommended that the surgeon performing the endarterectomy was the collaborating surgeon and not a trainee or assistant. The surgeon recorded details of the operation and of any adverse events which occurred prior to hospital discharge. Patients were reviewed by a physician 4 months after the operation. Transient ischaemic attack was defined as a focal neurological or retinal deficit lasting less than 24 h, minor stroke as any stroke lasting less than 7 days and major stroke as any stroke lasting 7 days or more. Disabling stroke was defined by a Rankin score of 3 or more. The main operative outcomes studied were death, non-fatal major stroke, and non-fatal myocardial infarction. Clinical details of outcomes, including CT scan and necropsy reports where available, were sent to the main trial centre for classification by a neurologist and then by a clinical audit committee who were blinded to treatment allocation. Details of any re-operation or postoperative arterial imaging were also requested. The local physician recorded any disability on the Rankin scale 6 months after any stroke. Myocardial infarction was defined on the basis of a suggestive clinical history with either electrocardiographic changes or increased cardiac enzyme concentrations. Other routinely recorded outcomes included deep venous thrombosis, pulmonary embolus, transient ischaemic attack and major stroke, cranial nerve palsy and wound infection. Only events occurring within 30 days of surgery were included in the analysis. Four patients had a stroke in the territory of the symptomatic carotid artery after randomisation but prior to surgery, and were not, therefore, operated. They are excluded from this analysis although they were, of course, included in the trial analysis of the overall effect of endarterectomy.

All surgeons participating in the ECST recorded their use of carotid shunts, patches, intraoperative anticoagulation, EEG monitoring, the total length of operation (skin to skin) and the total carotid artery occlusion time (defined as the total length of time
during which no blood was flowing distally into the internal carotid artery). The site of operation, type of anaesthetic used and carotid artery stump pressures were also recorded. The surgeon also rated the macroscopic appearance of the plaque, noting the presence of intra-arterial thrombus, whether there was obvious plaque ulceration and the apparent stenosis of the artery. At the end of the operation the surgeon classified the operation as “easy”, “average” or “difficult” based on his or her subjective impression. The main surgical outcome measure was death due to any cause, or stroke lasting longer than 7 days within 30 days of surgery. Other surgical complications such as cranial nerve injury, neck haematoma requiring re-operation, and abnormal postoperative blood pressure were also recorded.

**Analysis**

Heterogeneity of use of ancillary techniques was assessed by country using all the patients undergoing trial surgery. However, many of the trial surgeons randomised only one or two patients into the ECST and even those who entered more rarely submitted all of their patients. To gain an insight into the normal practice of individual surgeons we, therefore, studied only the 54 surgeons who had contributed 10 or more strokes lasting longer than 7 days within 30 days of randomisation. The number of operations performed per surgeon varied from 1 case (22 surgeons) to over 60 cases (2 surgeons), with 54 surgeons operating on 10 or more cases.

There were 17 (1.0%, 95% CI = 0.6–1.6) deaths within 30 days of trial surgery of which 11 were due to stroke. The median delay between randomisation and surgery was 14 days and 90% of operations were carried out within 52 days. Details of the postoperative assessment by the surgeon and the 4-month assessment by the study neurologist were available in all cases. A total of 147 individual surgeons entered patients into the ECST. The number of operations performed per surgeon varied from 1 case (22 surgeons) to over 60 cases (2 surgeons), with 54 surgeons operating on 10 or more cases.

A total of 1729 patients were randomised to surgery and underwent carotid endarterectomy within 1 year of randomisation. The median time from last ipsilateral carotid territory cerebrovascular symptoms to randomisation was 61 days. The median delay between randomisation and surgery was 14 days and 90% of operations were carried out within 52 days. Details of the postoperative assessment by the surgeon and the 4-month assessment by the study neurologist were available in all cases. A total of 147 individual surgeons entered patients into the ECST. The number of operations performed per surgeon varied from 1 case (22 surgeons) to over 60 cases (2 surgeons), with 54 surgeons operating on 10 or more cases.

Operative risk was defined as risk of any stroke or death that occurred within 30 days of trial surgery. Trial surgery was defined as the first endarterectomy that was performed within 1 year of randomisation in patients who had been randomised to surgery. The relationships between all recorded operative and anaesthetic factors and operative risk were analysed univariately using chi-squared or Fisher’s exact tests as appropriate. Each of the variables that approached significance (p<0.1) were entered individually into a multiple regression model along with all baseline clinical and angiographic characteristics that were predictive of operative risk to correct associations for imbalances in case-mix. A final multiple regression analysis was performed that included all baseline clinical and angiographic variables and all operative variables in order to correct for concomitant use of the different operative techniques. Comparison of means was performed using either a two-sample t-test or a Mann–Whitney U-test according to the data distribution. Calculations were performed using SPSS for Windows Version 10.0.5 (Copyright © SPSS Inc., 1989–1999).

**Results**

The mean length of surgery (skin to skin) was 88 min (95% range = 40–150). This was 92 min when a shunt was used vs 86 min when no shunt was used (p<0.001), 98 min when a patch was used vs 85 min in non-patched patients (p = 0.003), and 81 min in operations classed as “easy” vs 100 min in “difficult” operations (p<0.001). The mean carotid artery occlusion time for all patients was 20 min (95% range = 2–47). In the 627 (36%) patients in whom a shunt was used, the mean occlusion time was 10 min (median = 5, 95% range = 2–32) vs 26 min (median = 24, 95% range = 8–50) in the 1102 (64%) patients in whom no shunt was used (p<0.001). Stump pressures were recorded in 723 (41.8%) patients. The mean stump pressure was 60 mmHg (median = 60.0, 95% range = 20–99) in all patients, 65 mmHg (median = 66, 95% range = 28–99) in patients who were not shunted, and 44 mmHg (median = 40, 95% range = 10–82) in those who were shunted (p<0.001). Shunts were used in 100 of 219 (46%) patients with stump pressures between 25 and 50 mmHg and 38 of 52 (68%) patients with pressures <25 mmHg.
Table 1. The relationships between baseline clinical and operative characteristics and the surgeon's perception of difficulty of the operation. All factors were entered into a multiple regression model.

<table>
<thead>
<tr>
<th>Factors associated with &quot;easy&quot; operations opposed to &quot;moderate&quot; or &quot;difficult&quot;</th>
<th>Hazard ratio</th>
<th>p</th>
<th>95% CI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Significant</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Operation inside 1–1.5 h</td>
<td>1.37</td>
<td>0.004</td>
<td>(1.10–1.70)</td>
</tr>
<tr>
<td>No stroke or death within 30 days</td>
<td>2.27</td>
<td>0.002</td>
<td>(1.35–3.83)</td>
</tr>
<tr>
<td>Ipsilateral stenosis &lt;80%</td>
<td>1.64</td>
<td>0.001</td>
<td>(1.21–2.21)</td>
</tr>
<tr>
<td>Female sex</td>
<td>1.40</td>
<td>0.005</td>
<td>(1.11–1.78)</td>
</tr>
<tr>
<td>No shunt used</td>
<td>1.92</td>
<td>0.001</td>
<td>(1.45–2.48)</td>
</tr>
<tr>
<td>EEG used</td>
<td>1.26</td>
<td>0.050</td>
<td>(1.00–1.59)</td>
</tr>
<tr>
<td>Non-significant</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Operation on right side</td>
<td>1.03</td>
<td>0.79</td>
<td>(0.83–1.29)</td>
</tr>
<tr>
<td>Local anaesthetic used</td>
<td>1.71</td>
<td>0.058</td>
<td>(0.99–2.96)</td>
</tr>
<tr>
<td>No patch used</td>
<td>1.07</td>
<td>0.63</td>
<td>(0.81–1.34)</td>
</tr>
<tr>
<td>Age 75+</td>
<td>1.28</td>
<td>0.29</td>
<td>(0.83–2.08)</td>
</tr>
<tr>
<td>Presenting event ocular only</td>
<td>1.08</td>
<td>0.65</td>
<td>(0.79–1.51)</td>
</tr>
<tr>
<td>Anticoagulation used</td>
<td>1.26</td>
<td>0.30</td>
<td>(0.82–1.95)</td>
</tr>
</tbody>
</table>

Table 2. Frequency of use of individual surgical techniques in 1729 operations.

<table>
<thead>
<tr>
<th>Procedure</th>
<th>Number of patients</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carotid shunt</td>
<td>627</td>
<td>36</td>
</tr>
<tr>
<td>Carotid patch</td>
<td>479</td>
<td>28</td>
</tr>
<tr>
<td>Stump pressure measurement</td>
<td>723</td>
<td>42</td>
</tr>
<tr>
<td>Anticoagulation</td>
<td>1598</td>
<td>92</td>
</tr>
<tr>
<td>Local anaesthetic used</td>
<td>58</td>
<td>3.4</td>
</tr>
<tr>
<td>EEG monitoring</td>
<td>639</td>
<td>37</td>
</tr>
</tbody>
</table>

Surgeons rated 495 of the operations as easy, 955 as average and 272 as difficult. Ratings were not available for seven operations. Factors that were statistically significantly associated with the operation being rated as easy as opposed to either average or difficult were: an operation lasting 1–1.5 h; the absence of stroke or death within 30 days of surgery; ipsilateral carotid stenosis <80%; female sex; not using a shunt and use of EEG monitoring (Table 1).

Variation in use of ancillary techniques by country

Different countries varied widely in the rate of their use of each different ancillary technique (All p<0.0001, Fig. 2). For example, EEG was used in 98% of cases within 11 centres in Holland but only 1% of cases in six German centres. Similarly, patching was performed in 77% of cases in Norway vs 2% in Finland and shunting was used in 89% cases in Germany vs only 1% in France. Logistic regression analysis showed that there was significant heterogeneity of practice between countries, as well as between individual surgeons independent of the country in which they practise (shunting p<0.001, and patching p<0.001).

Univariate analysis of the risk of individual surgical techniques

The overall rate of use of each ancillary technique is shown in Table 2. There was considerable variation, among the 54 surgeons who operated on 10 or more cases, in the frequency of their use of shunting ($\chi^2_{df=53, p<0.0005}$), patching ($\chi^2_{df=62, df=53, p<0.0005}$), and EEG ($\chi^2_{df=150, df=53, p<0.00001}$). They were used in less than 10% of cases by 21 (39%), 23 (43%) and 27 (50%) of surgeons respectively, and in over 90% of cases by 10 (19%), 5 (9%) and 19 (35%) surgeons respectively (Fig. 1). The use of some techniques, such as local anaesthetic and anticoagulation, were more dichotomous. Intraoperative anticoagulation was used in all patients by 38 (70%) surgeons and in at least 70% of patients by all but two surgeons. Four (7.4%) surgeons operated under local anaesthetic, but none of these used it in more than 40% of their patients.
Fig. 2. Variation in rate of use of different ancillary surgical technique during carotid endarterectomy by country. Heterogeneity was tested for by a chi-squared test.
Fig. 3. Univariate relationships between operative data and 30-day stroke or death rates for the patients undergoing carotid endarterectomy in the European Carotid Surgery Trial. Significance is tested using a chi-squared test, or Fisher’s exact test unless stated otherwise.

**Multivariate analysis**

Analysis of the relationships between ancillary techniques and outcome was complicated by the fact that patients with specific clinical and angiographic characteristics were more likely to undergo operations involving a particular technique than other patients. For example, shunts were used in 40% of women vs 34% of men \((p = 0.05)\) and local anaesthetic in 8% of patients aged greater than 75 years vs 3% of patients.
Table 3. The univariate hazard ratios for operative risk of stroke and death due to endarterectomy according to the use of various surgical and anaesthetic techniques, the same hazard ratios corrected for differences in baseline characteristics, and those corrected for both baseline characteristics and use of the other techniques by inclusion of all variables in multivariate analysis.

<table>
<thead>
<tr>
<th>Technique</th>
<th>Uncorrected Hazard ratio (95% CI)</th>
<th>p</th>
<th>Corrected for use of technique Hazard ratio (95% CI)</th>
<th>p</th>
<th>Corrected for technique and case-mix Hazard ratio (95% CI)</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Local anaesthetic</td>
<td>0.22 (0.03–1.60)</td>
<td>0.12</td>
<td>0.27 (0.04–1.97)</td>
<td>0.20</td>
<td>0.30 (0.04–2.20)</td>
<td>0.20</td>
</tr>
<tr>
<td>Anticoagulation</td>
<td>0.41 (0.24–0.71)</td>
<td>0.001</td>
<td>0.43 (0.26–0.73)</td>
<td>0.002</td>
<td>0.47 (0.28–0.81)</td>
<td>0.002</td>
</tr>
<tr>
<td>Carotid shunt</td>
<td>1.52 (1.05–2.20)</td>
<td>0.02</td>
<td>1.39 (0.96–2.03)</td>
<td>0.08</td>
<td>1.25 (0.83–1.88)</td>
<td>0.28</td>
</tr>
<tr>
<td>Patch graft</td>
<td>1.31 (0.88–1.95)</td>
<td>0.18</td>
<td>1.20 (0.81–1.80)</td>
<td>0.36</td>
<td>1.18 (0.78–1.80)</td>
<td>0.44</td>
</tr>
<tr>
<td>EEG monitoring</td>
<td>0.68 (0.45–1.01)</td>
<td>0.06</td>
<td>0.66 (0.44–1.00)</td>
<td>0.05</td>
<td>0.69 (0.47–1.11)</td>
<td>0.09</td>
</tr>
<tr>
<td>Operation length</td>
<td>1.90 (1.21–2.98)</td>
<td>0.005</td>
<td>1.83 (1.16–2.90)</td>
<td>0.09</td>
<td>1.76 (1.11–2.80)</td>
<td>0.02</td>
</tr>
</tbody>
</table>

aged less than 75 (p = 0.02). Given the differences between patients who underwent surgery with the different techniques, it was necessary to adjust for associations with operative risk for case-mix. This was done by including the six baseline clinical and angiographic characteristics that were significantly related to surgical outcome in a multiple logistic regression analysis along with each ancillary technique.25 Both the crude and corrected associations between each of the techniques and the operative risk of stroke and death are shown in Table 3.

Each of the associations was weaker when corrected for case-mix apart from the decreased risk associated with use of EEG monitoring. The increased operative risk associated with the use of carotid shunting was no longer significant, but the decreased risk associated with intraoperative anticoagulation remained highly significant as did the relationship between operation length outside the range 1–1.5 h.

The ancillary techniques were not used independently of one another. If one technique was employed this would affect the likelihood of some of the other techniques being used. For example, patients who had an intraoperative shunt were 54% more likely to have a patch graft and 48% less likely to have EEG monitoring than those who were not shunted. We therefore corrected the associations between each of the techniques and operative risk for interactions due to differential use of other techniques. Table 3 shows the results of a multiple logistic regression analysis in which the associations were corrected for the use of other techniques as well as clinical and angiographic risk factors. The apparent associations between the operative risk of stroke and death and the use of EEG monitoring, shunting and local anaesthetic were no longer present when corrected for interactions with the use of other techniques. Only use of intraoperative anticoagulants and operation duration outside 1–1.5 h remained significant associations with surgical outcome. Stump pressure was not included in the regression analysis because results were only available for 723 (41.8%) of patients and exclusion of so many patients would have reduced the power of the regression model considerably.

Discussion

There are insufficient data from randomised controlled trials to indicate whether the routine use of ancillary surgical or anaesthetic and monitoring techniques have a significant effect on the operative risk of stroke and death.8–10 More trials are necessary. In the meantime, some information can be gained by studying large cohorts such as the ECST.20 Although non-randomised comparisons are always potentially confounded, the analyses reported above are helpful inasmuch as they help to define the areas in which future trials are necessary, and likely to be viable.

The ECST data can be criticised for only reflecting practice in the late 1980s and the 1990s. Moreover, surgical practice and patient selection may even have changed as a result of the trial itself. Local anaesthetic is now used in many more patients than it was previously, and as a result, methods and thresholds for determining when to use shunts have also changed. The accuracy and methods of quality control may also have improved, and many surgeons feel that the ECST 30-day stroke and death rate of 7.1% does not reflect the current outcome risk.26 Selected centres have been able to reliably produce much lower complication rates than those of the ECST and NASCET, particularly in asymptomatic patients.27 However, there is good evidence that the stroke and death rates of symptomatic patients in the U.S.A. and Europe, when all
surgeons and centres are included, remain between 5 and 8%. The fact that specialist centres are able to demonstrate a better outcome than the average highlights the importance of quality control and an understanding of which factors that influence outcome can be modified.

Length of operation

There is evidence that postoperative morbidity is increased in prolonged surgical procedures. Our results show a "U"-shaped relationship between outcome and operation time suggesting that there is an "ideal" length of operation of between 1 and 2 h. The average operation time did not vary much with operative technique. Although it is relatively easy to accept that a lengthy operation will result in a poor outcome it is perhaps harder to explain the increased risk observed with very short procedures. One explanation is that surgeons felt forced to rush operations in patients they perceived to be at higher risk, but there was no evidence of an increased frequency of adverse risk factors in the shorter operations group compared with longer operations. Indeed, short operations were significantly more likely to be rated as "easy" by the surgeon (p<0.0005). Alternatively, it is possible that hasty surgery is itself responsible for the increased operative risk.

Differences between individual surgeons

We found considerable heterogeneity in use of different techniques by different surgeons. For example, many surgeons did not use EEG monitoring, shunting or patching in any of their patients whilst others used these techniques in all of their patients. Relatively few surgeons used the techniques selectively indicating a tendency for individual surgeons to follow a relatively rigid operating style, rarely altering their techniques according to clinical circumstance, and this is further evidenced by the apparently limited effect of stump pressure on decision to shunt. The fact that the use of techniques was so variable between surgeons illustrates the lack of good evidence as to whether or not they are effective.

Differences between countries

There was great variation in the use of techniques between countries (Fig. 3). Some of the difference appeared to be explicable. For example, surgeons in Germany who tended to shunt almost all their patients used EEG in very few. Whereas surgeons in Italy, who have a tendency to monitor a large proportion of their patients, used shunts in only a small proportion. However, some countries, notably France, had a very low rate of use of any of the ancillary techniques. The variation in use of techniques by country was not the sole explanation for the heterogeneity in practice across the 54 surgeons studied. There was also significant heterogeneity between surgeons' use of techniques at a national level. This wide variation in practice, both on a national and international level, further highlights the lack of evidence for or against the use of any of these techniques.

The effect of surgical and anaesthetic technique on operative risk

The factors determining surgical outcome are likely to be multiple. We found associations (statistically significant for two techniques and approaching significance in the other three) between each of the five ancillary techniques studied and operative risk of stroke and death (Fig. 3). However, there were two obvious causes of confounding. Firstly, there were differences between the patients in which the different techniques were used, and there were significant relationships between the uses of the different techniques in individual patients. Correction for case-mix and for interactions between the techniques reduced the size and statistical significance of each of the apparent associations with operative outcome (Table 3). The only surgical technique that remained significantly associated with operative outcome was intraoperative use of anticoagulants with a doubling in the risk of stroke and death in those patients who were not anticoagulated. The vast majority of ECST surgeons used intraoperative anticoagulation routinely. There is no good evidence from randomised trials that it is
The use of general or local anaesthetic is currently the subject of a large multi-centre randomised controlled trial, and the use of anticoagulation is almost universally accepted by surgeons to be beneficial. The two main ancillary techniques for which data on efficacy are most lacking are shunting and patching. The ECST data and from Cochrane systematic reviews suggest that the effects of these interventions are likely to be moderate, e.g. in the range of a 40% relative risk reduction to a 40% increase in relative risk. In order to give an idea of the size of trials needed to show these effects we performed some power calculations based on these figures. In order to have 80% power to detect a 40% reduction in a control group risk of geographic predictors of stroke and death from carotid en-}

Conclusions

In the ECST, operative risk was more closely related to patient characteristics, length of surgery, and the surgeons’ perception of the difficulty of the operation, than to the use of particular ancillary operative techniques. With the exception of anticoagulation prior to carotid artery cross clamping we found no statistically significant independent associations between the use of ancillary surgical techniques and the operative risk of stroke and death due to carotid endarterectomy. Several operative variables showed univariate associations with surgical outcome but disappeared after correction for confounding by case-mix and use of other surgical techniques. This highlights the importance of treating non-randomised retrospective analysis of surgical results with caution and demonstrates the need for randomised controlled trials. The considerable variation between surgeons, and between countries, in the use of ancillary techniques is in keeping with the lack of convincing data from RCTs. This lack of consensus among surgeons suggests that there should be sufficient uncertainty to make large pragmatic trials possible. However, the lack of major associations with outcome in our non-randomised comparisons suggests that trials will need to recruit several thousand patients to reliably determine differences between policies.

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