Cost of Identifying Patients for Carotid Endarterectomy

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Background and Purpose—The cost of carotid endarterectomy (CEA) usually considers only the cost of the preoperative investigations and the procedure for the individual patient but ignores the cost incurred in selecting a patient from a referred “pool” of potential candidates or the “total direct program cost.” The aim of this study was to estimate the total direct program cost (workup and procedure) of CEA in a large major teaching hospital in Edinburgh, Scotland using a retrospective study design.

Methods—Participants were patients with transient ischemic attacks and mild strokes referred to the neurovascular clinics for assessment, investigation, and possible CEA. The “workup” was defined as the clinical consultation, carotid duplex, 1 follow-up visit, and a catheter angiogram where indicated. We used data routinely collected from the neurovascular clinics during a 1-year period to estimate the workup cost of patients who might be suitable for CEA. The CEA procedure cost was estimated prospectively in a concurrent study. Estimated costs were applied to the proportions assessed at the different levels of investigation to determine the total direct program cost of CEA.

Results—A total of 790 new patients with symptoms suggestive of transient ischemic attacks and mild strokes were identified. Four hundred one (51%) patients were referred for carotid duplex. Duplex identified 78 (10%) with carotid stenosis of ≥70%. Of the total of 790 patients, 26 (3.3%) had catheter angiogram and 18 (2.3%) had CEA. The total direct program cost to investigate this cohort was about £207 000, with 68% (£140 000) of the cost incurred before any surgery was performed.

Conclusion—The cost of identifying suitable patients for carotid surgery is quite high, with more than 30% of the cost attributed to the initial consultation at the neurovascular clinics. The cost of preventing 1 stroke by CEA is in the region of £100 000 at 1997/1998 prices if all the costs incurred in the workup of a cohort for potential CEA are included.

Key Words: carotid endarterectomy • costs • procedure • programs • transition ratio • workup

The cost of carotid endarterectomy (CEA) reported in the literature refers only to the cost of the preoperative investigations and of the surgical procedure for the individual patient.1–22 The cost incurred in “selecting” these patients from the potential “pool” of referred patients has been largely ignored. This pool consists of those experiencing symptoms suggestive of a transient ischemic attack (TIA) or mild stroke within the distribution of the carotid artery. If fit for surgery, the patient is usually referred for a duplex ultrasound investigation and then, depending on the findings, for catheter angiography before CEA. The aim of this study was to estimate the “total direct program cost” of CEA to the UK National Health Service as applied to a cohort of patients with TIA and nondisabling stroke referred to a teaching hospital for assessment and investigation before CEA. The total direct program cost incorporates the cost incurred during the workup of a potential pool of CEA patients, as well as the cost of the CEA procedure itself.

Methods

All costs reported refer to the direct and allocated costs. Direct costs are almost always directly associated with the medical treatment and care of the patient. Allocated costs include all other costs in providing a service to patients, also known as “hotel costs,” and include overhead costs and capital charges. Indirect costs and intangible costs were not investigated. The cost of identifying patients from a cohort of potential candidates who might be suitable candidates for CEA was described as the “workup” cost. The workup for CEA was defined as the assessment at the neurovascular clinics, the duplex examination, the follow-up consultation after duplex, and any catheter angiogram; the cost was estimated in a deterministic manner, also known as a top-down approach.1 The CEA “procedure” was defined as the episode of care in hospital and included the bed days and the theater component. The cost of CEA, the “procedure cost,” was estimated using patient-specific cost data (a bottom-up approach).23,24 prospectively collected in consecutive patients who underwent surgery in the Edinburgh Royal Infirmary and the Southern General Hospital, Glasgow and will be reported elsewhere. Costs were estimated by measuring the quantities of resources used and by assigning them a unit cost.25 Applying the estimated unit cost of a neurovascular consultation, a duplex, a follow-up visit, an angiogram, and the CEA procedure cost to the number of patients at each level of intervention, a total direct program cost for CEA was estimated. Because economic evaluations of health care procedures are costly and cannot always be performed when necessary and in all settings, a sensitivity analysis was performed and the cost estimates obtained in this study were used to address the uncertainty associated with various settings.
The carotid endarterectomy program.

Setting
The total direct program cost of CEA was estimated in a cohort of patients referred to the neurovascular clinics at the Western General Hospital, a large teaching hospital in Edinburgh, for assessment, investigation, and possible CEA. These neurovascular services are typical of many places in the United Kingdom. Patients selected for CEA were referred to the Edinburgh Royal Infirmary, also a large teaching hospital in Edinburgh, for carotid surgery.

Description of the Study Population
The workup cost of CEA was estimated over a 1-year period in a cohort of patients identified from the neurovascular clinics attendance book in conjunction with the Lothian Stroke Register (July 1996–June 1997), a hospital-based stroke register, also at the Western General Hospital.

Defining the Program
The “program” was defined as the workup to CEA and the CEA “procedure” itself (see Figure). Patients referred to the neurovascular clinics with possible TIA or stroke-like symptoms, and clinically assessed as having carotid territory ischemic events, were further investigated with noninvasive duplex imaging. Patients with a duplex finding of stenosis of the symptomatic carotid artery of ≥70% were referred for a catheter angiogram, usually as an inpatient procedure, to determine the degree of stenosis more accurately. Only patients with carotid stenosis of ≥70%, and not having an occluded vessel or any complications associated with angiography, were regarded as suitable candidates for CEA and referred for surgery.

Measurement of the Resource Quantities in the Program
The resource quantities used in the workup for a typical uncomplicated patient who proceeded to CEA included 1 attendance as a new patient at the neurovascular clinic, 1 carotid duplex ultrasound investigation, 1 follow-up consultation after the duplex investigation to inform the patient of the findings, and 1 catheter angiogram before the CEA. Resource quantities used in performing CEA included the resources used for 1 episode of care in hospital for the CEA from admission to discharge as well as the resources used during the follow-up visit at the vascular surgery outpatient department approximately 6 weeks after the procedure and 1 post-CEA duplex investigation performed at that time (manuscript in press).

Assignment of Prices or Unit Costs (1997/1998 Prices)
The average unit cost per new neurovascular attendance was based on the Scottish Health Service Costs 1996/1997. For a 45-minute outpatient consultation, this was £88 based on the arithmetic mean of the cost per neurovascular outpatient attendance at the Western General Hospital. A unit cost for a follow-up consultation of about 20 minutes at the clinic was half the cost of a new neurovascular attendance at £44.

The unit cost of a duplex investigation was estimated at £70. The cost of the duplex ultrasound equipment and consumables was calculated using capital cost of the room, depreciated current value of the machine, overhead costs, annual maintenance, and consumables. The human resource cost per examination included the salary of a full-time Superintendent III radiographer and 30% of a consultant radiologist’s annual remuneration. The estimated overhead cost included electricity, heating, and administration.

The unit cost of a catheter angiogram (selective arterial digital subtraction angiography) was estimated at £950 including overnight hospitalization using the mean estimated bed day cost of £298. The direct cost of equipment and consumables for catheter angiography was calculated from existing sources at the Department of Radiology at the Edinburgh Royal Infirmary. The hourly remuneration for human resources (radiologist, two radiographers, and an auxiliary nurse) was calculated using published pay scales for the medical staff involved and included superannuation and National Insurance. Hospitalization or bed day cost was estimated using the Health Service Cost 1996/1997 of the Information and Statistics Division of the National Health Service in Scotland. A unit cost estimate of other radiological procedures was based on cost estimates from the Departments of Radiology and Directorate of Imaging at the Western General Hospital and the Edinburgh Royal Infirmary.

The unit cost of CEA was estimated at £3716 using patient-specific cost data from a prospective costing study performed at the Edinburgh Royal Infirmary and Southern General Hospital during 1998 (manuscript in press).

Sensitivity Analysis
A deterministic sensitivity analysis was performed using the point estimates of the parameters in the total direct program cost of CEA. A base transition ratio model was constructed using the proportions in the transition from a consultation as a new patient to duplex investigation, to a subsequent follow-up consultation, to a catheter angiogram, and to the carotid surgery. The point estimates were applied to the transition ratio observed in the workup to CEA in this study to estimate the cost incurred at each level. The sensitivity analyses for the total direct program cost, were performed by altering the transition ratio observed in the program, by varying the individual cost parameters in the program, and by substituting catheter angiography with either an additional duplex or a magnetic resonance angiogram (MRA).

Data Management and Analysis
Normal probability plots were used to assess the empirical distributions for evidence of departure from normality. The arithmetic means are reported as a measure of location and 95% confidence intervals of the mean where appropriate. Standard errors are not reported, because although they reflect the precision of the estimated mean, they are not considered suitable to describe cost differentials. All statistical analyses were performed using SPSS for Windows (Professional and Advanced Statistics options), and all the sensitivity analyses were performed using Microsoft Excel version 5.

Results
Baseline Characteristics of the Patient Cohort Investigated to Estimate the Total Direct Program Cost (Workup and Procedure) of CEA
A total of 964 patients were seen at the neurovascular clinics during the 1-year period. Of these, 790 appointments were 30 minutes or longer and were assumed to be first time attendances for new neurological patients. Of 790 first or new consultations at the neurovascular clinics, 660 patients were entered into the Lothian Stroke Register for the study year. Four hundred twelve (52%) of the 790 patients had a carotid...
tory ischemic event and a modified Rankin score of less than 3 (ie, TIA or nondisabling stroke). Of these patients, 401 (97%) had a duplex investigation and 78 had >70% stenosis. Eleven patients did not have a duplex mainly because of subsequent ischemic events before the investigation, which rendered them unsuitable for further investigation for possible CEA. Of the 412 patients having carotid ischemic events, 26 (6.3%) had a catheter angiogram and 18 (4.4%) had a CEA. Of the 52 patients with >70% stenosis “not” having catheter angiography, 16 had documented comorbidities. After careful examination of the remaining 36 patient records, it was not clear why these patients did not have catheter angiography; possible explanations could only be assumed (eg, patient preference, time delay from most recent transient ischemic symptoms to assessment by a consultant to derive any benefit from CEA, etc.). The reasons why 9 patients had a catheter angiogram but did not go on to CEA ranged from stenosis <70% detected on angiography, occlusion of the symptomatic carotid artery, TIA during the angiogram, and patient decision not to proceed with surgery. Considering all the new patients referred to the neurovascular clinic, only 18 (2.3%) of 790 were operated on (Table 1).

**Estimate of the Total Direct Program Cost of CEA**

The total direct program cost of CEA from selecting a patient from a cohort of potential candidates (790) to surgery in a few (18) was estimated at £206 822 (Table 1). £139 934, or 68%, of the total direct program cost was incurred before the actual carotid procedure, ie, in the workup of the many patients who did not go on to surgery.

**Sensitivity Analysis**

Using the proportions of patients from the neurovascular clinic (790), to duplex (401), to angiography (26), to CEA (18), a transition ratio of approximately 50:25:1.5:1 was estimated for this study population. Applying the point cost estimates to this ratio, the cost of the base cohort was estimated. The baseline parameters for the sensitivity analysis are presented in Table 2. To evaluate the effect of any change in clinical practice by selectively performing angiography in the workup to CEA, a 1-way analysis was performed with no catheter angiogram but keeping all other parameters constant, which resulted in a cost reduction of 12%. This was considered unrealistic, because if a catheter angiogram is omitted it should either be replaced by an additional duplex investigation or an MRA, to confirm the original duplex result. A cost reduction of 11% was found for an additional duplex and of 9% for an MRA compared with the base transition ratio model (Table 2). Performing a multiway analysis on the individual cost parameters in the clinical pathway to CEA with a 25% increase in the base case and follow-up consultation cost, a 100% increase in the cost of a duplex investigation but with no angiogram cost and with the cost of a CEA procedure at £3716, the most favorable total direct program cost for CEA was found, a reduction of £847, or 17% (Table 3, b). Repeating the analysis under the same conditions, but increasing the cost of the CEA procedure by 10%, a reduction of 10% (c) was found. Substituting the catheter angiogram by an MRA under similar conditions resulted in a cost reduction of 10% (c) compared with the base cohort. Increasing the cost of the CEA procedure by 10% resulted in a 2.5% decrease in the base case cost (f).

**Discussion**

Studies that investigated both the “workup cost” of identifying symptomatic patients for CEA as well as the “procedure

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**TABLE 1. The Number of Patients at Each Level From the Neurovascular Clinics, to CEA, the Unit Cost (£), Total Cost Per Level of Investigation and the Total Direct Program Cost (Workup and Procedure Cost) of Investigating a Cohort of Patients for CEA (1997/1998 Prices)**

<table>
<thead>
<tr>
<th>Investigation Level</th>
<th>Patients (n)</th>
<th>Unit Cost (£)</th>
<th>Total Cost (£)</th>
<th>Proportion of Total Direct Program Cost (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Neurovascular clinics</td>
<td>790</td>
<td>88</td>
<td>69 520</td>
<td>34</td>
</tr>
<tr>
<td>Carotid ischemic events (TIA/mild stroke)</td>
<td>412 (52%)</td>
<td>...</td>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td>Duplex ultrasound</td>
<td>401 (97%)</td>
<td>70</td>
<td>28 070</td>
<td>14</td>
</tr>
<tr>
<td>Follow-up consultation</td>
<td>401 (97%)</td>
<td>44</td>
<td>17 644</td>
<td>8</td>
</tr>
<tr>
<td>Catheter angiogram</td>
<td>26 (6.3%)</td>
<td>950</td>
<td>24 700</td>
<td>12</td>
</tr>
<tr>
<td>Workup cost</td>
<td></td>
<td></td>
<td>139 934</td>
<td>68</td>
</tr>
<tr>
<td>Procedure cost</td>
<td>18 (4.4%)</td>
<td>3716</td>
<td>66 888</td>
<td>32</td>
</tr>
<tr>
<td>Carotid endarterectomy*</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total direct program cost</td>
<td></td>
<td></td>
<td>206 822</td>
<td>100</td>
</tr>
</tbody>
</table>

CEA indicates carotid endarterectomy; TIA, transient ischemic attack.

*Excluding workup, but including hospitalization and postoperative care.


<table>
<thead>
<tr>
<th>Consultation</th>
<th>Duplex</th>
<th>Follow-up</th>
<th>Confirmatory Imaging</th>
<th>CEA</th>
<th>Cohort cost (£)</th>
<th>Impact</th>
</tr>
</thead>
<tbody>
<tr>
<td>Base ratio</td>
<td>50</td>
<td>25</td>
<td>25</td>
<td>1.5</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Unit cost (£)</td>
<td>88</td>
<td>70</td>
<td>44</td>
<td>950</td>
<td>3716</td>
<td>12 391</td>
</tr>
</tbody>
</table>

All parameters constant in ratio, altering only angiogram

- C C C C
- C C C Duplex C
- C C C MRA C

CEA indicates carotid endarterectomy; C, constant.
The cost of CEA could not be identified in the literature. A number of studies addressed the cost of CEA itself, but the results are not readily transferable to other settings. Only one study, in which the cost of investigating patients before CEA was described, referred to the “program” cost to the National Health Service and concluded that current available data sources are unsatisfactory. Although it would have been ideal to have reported the cost of CEA from our prospective cost analysis study in this article, much of the detail of the cost analysis would have been lost, or it would have resulted in superficial reporting on a very detailed investigation. In fact, the cost estimate obtained in our prospective study was similar to the cost of CEA previously reported elsewhere, and the sensitivity analysis deals with the variation of procedure cost.

We acknowledge the limitations of this study regarding the generalizability to other healthcare settings. An extensive systematic literature review did not identify any previous studies investigating the “total” cost of CEA from workup to procedure. The objective of this study was to quantify the overall cost of CEA and to highlight the associated “hidden” costs of the procedure.

In our study the total direct program cost for CEA for 790 cases was about £207 000, with 68% of the cost accounted for before any carotid surgery was performed. The consultation cost of patients referred for evaluation of cerebral ischemia at the neurovascular clinic contributed 34% of the total direct program cost, making it the highest individual cost component in the program. Duplex investigation and follow-up visits contributed 22% and catheter angiography 12% to the total direct program cost. The actual procedure contributed only about 32% of the overall cost of the program. The main reason for this high proportional cost generated by the consultations at the neurovascular clinics was attributed to the large number of patients referred for evaluation, but with only a small proportion (2.3%) going on to carotid surgery. Many more patients were assessed to identify 1 patient for CEA in this study, than the 1 in 27 patients who were referred for evaluation of cerebral ischemia and were found to be fit for CEA in a US Veterans Affairs study.

It is, however, contentious whether all the cost of assessing patients referred for a specialist consultation should be added to the total direct program cost of CEA because it can be argued that this cost should be borne by the health service anyway. More than 50% of the workup cost was attributed to the initial consultation at the neurovascular clinic, which might indicate that patients were being referred too easily for consultant assessment perhaps and that the “gatekeepers” or primary care physicians need to either refine their diagnostic skills in managing patients with symptoms suggestive of cerebral ischemia or have direct access to carotid ultrasonography because the cost of a duplex investigation is less than specialist consultation. Considering also that only 78 (19%) of the 401 patients referred for duplex investigation were found to have stenosis of 70% or more might present a case for primary healthcare physicians to request duplex ultrasound as a case-finding tool before referring a patient to a consultant.

It might be argued that too many patients had ultrasound and that the clinical assessment of patients should have “prevented” unnecessary referrals for ultrasound. But the cost of an ultrasound investigation is relatively small and it is doubtful whether fewer ultrasound investigations would have resulted in a much lower total direct program cost.

The sensitivity analysis was found to be relatively insensitive to small variations in the individual parameters in the base transition ratio model. Catheter angiography did not contribute much to the overall program cost of CEA, where 1.5 angiographies were performed for every 1 CEA, particularly bearing in mind that if catheter angiography is omitted it is mostly replaced by another duplex or an MRA to confirm the findings from the initial duplex.

Extrapolating from the transition ratio observed in this study, about 50 patients have to be investigated to find 1 patient for CEA. If the total direct program cost of CEA is £11 490 (£206 822/18) per operation, and given that about 9 operations have to be done to prevent one stroke, then the cost per stroke prevented is £103 410 (£11 490×9).

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