Improving the cost-effectiveness of carotid endarterectomy

Martin R. Back, MD, Timothy R. S. Harward, MD,
Thomas S. Huber, MD, PhD, Lori M. Carlton, RN, Timothy C. Flynn, MD,
and James M. Seeger, MD, *Gainesville, Fla.*

Purpose: Carotid endarterectomy (CEA) has been shown to significantly reduce the risk of stroke caused by carotid artery stenosis. Limiting the costs of CEA without increasing the risks will improve the cost-effectiveness of this procedure.
Methods: Results were prospectively collected from 63 consecutive CEAs performed in 60 patients who were entered into a clinical pathway for CEA that included avoidance of cerebral arteriography, preferential use of regional anesthesia, selective use of the intensive care unit (ICU), and early hospital discharge. The mortality rate, complications, hospital costs, and net income in these patients were then compared with results from 45 CEAs performed in 42 consecutive patients immediately before beginning the CEA pathway. Age, comorbid risk factors, incidence of symptoms, and degree of carotid artery stenosis were similar in both patient groups.
Results: The rates of mortality and complications associated with CEA were low (mortality rate, 0%; stroke, 0.9%; transient ischemic attack, 2.8%) and did not vary between the two groups. Implementation of the CEA pathway resulted in significant ($p < 0.001$) reductions in the use of arteriography (74% to 13%), general anesthesia (100% to 24%), ICU use (98% to 30%), and mean hospital length of stay (5.8 days to 2.0 days). These changes resulted in a 41% reduction in mean total hospital cost ($9652 to $5699) and a 124% increase in mean net hospital income ($1804 to $4039) per CEA ($p < 0.01$). For the 39 patients (62%) who achieved all elements of the CEA pathway, the mean hospital length of stay was 1.3 days, the mean hospital cost was $4175, and the mean hospital income was $4327.
Conclusion: Costs associated with CEA can be reduced substantially without increased risk. This makes CEA an extremely cost-effective treatment of carotid disease against which new therapeutic approaches must be measured. (J Vasc Surg 1997;26:456-64.)

Carotid endarterectomy (CEA) is currently the most frequently performed peripheral vascular operation. Although the value of CEA has been questioned in the past, multiple recent trials have shown the benefit of CEA in reducing the risk of stroke as a result of high-grade carotid artery stenosis in both symptomatic[1,2] and asymptomatic[3,4] patients. The findings of these studies will likely greatly expand the number of CEAs performed and thereby significantly increase the number of patients who can derive benefit from CEA. The challenge that now faces vascular surgeons involves minimizing the costs associated with CEA in the current era of limited economic resources while avoiding adverse operative outcomes in an aged population with frequent medical comorbidities.

In the last 10 years, numerous revisions of conventional diagnostic and therapeutic algorithms for patients who require CEA have been implemented.[5-16] Reports that detail these new approaches describe changes in the preoperative assessment of carotid artery stenosis, the influence of anesthetic techniques during CEA, the need for intensive care unit monitoring after CEA, and a reduction in the length of hospitalization. Patient safety has not been compromised by any of these changes, and cost savings as a result of these changes have been implied. However, detailed hospital cost and reimbursement data is lacking in the majority of these studies. In

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Reprint requests: James M. Seeger, MD, Section of Vascular Surgery, University of Florida College of Medicine, PO Box 100286, Gainesville, FL 32610-0286.

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addition, the authors of most of these studies have not used all of these diagnostic and therapeutic modifications in attempting to streamline care and therefore have not fully evaluated the potential optimal management of CEA patients in terms of safety and cost.

In 1994 we developed and implemented a clinical pathway for CEA that included reliance on duplex ultrasound as the primary method of characterization of carotid artery stenosis, preferential use of regional anesthesia, selective use of postoperative intensive care, and attempted early hospital discharge. The frequency of adverse operative events, hospital costs, and net hospital income were collected prospectively in patients treated in this manner. This report compares results from consecutive patients who entered the CEA pathway and a consecutive group of patients who underwent CEA by the same surgeons in the same institution immediately before initiation of the CEA pathway.

METHODS

CEA pathway patients. During the 22-month interval from October 1994 to July 1996, all patients who underwent elective CEA at Shands Hospital at the University of Florida were entered into a CEA clinical pathway and prospectively studied. Only patients who underwent unilateral CEA as the primary procedure were included in the study. Combined procedures that involved coronary, subclavian, or vertebral artery revascularization and urgent operations were excluded. Bilateral CEAs were performed in a staged fashion during separate hospitalizations. Operative candidates included symptomatic patients (hemispheric transient ischemic attacks, amaurosis fugax, mild stroke) with $\geq$70% stenosis of the ipsilateral internal carotid artery and asymptomatic patients with $\geq$80% internal carotid artery stenosis. Assessment of carotid artery stenosis and development of an operative plan was performed using duplex ultrasound scanning alone if possible. Contrast cerebral arteriography was indicated only for inadequate imaging of the carotid bifurcation using duplex ultrasound, possible internal carotid artery occlusion, recurrent stenosis after previous CEA, and suspected diffuse or proximal carotid occlusive disease. Preoperative evaluation included history and physical examination, complete blood count, chemistry panel, coagulation parameters, urine analysis, and electrocardiogram. Further cardiac or pulmonary evaluation was not performed unless recent symptoms suggested exacerbation or significant progression of preexisting disease (e.g., unstable angina, congestive heart failure, or severe chronic obstructive pulmonary disease). After informed consent was obtained at the outpatient preoperative visit, the patient received a verbal and written overview of the CEA pathway and the planned perioperative care.

After same-day admission, patients had indwelling radial artery catheters placed and intravenous antibiotics administered in the preoperative holding area. Regional (cervical block) anesthesia was used preferentially during CEA, and general anesthesia was reserved for patient's who were nervous, restless, or anxious, those with known high carotid bifurcations by preoperative arteriography, those who required redo carotid procedures, and those who refused regional anesthesia. Continuous assessment of the patient's level of consciousness and neurologic status was done by frequent questioning and assessment of the patient's ability to squeeze toy squeakers in both hands when regional anesthesia was used. Intraoperative electroencephalograph (EEG) monitoring was used rarely according to the preference of the attending anesthesiologist. CEA was performed using standard surgical techniques, and temporary carotid shunts were placed only for adverse neurologic changes. Patch angioplasty of the carotid closure was liberally applied, with decreasing use of saphenous vein and increasing use of the Dacron Hemashield patch (Meadox Medical Inc, Oakland, N.J.) during the series.

Patients were closely monitored in the postanesthetic care unit (PACU) for 2 to 6 hours after surgery. No laboratory tests were obtained after surgery unless warranted by severe preexisting medical conditions or adverse intraoperative events. If the patient's neurologic, cardiac, and pulmonary status had not been compromised, significant cervical hematoma did not evolve, and blood pressure was stable or easily controlled without continuous infusions of vasoactive agents, direct transfer to the surgical floor was done at the end of this time period. Direct admission to the surgical intensive care unit (SICU) from the operating room was done for significant intraoperative hemodynamic instability or intraoperative complications (e.g., myocardial ischemia, ischemic neurologic event). Transfer from the PACU to the SICU was done when blood pressure instability was not easily controlled using oral medications or when significant complications (e.g., cervical hematoma requiring drainage) developed. After transfer to the surgical ward, neurologic checks were performed every 2 hours for 8 hours and then every 4 hours, and vital signs were monitored every 4 hours by the ward personnel. Patients were discharged home on the first postoperative day if no neurologic, cardiac, pulmonary, or wound problem developed, blood pressure was well controlled, significant headache was not present, and they were able to eat, void, and ambulate. Clinic visits were scheduled for 1 week and 1 to 3 months after surgery.

Pre-CEA pathway patients. Before instituting the CEA pathway, patients were treated in a standard manner, as well. Duplex ultrasound scanning was used to initially determine the degree of carotid disease present in patients who were being considered for CEA, and this assessment was confirmed by contrast cerebral arteriography unless that study was contraindicated (contrast allergy, no vascular access, patient refusal). The clinical management plan was then based on results of both of these studies. Comparison of results of these two imaging studies was also used to confirm the accuracy of duplex ultrasound carotid imaging in the Vascular Diagnostic Laboratory. General anesthesia was used routinely, shunting was performed in all patients, and EEG monitoring was used whenever possible. Patients were monitored in the SICU for at least 24 hours after CEA and were then observed on the surgical ward for approximately 4 days before discharge. After hospital discharge, follow-up was the same as for patients entered into the CEA pathway.

Data collection and statistical analysis. Data describing patient demographics, neurologic symptoms, comorbid medical conditions, preoperative carotid assessment, anesthetic route, operative technical maneuvers, postoperative management, length of hospitalization, complications and deaths within 30 days of operation, and hospital costs and income were collected. Hospital costs and reimbursement associated with each patient who underwent CEA were obtained from the Office of Clinical Resource Management, Shands Hospital at the University of Florida. Direct variable and total hospital costs and hospital reimbursement were provided for each patient, allowing calculation of net hospital income (hospital reimbursement – total hospital costs). Direct variable costs represent the savings to the institution for each instance that a specific resource is not used, whereas total cost reflects all costs that are incurred on each resource use as well as fixed costs associated with the site of use, such as the operating room and its personnel. Fixed costs are equally distributed over all patients who use a specific hospital resource. Hospital patient charges were not used, as these represent the highest level mix of local and distant institutional costs shifted among sites that generate revenues and losses.

Data collected for patients in the CEA pathway were compared with data from a similar consecutive patient cohort of patients who underwent CEA in the 33 months before implementation of the pathway (January 1992 to October 1994). Statistical analysis between CEA pathway and prepathway groups and within groups was performed with unpaired t tests for continuous variables that have an assumed normal distribution. For nonparametric distributions, χ^2 analysis was used for nominal measures and Mann-Whitney rank sum tests for ordinal variables. Statistical significance was defined as a p value less than 0.05. Data are presented as mean ± standard deviation where appropriate.

RESULTS

Sixty-three CEA procedures were performed in 60 consecutive patients using the CEA pathway. Forty-five CEAs were performed in 42 consecutive patients in the 33 months preceding implementation of the CEA pathway. Three patients in each group underwent staged, bilateral CEAs during separate hospitalizations. Fifty-one CEA procedures (47%) were performed in 51 patients for neurologic symptoms, including recent transient ischemic attacks or amaurosis fugax in 40 patients and recent reversible ischemic neurologic deficits or documented strokes in 11. Fifty-seven CEA procedures (53%) were performed in 51 patients (six bilateral staged CEAs) for asymptomatic, high-grade (>80%) carotid artery stenosis. The mean age of all patients who underwent CEA was 69 years (range, 50 to 90 years). Preoperative hypertension was present in 63 patients, significant coronary artery disease in 50, and congestive heart failure in 13. Eighty-three patients were current or prior tobacco users, and 10 had chronic obstructive pulmonary disease. A previous CEA procedure had been performed in 20 patients (five ipsilateral and 15 contralateral). Age distribution, presence of comorbid risk factors, incidence of neurologic symptoms and previous CEA, and degree of carotid artery stenosis did not differ statistically between the CEA pathway and prepathway patient groups ($p > 0.05$; Table I).

No perioperative deaths occurred. The overall adverse neurologic event rate was 3.7%, with one probable stroke (0.9%) and three transient ischemic attacks (2.8%). Temporary cranial nerve injuries occurred in six cases (5.6%), cervical hematomas that required operative evacuation in three cases (2.8%), and cervical wound infections in four cases (3.7%). All cranial nerve deficits were transient and were manifested by hoarseness in three cases of presumed

Table I. Demographic data and neurologic symptoms between CEA groups

	CEA pathway (n = 60)	*Prepathway (n = 42)*
Mean age (yr)	68.9	69.3
Hypertension	63%	60%
Tobacco use	79%	84%
Coronary artery disease	50%	48%
Congestive heart failure	12%	14%
Chronic obstructive pulmonary disease	12%	7%
Overall symptomatic	46%	49%
Previous stroke	13%	7%
TIA/amaurosis fugax	33%	42%
Previous CEA	16%	22%
Mean % stenosis by duplex	82%	79%

vagal injury, marginal mandibular nerve palsies in two cases, and difficult deglutition in one case of hypoglossal injury. One cranial nerve injury occurred during CEA in one of the five patients who was undergoing a redo ipsilateral procedure. Other complications included three saphenous vein harvest wound infections, two cases of perioperative cardiac ischemia, one myocardial infarction (which occurred 1 week after discharge home), and single instances of postoperative syncope, urinary retention, and corneal abrasion. All cervical and vein harvest site wound infections were superficial but required a course of antibiotics, and several required open packing. Only the CEA patient who had a myocardial infarction after discharge home required readmission within 30 days for complications related to CEA. The rates of adverse neurologic events, cranial nerve injury, wound complications, and other complications were similar between pathway and prepathway patient groups ($p > 0.05$; Table II).

Duplex ultrasound scanning provided adequate preoperative assessment of the degree of carotid artery stenosis in 52 of 60 CEA pathway patients (87%). Cerebral contrast arteriograms were obtained for the remaining eight pathway patients for inadequate imaging at the carotid bifurcation in four patients, possible internal artery occlusion in two, and recurrent stenosis and previous proximal common carotid artery reconstruction in one each. In contrast, 31 of 42 patients (74%) who underwent CEA before institution of the CEA pathway underwent preoperative cerebral contrast arteriography ($p < 0.001$).

CEA was performed with the patient under regional anesthesia in 48 pathway cases, whereas 15 procedures were performed with the patient under general anesthesia, including two procedures in which regional anesthesia was converted to general

Table II. Adverse outcomes after CEA

	CEA pathway (n = 63)	*Prepathway (n = 45)*
Stroke	1 (1.6%)	0 (0%)
Transient ischemic attack	2 (3.2%)	1 (2.2%)
Cranial nerve injury	4 (6.4%)	2 (4.4%)
Cervical hematoma	3 (4.8%)	0 (0%)
Wound infection	2 (3.2%)	2 (4.4%)
Other complications	6 (9.6%)	3 (6.6%)

Table III. Operative management of CEA groups

	CEA pathway (n = 63)	*Prepathway (n = 45)*
Regional anesthesia use	76%	0%*
Carotid shunting	29%	100%*
EEG monitoring	21%	82%*
Patch closure	65%	89%*

*Significant difference at $p < 0.01$.

anesthesia during the procedure because of an inadequate block (Table III). The indications for general anesthesia in the remaining 13 patients were patient preference in 11, a high lesion at the level of the second cervical vertebra in one, and a redo carotid procedure in one. The average times of operating room use for CEA pathway procedures performed with the patient under regional and general anesthesia were identical (4.2 hours). Eighteen pathway patients required temporary carotid shunting, and 13 had EEG monitoring. However, shunting was necessary for altered neurologic status in only three of 48 procedures performed with the patient under regional anesthetic. Shunts were placed during the remaining 15 procedures because of surgeon preference in patients who undergo CEA under general anesthesia. Similarly, EEG monitoring was only performed in the 13 pathway patients in whom general anesthesia was planned. All patients who underwent CEA before the CEA pathway underwent the operation with general anesthesia and temporary carotid shunting, and 37 had EEG monitoring. Patch closure of the carotid artery was performed less frequently in pathway cases than in prepathway cases.

SICU monitoring/management was necessary after 19 CEAs (30%) performed after the institution of the CEA pathway (Table IV). PACU monitoring (for an average of 5.2 hours) was done after the remaining 44 cases. Thirteen of 15 patients who underwent CEA under general anesthesia were admitted to the SICU, compared with six of 48 patients

Table IV. Indications for ICU admission in CEA pathway patients

	No. of patients
Surgeon preference	4
Preoperative comorbid conditions	4
Cardiac ischemia	3
Dysrhythmias	3
Cervical hematoma	2
Hypertension requiring intravenous infusions	1
Hoarseness/airway compromise	1
Altered mental status	1
Total	19

Table V. Hospital costs and reimbursement associated with CEA

	CEA pathway (n = 63)	*Prepathway (n = 45)*
Direct variable cost ($)	2415 ± 2616	4147 ± 1311*
Total hospital cost ($)	5699 ± 5673	9652 ± 3153*
Net reimbursement ($)	9739 ± 4151	11,456 ± 4072*
Net hospital income ($)	4039 ± 3946	1804 ± 4143*

*Significant difference at $p < 0.05$.

who underwent CEA with regional anesthesia ($p < 0.001$). Admission to the SICU was directly from the operating room in 16 cases, and problems developed in the PACU that required subsequent SICU monitoring in three cases (two neck hematomas, one of which required operative drainage, and one episode of cardiac ischemia). No CEA pathway patients required admission to the SICU after discharge from the PACU to the surgical floor. SICU monitoring was done in 43 of 44 prepathway cases (98%; $p < 0.001$). The length of observation in the SICU was for 1 day or less in 18 of 19 pathway cases (95%) and 37 of 43 (86%) prepathway cases.

The mean hospital length of stay was 1.98 ± 2.39 days in the CEA pathway group compared with 5.78 ± 3.65 days in the prepathway group ($p < 0.001$). Admission before CEA for preoperative evaluation, cerebral arteriography, or both (range, 1 to 6 days; mean, 1.7 days) and longer postoperative observation both contributed to a longer length of stay in the prepathway patients. Fifty-two percent of pathway patients were discharged home on the first postoperative day, and 83% were discharged by the second postoperative day. In contrast, only three of the patients treated before beginning the CEA pathway were discharged home by the second postoperative day. Postoperative complications were the primary determinant of length of stay in CEA pathway patients, in whom complications occurred before discharge in only 7.7% of patients discharged by the second postoperative day compared with 73% of those discharged after the second postoperative day. The type of anesthesia used in pathway patients appeared to strongly influence the incidence of complications, with the complication rate in pathway patients who underwent CEA with regional anesthesia being 12.5% (six adverse events in 48 patients) compared with 53.3% (eight events in 15 patients) in those who underwent CEA under general anesthesia ($p < 0.01$).

Both mean direct variable costs and mean total costs were higher for prepathway CEA patients compared with CEA pathway patients (Table V). Net hospital reimbursement was also greater for the prepathway group compared with the CEA pathway group, and this could not be attributed to varying contributions from different primary payers because Medicare was the primary payor for the majority of patients in this study. However, the higher reimbursement for prepathway patients was not sufficient to offset higher direct variable and total hospital costs, so that mean net hospital income (difference between net reimbursement and total cost) was greater for CEA pathway patients than for prepathway patients ($p < 0.01$). Cost reductions were achieved primarily by use of duplex ultrasound imaging (average total cost, $164) rather than cerebral contrast arteriography (average total cost, $2099) for preoperative carotid imaging, by use of the PACU (average total cost, $483 for 5.2 hours) rather than the SICU (average total cost, $1035 for 1 to 24 hours) for initial postoperative monitoring, and by early discharge from the hospital (the average total cost for 1 postoperative day of care in uncomplicated pathway patients was $181 versus $2079 for the average total costs for 5 postoperative days of care in uncomplicated prepathway patients). The large disparity between average total costs for postoperative days of pathway and prepathway patients is a result of the high costs of ICU care extending into the first postoperative day and the additional days of observation on the surgical ward in prepathway patients and the minimal costs occurring on the first postoperative day when more than half of the pathway patients went home. Operating room total costs were not different between patients who underwent CEA with either regional or general anesthesia. However, successful regional anesthesia in pathway patients eliminated the need for EEG monitoring, resulting in an average additional savings of $701 in total costs. Total hospital cost was lowest (mean, $4175) and net hospital income was highest (mean, $4327) for patients who achieved all of the goals of the pathway (avoidance of contrast arteriography, use of regional anesthesia, direct transfer to the surgical ward from the PACU, and early hospital discharge). Furthermore, compared with prepathway values, the total hospital cost was also lower (mean, $8185) and the net hospital income was also higher (mean, $3582) for patients entered into the pathway who only partially achieved these goals.

DISCUSSION

This study demonstrates that the introduction of a critical pathway for patients who undergo CEA for both symptomatic and asymptomatic carotid disease can lead to significant cost reductions without affecting the risk of the procedure. Similar to the approach advocated by Collier,[5] this pathway consisted of preoperative carotid evaluation using only duplex ultrasound, hospital admission the day of CEA, use of regional anesthesia, postoperative monitoring in the recovery room, and discharge home within 24 hours whenever possible. Dawson et al.[6] have reported that a technically adequate carotid duplex ultrasound provides sufficient information for the development of an accurate preoperative plan in 98% of CEA cases, and Golledge et al.[7] and Shifrin et al.[8] have shown that additional information from cerebral contrast arteriograms modifies the care of patients who undergo CEA at most 1% of the time. In addition, the majority of changes in care based on information obtained from the cerebral arteriogram could be made on the basis of operative findings, as well. Corson et al.[9] have reported that CEA performed with the patient under regional anesthesia is associated with less postoperative hypertension than CEA performed with the patient under general anesthesia, and Allen et al.[10] found fewer cardiopulmonary complications after CEA using regional anesthesia compared with general anesthesia, similar to the results reported here. O'Brien et al.,[11] McGrath et al.,[12] and Morasch et al.[13] have shown that only 18%, 18%, and 21%, respectively, of patients who undergo CEA require ICU care, and that subsequent problems that necessitate ICU care rarely develop in patients who are neurologically and hemodynamically stable in the recovery room for 2 to 4 hours. Finally, Collier[5] and Hoyle et al.[14] have shown that early hospital discharge after CEA is safe and that few patients will have problems that require readmission. Acceptable perioperative morbidity and mortality rates have been maintained in all of these reports when these modifications of conventional diagnostic and therapeutic algorithms for CEA have been used. The study presented here demonstrates that low morbidity and mortality rates (combined stroke and death rate of 1.6%) can be achieved when these modifications are combined.

Because the morbidity and mortality rates associated with conventional treatment algorithms for patients who undergo CEA are low, a primary motivation in investigating these modifications of CEA has been reducing the costs associated with the procedure. Hoyle et al.[14] reported a 29% cost reduction for CEA with the introduction of a case management protocol for cerebral revascularization that consisted of CEA performed with the patient under general anesthesia, observation in the recovery room for 3 hours, intensive monitoring on the surgical ward by specially trained nurses, and discharge on the second postoperative day. Similarly, Hirko et al.[15] demonstrated a 32% decrease in hospital charges between 1990 and 1994 as cerebral contrast arteriography use, SICU use, and hospital length of stay associated with CEA decreased. Kraiss et al.[16] reported a more substantial 47% reduction of hospital charges associated with CEA with the use of a streamlined protocol that eliminated routine cerebral arteriography, used regional anesthesia, and limited SICU monitoring to high risk patients. However, only 18 patients who underwent CEA using this streamlined protocol were studied.

The CEA pathway used in the current study is similar to the streamlined protocol used by Kraiss et al.,[16] and the 41% reduction in total hospital costs and 41.8% reduction in direct variable costs are similar to the 47% reduction in hospital charges reported by those authors. These findings in a larger group of patients further demonstrate the success of this aggressive approach to reducing the costs associated with CEA. In addition, the results presented here may more accurately reflect the impact of these modifications in patient care on costs associated with CEA as direct variable costs and total hospital costs rather than hospital charges (which are subject to more variability) were used. Limiting use of routine preoperative cerebral contrast arteriography, SICU monitoring, and postoperative observation on the surgical ward each resulted in direct cost reductions. In contrast, use of regional anesthesia was associated with the same direct variable and total operating room costs as general anesthesia. However, use of regional anesthesia resulted in direct cost savings from decreased use of EEG monitoring and indirect savings from decreased ICU monitoring and risk of postoperative complications compared with general anesthesia. The incidence of complications occurring in pathway patients who underwent CEA under general anesthesia was high compared with our prepathway patients and the series of others that describe CEA performed with the patient under a general anesthetic but could not be accounted for by differences in comorbid factors or neurologic symptoms. Any conclusions drawn from this observation must be tempered by the small numbers of patients in this group and the absence of a randomized protocol for comparing the types of anesthesia used in our study. Regardless, the significant increase in net hospital profit confirms the pathway's value in improving the cost effectiveness of CEA.

Publication of the results from large multicenter trials of treatment of symptomatic[1,2] and asymptomatic[3,4] patients with significant carotid atherosclerosis has led to increased use of CEA in patients with carotid artery disease.[17] The estimated cost of this increased use in the state of Florida may be as high as $50 million annually.[18] Therefore, with the continuing efforts to limit the economic resources devoted to medical care, it is imperative for CEA to be made as cost-effective as possible so that this highly effective procedure for stroke prevention will remain widely available. In addition, carotid balloon angioplasty and stenting are currently being investigated as an alternative to CEA in the treatment of significant carotid atherosclerosis, and one of the proposed potential benefits of carotid balloon angioplasty is a reduction in the cost of therapy.[19] Initial use of this procedure in our institution has been associated with direct variable costs that range from $2400 to $5200 and total costs that range from $5800 to $11,400. Although these costs will likely diminish as carotid angioplasty and stent placement procedures are refined, at least at present it does not appear that carotid balloon angioplasty and stenting will be significantly less costly than CEA performed in a cost-effective manner. Comparison of balloon angioplasty with stenting and standard CEA for the treatment of significant carotid disease can therefore be based on the clinical effectiveness and risks of each procedure, as their costs appear to be similar.

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DISCUSSION

Dr. William H. Edwards, Sr. (Nashville, Tenn.). I want to congratulate Dr. Back on his presentation and the Florida group for bringing this very timely topic to us. By creating a pathway for patients with cerebral occlusive disease, they have initiated a study that has supported the fact the quality of care is not impaired by cost resource use. They now have undertaken the difficult task of standardizing surgical care in one specific area, carotid endarterectomy. We began a similar process at St. Thomas in 1991 in which we looked only at the length of stay in the intensive care unit and hospital length of stay. The report this morning, of course, extends this to the type of anesthetic used as well as preoperative angiography. This study confirms our findings, which showed a decreased length of stay in both the intensive care unit and hospital and a mean savings to the hospital of about $2000 per patient. Intuitively, the site of convalescence after CEA probably should have no effect on the morbidity or mortality rate. This was the case in their 60 patients on the pathway when compared with the comparable group of 42 patients who underwent operation before the institution of the pathway. By the same token, shortened hospital length of stay should have no effect on the morbidity or mortality rate. All of us who perform CEAs know full well that if the patient is neurologically intact with no hematoma 8 to 24 hours after the operation that there is probably not going to be a serious stroke or a hemorrhage. Whether or not we agree, it is time to step back and evaluate the use of resources in patients who need CEA and, for that matter, any other vascular or other surgical procedure.

None of us question the efficacy of CEA. We now need to critically evaluate our use of resources. Dr. Back's group has included angiography in their evaluation. I think this is very important. Angiography, of course, has been the standard against which noninvasive studies have been judged for many years, and this was pointed out this morning. When a diagnostic procedure, however, carries a risk of stroke, as well as the complications of the contrast medium, it is time to seriously reassess its role. The early reports, which relied on duplex scans alone, were begun to reduce these risks, and probably the first report was by Bill Blackshear some 14 years ago. Bill was a member of this organization. In the study by Dr. Back and his colleagues, they reduced the use of angiography from 74% to 13%. The need for resource use gives us added incentives to reevaluate some of these preconceived and previous concepts. Much has been said and written about pathways, best practice patterns, and practice guidelines. To many, it is perceived as an intrusion on the surgeon and the management of their patients. This notwithstanding, it is an efficient, effective technique in the management of particular surgical procedures such as CEA but can also be extended to all vascular procedures or all other surgical procedures. When we initiated case management, we believed that it was essential to involve all the personal who were going to be involved in patient care. We clearly explained to the patient that they would be able to leave the hospital much sooner than they had in the past or that was the usual case and that they would probably not spend any time in an intensive care unit but would return to their room to be with their families overnight. They liked this and were very accepting of the concept.

I would ask Dr. Back, did you find the same thing? Because in the manuscript you detailed the fact that you talked to the patients to explain to them exactly what was going on. You reported a wound infection rate, however, of two cases in each series. It seemed a little bit high. In the manuscript, you do not describe the antibiotic regimen. I wonder whether you might tell us what it was. Before the pathways, you were patching 89% and shunting 100% of patients. In the pathway group, the use of patches decreased to 65%, and most patches were Dacron as he has stated in his manuscript. Before that time, they were using saphenous vein. The use of shunts also decreased. Was there any relationship between this decreased use of shunts and the change in the percentage of patching? Dr. Back points out in his manuscript that the interventionalists are eagerly awaiting the opportunity to capture the care of the patient, meaning a CEA. It is essential that we all work very diligently to continue to lower the cost of CEA without impairing quality.

Dr. Martin R. Back. Thank you, Dr. Edwards, for your insightful overview and questions. The first question pertains to preoperative patient education. All patients, when seen in the vascular surgery clinic, were given a verbal and a written overview of the planned pathway and their perioperative care, and any questions were initially answered at that time. The second question pertained to antibiotic regimen. All patients received a single dose of a first-generation cephalosporin before their operation. No postoperative antibiotics were used, and that was independent of the use of patch closure. The final question regarded the use of shunts and patch closures. Patch closure, although widely used at our institution, was performed less frequently after the implementation of the pathway because of a change in preference of one of the attending surgeons. The decreased use of shunts during the pathway occurred because most procedures were performed with the patient under regional anesthesia, where neurologic status could be continuously monitored. The trends in shunt use and path closure were not directly related.

Dr. John A. Mannick (Boston, Mass.). I am a little concerned about leaving the audience with the impression that general anesthesia is automatically followed by a stay in an ICU after carotid endarterectomy. I don't really think, in spite of your data, that is likely to be the case at most hospitals. Certainly, in our own unit, we have used general anesthesia in 100% of CEA procedures for years, and I cannot remember the last time we sent one of those patients to the ICU after the operation.

Dr. Back. Only a small number of patients in the pathway received a general anesthetic, so any conclusions drawn from their analysis must be tempered. In this group, however, we observed more frequent use of the ICU after the operation mainly as a result of a higher rate of complications than for patients receiving regional anesthesia.

Dr. John S. Kirkland (Rome, Ga.). I enjoyed your paper. We have recently looked at some of the same issues you have raised. In 1993 we were having an angiographic use rate of about 70%. The incidence of ICU stay was about 50%, and the mean length of stay was around 7 days. In 1996, using an approach similar to yours, our rate of angiographic use is less than 30%, and the ICU is used in less than 10% of cases. We do use 100% general anesthesia. The mean length of stay in the most recently reported period through 1996 was 1.8 days, and the hospital cost was $4284. This is in approximately 300 patients. It is certainly possible to achieve a very limited use of the ICU and still use general anesthesia. I am likewise a bit concerned about the number of complications in your general anesthetic patients. Do you think that is because you selected the sicker patients for general anesthesia, or is there some other factor?

Dr. Back. In the review of our data, we were unable to find a higher incidence of medical comorbidities or neurologic symptoms in the pathway patients who received general anesthesia to help explain the higher complication rate in this group.