Carotid Endarterectomy Trends in the Patterns and Outcomes of Care at Academic Medical Centers, 1990 Through 1995

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**Objective:** To evaluate whether the patterns of inpatient care and patient characteristics have changed for patients undergoing a carotid endarterectomy across a group of academic medical centers from 1990 through 1995. If changes occurred, we investigated whether they had an impact on patient outcomes.

**Design:** Retrospective evaluation of patients undergoing a carotid endarterectomy using a hospital discharge data set compiled by the Academic Medical Center Consortium.

**Setting:** Ten academic medical centers.

**Patients:** A total of 7019 hospital admissions for patients who had 1 carotid endarterectomy performed as a principal procedure from January 1990 to December 1995.

**Main Outcome Measures:** Trends in patient demographics, comorbidities, length of stay, days in the intensive care unit, and inpatient cerebral arteriogram use were determined. Patient outcomes included inpatient mortality, discharge to an institution, 30-day readmission rate, and selected diagnoses (postoperative hemorrhage, infection, or seizure; acute myocardial infarction; or cranial nerve palsy) and postprocedure diagnostic tests (computed tomography and magnetic resonance imaging of the head and electroencephalogram) indicative of complications.

**Results:** Over the 6-year study period, the number of carotid endarterectomies performed more than doubled and the percentage of hospital admissions for patients 65 years or older increased from 65% to 75%. The mean and median length of stay halved and the percentage of admissions with transfers to the intensive care unit decreased from 56% to 26% of cases. In addition, the percentage of cases with a cerebral arteriogram during the same admission but prior to the day of the carotid endarterectomy decreased from 52% to 27%. There were no trends in inpatient mortality, discharge to an institution, or 30-day readmission rate. There were no significant trends indicative of poorer quality of care as measured by the frequency of secondary diagnoses or postprocedure diagnostic test use.

**Conclusions:** Despite dramatic changes that have occurred in patient characteristics and in hospital management practices for patients undergoing a carotid endarterectomy from 1990 to 1995, we were unable to detect any measurable impact on patient outcomes. These data have implications for monitoring and evaluating the impact of systemwide change on the overall quality of care for patients undergoing a carotid endarterectomy.

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**CAROTID ENDARTERECTOMY (CEA)** is a common inpatient surgical procedure performed to prevent stroke in selected patients with high-grade atherosclerotic occlusive disease of 1 or both carotid arteries. In 1992 and 1993, approximately 90,000 CEAs were performed in the United States. The first half of the 1990s saw revolutionary changes for patients undergoing a CEA. These changes have affected several aspects of patient care, including the diagnostic evaluation and management of patients. Little is known, however, about the extent and impact of these changes on patient outcomes.

Therapeutically, unprecedented achievement occurred in 1991 when 2 landmark randomized controlled trials were published that showed unequivocal benefit of CEA in symptomatic patients with high-grade carotid stenosis (70%-99%). In 1993 and 1995, 2 additional studies were published that documented the potential beneficial effects of CEA in asymptomatic patients with carotid artery stenosis. These trial results provide a solid foundation of medical evidence, but we know little about how this evidence has influenced the practicing physicians’ decisions to recommend and perform the procedure.

Diagnostically, the conceptual foundation underlying the evaluation of pa-
DATA AND METHODS

DATA SOURCE

This study was performed using a data set compiled by the Academic Medical Center Consortium (AMCC). The AMCC was created in 1989 with the stated mission of improving health care through multi-institutional, collaborative health services research. The AMCC compiled a comparative data set from its member institutions beginning with hospital discharges during the 1990 calendar year. The data were collected in an augmented version of the Unified Hospital Discharge Data Set (UHDDS specifications), which was developed for statewide reporting requirements. This data set contains all hospital discharges from its member institutions for 6 years representing the calendar years 1990 through 1995. (A complete list of AMCC members participating in this study is given in the acknowledgments.)

For each hospital discharge, the data set contains demographic, clinical, and administrative variables. Demographic variables include age, sex, race, and insurance status. Clinical variables include the International Classification of Diseases, Ninth Revision, Clinical Modification (ICD-9-CM) coded principal diagnosis and principal procedure and up to 14 secondary diagnoses and procedures for years 1990 through 1992, and 20 secondary diagnoses and procedures for years 1993 through 1995, all with the associated procedure dates. Administrative variables include LOS, ICU days, and discharge disposition.

STUDY GROUP SELECTION AND CLASSIFICATION

The study sample was drawn from data obtained from 10 AMCC member institutions for the years 1990 to 1995. From these institutions, we selected all hospital discharges for patients aged 18 years and older with an ICD-9-CM procedure code of 38.12, either as a principal or a secondary procedure. This ICD-9-CM code represents an endarterectomy of nonintracranial vessels of the head and neck. A total of 7918 CEAs were performed in these institutions during the 6-year study period. We excluded 766 hospital discharges whose CEA was coded as a secondary procedure because, in more than 65% of these cases, the principal procedure was either an aortocoronary bypass or other peripheral vessel bypass procedure.

Of the remaining 7152 cases that had a CEA coded as a principal procedure, we excluded an additional 133 patients who had more than 1 CEA coded per admission. Performing 2 CEAs in 1 admission is rare and is performed in patients with unusual or precarious cerebrovascular disease. The remaining 7019 hospital discharges had 1 CEA coded per discharge in the principal procedure field. All analyses were performed on this group of patients.

ESTABLISHING THE COMPARABILITY OF CEA COHORTS OVER TIME

We compared age, sex, ethnicity, and primary reimbursement status across study years. We also compared across years the frequencies of 5 comorbid conditions identified on the discharge abstracts: hypertension, congestive heart failure, diabetes mellitus, chronic obstructive pulmonary disease, and valvular heart disease. Finally, we examined the annual change in Charlson Index Scores as adapted by Deyo et al for use with ICD-9-CM administrative databases. This index represents the sum of selected chronic conditions (reported as secondary diagnoses) associated with poor outcomes.

DEFINING THE CHANGING PROCESS OF INPATIENT CARE

We examined the yearly trend of several measures indicative of changing inpatient management styles, including changes in total LOS, as well as the changes in the LOS before patients with carotid artery disease is changing. The development and refinement of reliable noninvasive diagnostic tests has raised questions about the need for a conventional cerebral arteriogram before the procedure. As a result, some vascular surgeons and neurologists are proceeding to a CEA based on the results of either a carotid ultrasound or a magnetic resonance (MR) angiogram. Evidence for the uncoupling of carotid arteriography and CEA was seen as the rate of CEA rose in 1992 against the background of a steadily declining arteriography rate from 1985 to 1993.1

Last, and arguably most dramatically, there have been health care systemwide changes that have influenced how physicians, and the hospitals in which they practice, manage patients undergoing a CEA. Consistent with the incentives of managed care and capitated health care delivery systems, the underlying theme driving these changes has been to seek ways of providing health services more efficiently. Most studies exploring this issue have focused on limiting hospital resource use and have been retrospective case series from either single community hospitals or academic medical centers (AMCs).

For example, some studies have successfully limited hospital resource use by admitting patients the same day or 1 day prior to the scheduled procedure. Others have curtailed resource use by limiting postoperative intensive care services to selected high-risk patients. Others have realized potential savings by using case management, using regional rather than general anesthesia, or instituting hospital clinical pathway protocols. For several reasons, it is important to evaluate the impact of the new medical evidence and the changing markets on patient outcomes. Clinical practice may be strongly influenced by the mere publication of a few large, well-designed randomized controlled trials. Clinical practice may be influenced as much, if not more, by administrative and economic incentives and constraints. Depending on the extent of these influences, there exists a need to monitor such change, particularly if quality of care may be compromised. This is particularly relevant if large-scale reductions are occurring in hospital resource use given the low margin of error in performing a CEA procedure. Recent guidelines have highlighted the importance of attaining a 30-day postoperative complication rate of less than 6% for symptomatic patients and less than
and after the procedure. We also examined the frequency of cases admitted to the ICU and the frequency of inpatient cerebral arteriography. For those cases having an inpatient cerebral arteriogram, we evaluated the yearly trends of the frequency of having 1 arteriogram per admission, as well as the frequency of having 2 arteriograms per admission. Finally, we analyzed the frequency of arteriograms by the timing of the CEA: occurring before the CEA, occurring the day of the CEA, and occurring after the CEA. Analyses of the frequency of ICU admission used data from only 7 of the 10 institutions, because 3 of the institutions did not systematically collect data for this variable.

DEFINING PATIENT OUTCOMES

We analyzed by year a variety of database-derived patient outcomes that are commonly used in drawing inferences about hospital quality of care: inpatient mortality, discharge to an institution (skilled nursing facility or other acute care facility with an acute rehabilitation unit), and 30-day same-institution readmission rate. In addition, we measured several proxies for postoperative complications that were defined in several ways. First, a postoperative complication was defined as use of a selected diagnostic test after the day of surgery. Specifically, the frequencies of the following coded secondary procedures were examined: (1) head computed tomogram (CT) or MR, and (2) an electroencephalogram. Procedures occurring on the day of the CEA were excluded because it is impossible to distinguish if the procedure was performed preoperatively, perioperatively, or postoperatively. Therefore, the reported frequencies of postoperative complications are likely underestimates of the true frequencies. Second, the annual frequency of the following secondary diagnoses that may indicate a complication were examined: (1) hemorrhage or hematoma complicating a surgical procedure, (2) acute myocardial infarction, (3) postoperative seizure, (4) cranial nerve disorders (facial, accessory, or hypoglossal nerves), and (5) postoperative infection. Many of these complications are self-explanatory. Several cranial nerve disorders that are known complications of the surgical dissection were combined. Acute myocardial infarction was included as a complication because it would be rare for a surgeon to perform a CEA in a patient known to be having an acute myocardial infarction; therefore, its presence would most likely indicate a postoperative event. We were unable, however, to reliably capture the frequency of postoperative strokes because a diagnostic code indicative of stroke could represent either a preoperative or postoperative event.

STATISTICAL ANALYSIS

Multiple regression analyses were used to assess the significance of trends over time for variables of interest. Ordinary linear regression was used to analyze continuous dependent variables and logistic regression was used to analyze dichotomous dependent variables. Year was treated as a continuous independent variable in the models, and the significance of its regression coefficient indicated a trend over time in the dependent variable. Length-of-stay data were log-transformed for the purposes of statistical analyses. Multiple regression was used to control for variables that might confound comparisons of changing patterns of care and patient outcomes over time. These covariates included age, sex, race, Charlson Index Score, and an indicator variable for a secondary diagnosis of hypertension. Congestive heart failure, diabetes mellitus, and chronic obstructive pulmonary disease were not included as covariates because these diagnoses are included in the Charlson Index. All models included institution as a stratification variable. All statistical tests were 2 sided and P values less than .05 were considered significant. Ninety-five percent confidence intervals were calculated and reported on the odds ratios for the logistic regression models and on the slope coefficients for the linear regression models. All analyses were conducted using the SAS software package (SAS Institute Inc, Cary, NC).

RESULTS

COMPARABILITY OF YEARLY CEA PATIENTS OVER TIME

Table 1 shows the comparison of patient demographics over the 6-year study period. During this period, the mean age of the sample increased from 67.6 years to 69.5 years (P < .001). The increasing age is also reflected in the percentage of cases aged 65 years or older, which increased from 65% in 1990 to 75% in 1995 (P < .001). Similarly, the percentage of Medicare primary reimbursement increased from 61% of cases in 1990 to 67% in 1995 (P < .001). There was no trend seen in the percentages of case patients who were male or who were white.

We also tried to establish the comparability of the study cohorts with regard to their comorbid conditions (Table 2). Hypertension was coded in 55% of cases in 1991 and in 65% of cases in 1995, showing an increasing trend over time (P < .001). There was also a significant increase in cases with a secondary diagnosis of congestive heart failure (P = .02), and a marginally significant increase in cases coded with diabetes mellitus (P = .04).
or chronic obstructive pulmonary disease ($P = .09$). The percentage of cases with valvular heart disease, however, did not change significantly over the study years. No significant trend over time was noted in the mean Charlson Index Score ($P = .57$).

**CHANGING INPATIENT MANAGEMENT PRACTICES**

Over the course of the 6-year study period there were dramatic changes in the inpatient management practices across the 10 institutions. The number of CEAs performed increased from 823 in 1990 to 1839 in 1995. Although there was an increase in frequency every year during the study period, 60% of the rise occurred between 1994 and 1995. Table 3 shows the changing LOS and ICU profiles of patients during this period. The mean LOS declined by more than 50% from 8.8 days in 1990 to 4.3 days in 1995 ($< .001$). The decline in LOS was accomplished by decreasing both the preprocedure LOS, which decreased from 2.8 to 1.2 days, as well as the postprocedure LOS, which decreased from 5.9 to 3.0 days. The median LOS also declined by 50% from 6 days in 1990 to 3 days in 1995. In addition, the percentage of cases admitted to the ICU decreased from 56.5% in 1990 to 26.3% in 1995 ($< .001$), and the mean ICU stay for those cases admitted to the ICU showed a decreasing trend over time ($P = .02$).

**Table 4** shows the dramatic reductions over time in the frequency of CEA admissions with an outpatient cerebral arteriogram. The percentage of cases with 1 arteriogram per admission declined from 58.1% in 1990 to 38.3% in 1995 ($P < .001$). A striking decline was also seen for patients having 2 arteriograms per admission, from 5.7% in 1990 to 1.2% in 1995 ($P < .001$). The frequency and magnitude of change for the cerebral arteriogram depended greatly on the timing of the procedure with respect to the CEA. Significant decreases were seen over time for both pre-CEA and post-CEA cerebral arteriograms; pre-CEA arteriograms declined from 52% (of CEA cases) in 1990 to 27% in 1995 ($P < .001$) and post-CEA arteriograms declined from 6.4% in 1990 to 1.4% in 1995 ($P < .001$). Over the 6-year study period, however, there was no significant trend noted in the frequency of cerebral arteriograms coded on the same day of the CEA ($P = .15$).

**PATIENT OUTCOME TRENDS**

**Table 5** shows annual data on inpatient mortality, percentage of cases discharged to an institution, and 30-day readmission rate. Inpatient mortality ranged from a low of 0.22% in 1995 to a high of 0.82% in 1992, without a linear trend ($P = .11$). In addition, the percentage of patients being discharged to an institution across years ranged between 4.2% and 5.5% ($P = .57$). The 30-day same-institution readmission rate

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>1990 (n=823)</th>
<th>1991 (n=966)</th>
<th>1992 (n=983)</th>
<th>1993 (n=1065)</th>
<th>1994 (n=1223)</th>
<th>1995 (n=1839)</th>
<th>Analysis†</th>
<th>Year</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean (SD) age, y</td>
<td>67.6 (8.9)</td>
<td>68.1 (8.9)</td>
<td>68.5 (9.0)</td>
<td>68.8 (8.7)</td>
<td>68.7 (9.1)</td>
<td>69.5 (8.5)</td>
<td>0.32 (0.20 to 0.44)</td>
<td>.001</td>
</tr>
<tr>
<td>Aged ≥65 y, %</td>
<td>65</td>
<td>67</td>
<td>71</td>
<td>72</td>
<td>72</td>
<td>75</td>
<td>1.09 (1.05 to 1.11)</td>
<td>.001</td>
</tr>
<tr>
<td>Male, %</td>
<td>62</td>
<td>62</td>
<td>60</td>
<td>64</td>
<td>65</td>
<td>62</td>
<td>1.01 (0.98 to 1.04)</td>
<td>.44</td>
</tr>
<tr>
<td>White, %</td>
<td>97</td>
<td>98</td>
<td>96</td>
<td>97</td>
<td>97</td>
<td>97</td>
<td>0.97 (0.89 to 1.05)</td>
<td>.42</td>
</tr>
<tr>
<td>Medicare beneficiaries, %</td>
<td>61</td>
<td>63</td>
<td>63</td>
<td>65</td>
<td>68</td>
<td>67</td>
<td>1.05 (1.02 to 1.08)</td>
<td>.001</td>
</tr>
</tbody>
</table>

*All patients 18 years and older discharged from the hospital with a principal procedure carotid endarterectomy from 10 academic medical centers, 1990 to 1995.†Odds ratios (ORs) were obtained from logistic regression models for dichotomous outcomes and slopes were obtained from regression models for continuous outcomes. P values, ORs, slopes, and 95% confidence intervals (CIs) are from multiple regression models adjusting for institution.

**Table 2. Comorbidities in Patients Undergoing a Carotid Endarterectomy, 1990-1995**

<table>
<thead>
<tr>
<th>Comorbid Conditions</th>
<th>1990 (n=823)</th>
<th>1991 (n=966)</th>
<th>1992 (n=983)</th>
<th>1993 (n=1065)</th>
<th>1994 (n=1223)</th>
<th>1995 (n=1839)</th>
<th>Analysis†</th>
<th>Year</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hypertension, %</td>
<td>56</td>
<td>55</td>
<td>60</td>
<td>62</td>
<td>62</td>
<td>65</td>
<td>1.09 (1.06 to 1.12)</td>
<td>.001</td>
</tr>
<tr>
<td>Congestive heart failure, %</td>
<td>3.8</td>
<td>3.5</td>
<td>5.5</td>
<td>4.7</td>
<td>6.0</td>
<td>5.4</td>
<td>0.18 (1.01 to 1.15)</td>
<td>.02</td>
</tr>
<tr>
<td>Diabetes mellitus, %</td>
<td>19.3</td>
<td>19.4</td>
<td>21.4</td>
<td>20.3</td>
<td>21.8</td>
<td>22.1</td>
<td>1.04 (1.00 to 1.07)</td>
<td>.04</td>
</tr>
<tr>
<td>Chronic obstructive pulmonary disease, %</td>
<td>11.5</td>
<td>7.9</td>
<td>11.1</td>
<td>10.8</td>
<td>10.4</td>
<td>12.3</td>
<td>1.04 (0.99 to 1.09)</td>
<td>.09</td>
</tr>
<tr>
<td>Valvular heart disease, %</td>
<td>4.7</td>
<td>2.2</td>
<td>3.1</td>
<td>4.5</td>
<td>4.1</td>
<td>3.6</td>
<td>1.02 (0.95 to 1.10)</td>
<td>.60</td>
</tr>
<tr>
<td>Mean (SD) Charlson Index Score</td>
<td>1.2 (1.3)</td>
<td>1.1 (1.5)</td>
<td>1.2 (1.4)</td>
<td>1.1 (1.4)</td>
<td>1.1 (1.5)</td>
<td>1.2 (1.5)</td>
<td>-0.006 (−0.025 to 0.01)</td>
<td>.57</td>
</tr>
</tbody>
</table>

*All patients 18 years and older discharged from the hospital with a principal procedure carotid endarterectomy from 10 academic medical centers, 1990 to 1995.†Odds ratios (ORs) were obtained from logistic regression models for dichotomous outcomes and slopes were obtained from regression models for continuous outcomes. P values, ORs, slopes, and 95% confidence intervals (CIs) are from multiple regression models adjusting for institution.
Table 3. Length-of-Stay and Intensive Care Unit (ICU) Characteristics for Patients Undergoing a Carotid Endarterectomy, 1990-1995*

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>1990 (n=823)</th>
<th>1991 (n=866)</th>
<th>1992 (n=983)</th>
<th>1993 (n=1065)</th>
<th>1994 (n=1223)</th>
<th>1995 (n=1839)</th>
<th>Analysis†</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length of stay, d</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean</td>
<td>8.8 (13.7)</td>
<td>7.7 (6.9)</td>
<td>7.2 (6.1)</td>
<td>6.4 (8.2)</td>
<td>5.2 (5.3)</td>
<td>4.3 (4.5)</td>
<td>-0.157 (-0.165 to -0.149) &lt;.001§</td>
</tr>
<tr>
<td>Preprocedure</td>
<td>2.8</td>
<td>2.6</td>
<td>2.5</td>
<td>2.1</td>
<td>1.8</td>
<td>1.2</td>
<td>-0.529 (-0.558 to -0.499) &lt;.001§</td>
</tr>
<tr>
<td>Postprocedure</td>
<td>5.9</td>
<td>5.1</td>
<td>4.7</td>
<td>4.2</td>
<td>3.4</td>
<td>3.0</td>
<td>-0.134 (-0.142 to -0.126) &lt;.001§</td>
</tr>
<tr>
<td>Median (25th percentile, 75th percentile)</td>
<td>6 (4, 9)</td>
<td>6 (4, 9)</td>
<td>5 (4, 9)</td>
<td>5 (3, 7)</td>
<td>4 (2, 6)</td>
<td>3 (2, 5)</td>
<td>. . . . . .</td>
</tr>
<tr>
<td>% With ICU stay‡</td>
<td>56.5</td>
<td>32.2</td>
<td>29.7</td>
<td>25.1</td>
<td>21.8</td>
<td>26.3</td>
<td>0.75 (0.64 to 0.88) &lt;.001§</td>
</tr>
<tr>
<td>Mean (SD) ICU stay§</td>
<td>2.4 (5.3)</td>
<td>1.9 (2.6)</td>
<td>2.4 (2.9)</td>
<td>2.2 (2.5)</td>
<td>2.3 (3.8)</td>
<td>1.8 (2.1)</td>
<td>-0.021 (-0.038 to -0.004) .02</td>
</tr>
</tbody>
</table>

* All patients 18 years and older discharged from the hospital with a principal procedure carotid endarterectomy from 10 academic medical centers, 1990 to 1995.
† Odds ratios (ORs) were obtained from logistic regression models for dichotomous outcomes and slopes were obtained from regression models for continuous outcomes. P values, slopes, ORs, and 95% confidence intervals (CIs) are from multiple logistic regression models adjusting for age, institution, race, sex, Charlson Index Score, and a secondary diagnosis of hypertension.
‡ Data are based on 7 of the 10 institutions because 3 of the institutions did not provide data on ICU status for the study period.
§ Based on log-transformed length of stay. For preprocedure and postprocedure length of stay, 0.01 was added to all results to avoid taking the log of zero.

Table 4. Patterns of Cerebral Arteriography Use in Patients Undergoing a Carotid Endarterectomy (CEA) 1990-1995*

<table>
<thead>
<tr>
<th>Pattern</th>
<th>1990 (n=823)</th>
<th>1991 (n=966)</th>
<th>1992 (n=983)</th>
<th>1993 (n=1065)</th>
<th>1994 (n=1223)</th>
<th>1995 (n=1839)</th>
<th>Analysis†</th>
</tr>
</thead>
<tbody>
<tr>
<td>One cerebral arteriogram per admission, %</td>
<td>58.1</td>
<td>61.8</td>
<td>58.5</td>
<td>51.2</td>
<td>44.8</td>
<td>38.3</td>
<td>0.80 (0.78 to 0.82) &lt;.001</td>
</tr>
<tr>
<td>Two cerebral arteriograms per admission, %</td>
<td>5.7</td>
<td>4.8</td>
<td>3.2</td>
<td>2.4</td>
<td>1.8</td>
<td>1.2</td>
<td>0.71 (0.65 to 0.78) &lt;.001</td>
</tr>
<tr>
<td>Cerebral arteriogram by timing of CEA, %</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pre-CEA</td>
<td>51.6</td>
<td>56.0</td>
<td>49.3</td>
<td>40.8</td>
<td>32.5</td>
<td>26.7</td>
<td>0.75 (0.73 to 0.77) &lt;.001</td>
</tr>
<tr>
<td>Day of CEA</td>
<td>12.2</td>
<td>11.4</td>
<td>11.3</td>
<td>13.2</td>
<td>14.1</td>
<td>12.7</td>
<td>1.04 (0.99 to 1.09) .15</td>
</tr>
<tr>
<td>Post-CEA</td>
<td>6.4</td>
<td>5.2</td>
<td>4.5</td>
<td>3.2</td>
<td>1.8</td>
<td>1.4</td>
<td>0.71 (0.66 to 0.78) &lt;.001</td>
</tr>
</tbody>
</table>

* All patients 18 years and older discharged from the hospital with a principal procedure carotid endarterectomy from 10 academic medical centers, 1990 to 1995.
† P values, odds ratios (ORs), and 95% confidence intervals (CIs) are from multiple logistic regression models adjusting for age, institution, race, sex, Charlson Index Score, and a secondary diagnosis of hypertension.

This study shows that in the first half of the 1990s, in this group of AMCs, the frequency of CEAs more than doubled, patient age increased, and LOS was halved. In addition, the percentage of cases with an ICU admission declined by nearly 50%, as did the percentage of cases with an inpatient cerebral arteriogram. These changes reflect a complex web of influences that have globally impacted on physicians’ diagnostic, management, and decision-making styles. This study furthers our understanding of what has happened in this group of AMCs during this critical period of CEA technology.

These data extend previous observations that show a marked increase in the number of CEAs performed at nonfederal US hospitals from 1991 to 1993. The present study would suggest that the frequency has continued to rise, as 75% of the total increase in the number of CEAs performed from 1990 through 1995 was observed in 1994 and 1995. This increase was seen during a pe-
This study also provides preliminary insights into how patient characteristics have changed over time. First, patient age increased by 2 years, representing a 10% increase in those 65 years or older. Second, the percentage of CEA admissions with a concurrent diagnosis of hypertension increased by nearly 10%. Less robust but significant increases were seen in the percentage of admissions with secondary diagnoses of congestive heart failure, diabetes mellitus, or chronic obstructive pulmonary disease. Third, the Charlson Index Score did not change over the study period. We cannot determine, however, the changing proportion of symptomatic vs asymptomatic patients being offered the procedure over time.

At the same time that the frequency of CEA use and patient age have increased, hospital resource use has dramatically decreased. The mean and median LOS halved during the study period, as did the percentage of CEA admissions with transfers to the ICU. This rapid decline in the mean LOS greatly outpaces the 20% decline in LOS seen for all inpatient admissions between 1980 and 1995. These data also show that institutions have realized the decrease in LOS by successfully decreasing the LOS both before and after the CEA. Although this study cannot determine the exact methods by which LOS has been reduced, the literature suggests that a variety of mechanisms have been successfully implemented, including institutional practice guidelines, utilization review, and case management. As the LOS declined, so did the percentage of cases with at least 1 inpatient cerebral arteriogram per admission: from 64% of cases in 1990 to 39% of cases in 1995. There are several potential reasons for the declining use of inpatient cerebral arteriography, a trend that has been occurring since the mid-1980s. First, as a result of reimbursement mechanisms and utilization review policies, many preprocedure cerebral angiograms are being performed in the outpatient setting prior to the inpatient admission. Second, physician practice styles are changing. Many patients are proceeding to a CEA without having a cerebral arteriogram to confirm arterial patency based on the results from noninvasive imaging tests. This trend also provides preliminary insights into how patient characteristics have changed over time. First, patient age increased by 2 years, representing a 10% increase in those 65 years or older. Second, the percentage of CEA admissions with a concurrent diagnosis of hypertension increased by nearly 10%. Less robust but significant increases were seen in the percentage of admissions with secondary diagnoses of congestive heart failure, diabetes mellitus, or chronic obstructive pulmonary disease. Third, the Charlson Index Score did not change over the study period. We cannot determine, however, the changing proportion of symptomatic vs asymptomatic patients being offered the procedure over time.

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Although we cannot determine the clinical indication for which the CEA was performed, there is certainly no compelling evidence that the prognostic profiles of patients improved over time. In fact, the prognostic profile of patients receiving CEA may actually have worsened over time given the increasing age of the yearly cohorts, since advancing age has been shown to be a prognostic risk factor in some studies.\textsuperscript{33,34} This has not, however, been a universal finding.\textsuperscript{35,36}

By aggregating the results from all AMCs across years, we do not intend to conceal the underlying variability in the behavior of institutions over time. Indeed, the LOS varied considerably across institutions as did the extent of decrease. The overwhelming trend over time, however, was one of decline. The mean LOS declined for all 10 institutions and even the most “stable” institution’s LOS declined by 36%. Even though our intent was not to study the interinstitutional variability over time, this issue deserves further investigation. There is an increasing need to provide comparative data on the performance of different providers and institutions to ensure efforts to improve the quality of care.\textsuperscript{37}

More work is also needed in studying other nonclinical determinants of patient outcomes, such as the CEA volume of the surgeon (high caseload vs low caseload) and the type of hospital in which the procedure is performed, both of which can systematically affect patient outcomes.\textsuperscript{36,39} Because this study involved only a selected number of AMCs, the results have limited generalizability to other hospitals, although previous research would indicate similar trends are occurring in community hospitals.\textsuperscript{1,11-13,40} Finally, more research is needed to develop validated risk-adjusted algorithms for CEA as has been developed for coronary artery bypass grafting.\textsuperscript{41} Preliminary work suggests that risk-adjusted models can be developed from databases for patients undergoing a CEA.\textsuperscript{35}

There are many well-recognized limitations in using hospital administrative data. First, discharge diagnosis and procedure codes may not be completely reliable because of inconsistent or incomplete coding.\textsuperscript{42} Hospital administrative databases also have been shown to underreport chronic conditions such as hypertension\textsuperscript{43} and to “upcode” diagnoses and procedures over time (a phenomenon referred to as “DRG [diagnosis related group] creep”).\textsuperscript{44} Therefore, the changes found in comorbidity over time in this study should be interpreted with caution. Limitations specific to CEA include the inability to distinguish between the right and left side as well as an inability to determine the clinical indication for the procedure (ie, symptomatic vs asymptomatic). Nonetheless, administrative databases can serve a useful role in assessing routine clinical practices after clinical trials establish what treatments work for patients.\textsuperscript{45} An extension of this role is to monitor and screen for potential quality-of-care problems in populations of patients in a rapidly changing health care environment, particularly in situations for which randomization is not feasible. It is in both of these capacities that we have used hospital discharge data for patients undergoing a CEA.

In conclusion, this study shows that CEA has become a more frequent procedure in this group of AMCs and is being offered to an increasingly older population.
of patients. In addition, this study identifies rather striking, widespread changes in the process of inpatient management with no apparent detriment to patient outcomes. This type of timely, early, and rigorous assessment process should accompany any effort at reducing the utilization of care, particularly in conditions where the margin of error is so low and the stakes are so high as in the inpatient management of carotid endarterectomy.

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