Evaluating Quality, Cost-effective Health Care

Vascular Database Predicated on Hospital Discharge Abstracts

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This population-based study examines all carotid endarterectomies (CE) performed by all surgeons in a single state over a 10-year period. The methodology is designed to determine morbidity rate, mortality rate, cost, and length of stay, as well as to understand the effect of pre-existing chronic disease, physician, and hospital volume on these outcome variables. The data source consisted of hospital discharge abstract data uniformly collected on all admissions (N = 5.9 million) to acute care hospitals in the state. In the decade 1979 to 1988, 11,199 patients underwent CE. Mortality rate from CE was 2.1%, and the postoperative stroke rate was 3.7% over this period. High physician volume decreased the mortality rate ($p < 0.05$) and stroke rate ($p < 0.01$) by 50% and significantly ($p < 0.001$) reduced hospital cost and length of stay independent of patient complexity. Examination of cost data, adjusted for inflation, showed a decrease in mean cost for CE over the decade. Thus physicians are providing better care for less hospital dollars. Both patient and payor outcome is improved by concentrating CE patients in the hands of high-volume surgeons. Although the data suggests this trend is already evolving, the pace of this evolution can be expected to increase as payors recognize that regionalization of this procedure lowers costs.

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ATHEROSCLEROSIS IS A chronic homogeneous disease variable only by severity and socioeconomic impact. Historically older adults with positive cardiovascular risk factors have suffered the consequences of this devastating process. Through the years both surgical and medical advances have improved patient survival and quality of life.

Extracranial carotid atherosclerosis (CA) with resulting cerebral ischemia or infarction is the third leading cause of death in North America.[1,2] If not initially fatal, stroke may cause permanent functional impairment. Carotid endarterectomy (CE) was introduced four decades ago for relief of extracranial CA.[3] It is now the most frequently performed peripheral vascular operation, despite its controversial value in stroke prevention.[4]

Current reports on outcome of CE contain disparities in morbidity and mortality rates dependent on operative indication, surgeon experience, and geography of service.[5–8] No population-based study defines patient outcome and addresses cost issues for CE. The health care delivery system in the United States must contain rising expenditures; therefore the indications for all surgical procedures are being examined to identify cost efficiencies. All parties, patient, provider, and payor are clamoring for the delivery of quality, effective care for the fewest dollars.[9] Physicians must address these issues or risk restrictions on their ability to practice.

Methods

Data Source

The study data source consisted of computerized hospital discharge abstract data uniformly collected on all discharges from acute care hospitals in a single state between January 1, 1979 and December 31, 1988. This database includes the following: patient demographics, type of admission, length of stay, discharge status, and five diagnoses and three procedures codes using the International Classification of Disease, 9th Revision, Clinical Modification ICD-9-CM.[10] In addition, each hospital and physician was represented by a coded value. Changes in physician identification codes were made in mid-1985, which permitted double counting of physician operations. This structural variation in the database disqualifies 1985 data for physician volume analysis.

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The Study Population

Patients undergoing carotid endarterectomy were defined as having a procedure code ICD-9-CM, 38.12, (endarterectomy with embolectomy, patch graft, temporary bypass, or thrombectomy of intracranial vessels). Thirty-two patients (0.3%) less than 30 years old, or who had bed service listed as obstetrics, newborn, pediatric, psychiatry, or rehabilitation clearly represented coding errors and were excluded. Over the 10-year period there were 5,981,941 hospital admissions. Of these 11,199 patients underwent carotid endarterectomy and form the basis of this study.

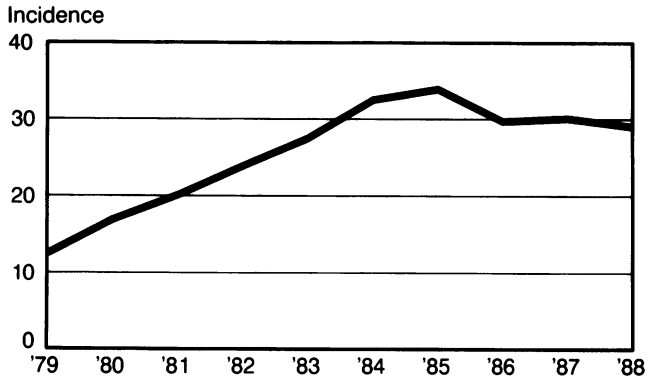

FIG. 1. Incidence of carotid endarterectomies/100,000 population.

Definition of Terms

Mortality: Defined as in-hospital death. No information is available from the database about long-term follow-up.

Stroke: Patients with ICD-9-CM codes 434.0, 434.1, and 431.9 (occlusion of cerebral arteries) and 997.0 (central nervous system complications resulting from procedure) were defined as in-hospital stroke.

Costs: Total hospital charges by cost centers were provided in the abstracted data. Because of the unique and stndardized system of costs-to-charge ratios used throughout the state, hospital charges can be taken for a proxy for costs to the hospital. This figure does not, however, include physician charges or postoperative follow-up.

Length of Stay (LOS): defined as the number of days in the hospital during which the carotid endarerectomy was performed.

Pre-existing Conditions (PEC): Chronic medical conditions that were coded as secondary diagnoses on the hospital discharge abstract. Four pre-existing medical conditions were considered to potentially complicate a patient's hospital course: ischemic heart disease, chronic obstructive pulmonary disease, diabetes mellitus, and hypertension (Table 1).

Physician Volume: Each physician in the state was assigned a numerical identification code associated with each operative procedure. All physicians performing endarterectomies in the state were then grouped according to the volume of CEs performed in a given year. Each year a physician was assigned to either low-, medium-, or high-volume groups based on the number of CEs in that year. Low-volume physicians were defined as performing between 1 and 12 CEs. Medium-volume physicians performed 13 to 49 procedures, and high-volume physicians (HVP) performed 50 or more procedures in a given year.

Hospital Volume: Each hospital within the state was assigned a unique identifier code. To determine the system effect distinct from physician technique, patient outcome was examined as a function of hospital volume. Hospitals were assigned to high, medium, or low volume based on the number of CEs performed in a given year. High volume was defined as over 50 procedures a year (mid-volume, 13 to 49; and low volume, 1 to 12 CEs). It is possible for an individual hospital, or physician to change volume groups from 1 year to the next.

TABLE 1. *Pre-existing Conditions (PEC)*

PEC	N (%)	ICD-9CM Code
Hypertension	3,241 (28.9)	401–405
Ischemic heart disease	1,736 (15.5)	411–414
Diabetes	1,473 (13.2)	250
COPD	707 (6.3)	490–496

Statistical Analysis

The yearly incidence of CE was calculated by dividing the number of persons undergoing the procedure by the state population as reported by the state's department of planning. Dichotomous outcome indicators for patients undergoing CE by low-, middle-, or high-volume institutions for physicians were compared using 2×3 chi square tests. In addition, low- and high-volume hospital procedures were compared using 2×2 chi square tests. Differences in continuous outcome variables (length of stay and cost) were tested using analysis of variance, and a linear contrast was performed to test the low *versus* high hospital and physician volume procedures. For outcome by volume and PEC analysis, separate chi square tests were performed for patients with a PEC and for the overall study population.[11]

Results

Over a 10-year period, 11,199 patients underwent CE in a single state. Two hundred thirty-one patients died (2.1%) and 415 patients (3.7%) suffered a stroke before discharge. The mean length of stay for the entire population was 11.2 days. The mean cost per patient over the

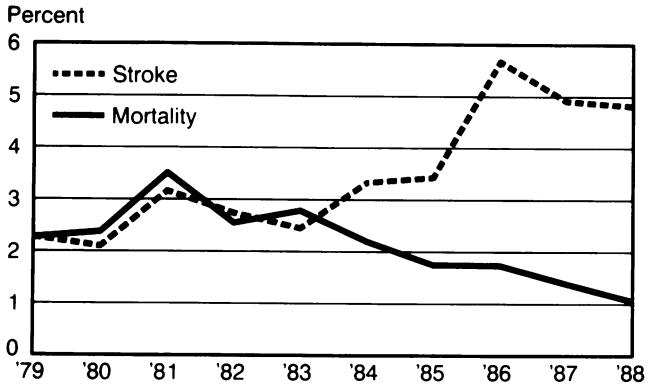

FIG. 2. Peak in stroke rate occurred in 1986.

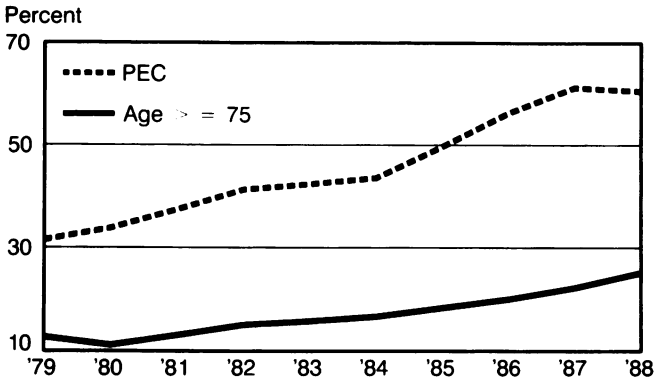

FIG. 4. Increasing age and number of complex patients. PEC, pre-existing condition.

10-year period was $6150.00, and the total cost for CE during the 10-year period was $68.8 million.

Figure 1 demonstrates the incidence of CE per 100,000 population. The incidence increases through the year 1985, and then remains stable for the last 4 years of the study. Figure 2 contrasts the declining mortality rate with the increasing rate of postoperative stroke. The stroke rate in the last year of the study was 4.8%, whereas the mortality rate in the final year of the study was 1.05%.

The mean LOS for CE over the 10-year period steadily decreases, from a peak of 15.5 days in 1979 to a nadir of 7.7 days in 1988 ($p < 0.001$). The majority of this improvement in mean hospital stay is attributable to the decrease in the number of patients who had an extended hospital stay of over 21 days. In 1979, 20% of patients were in the hospital for 21 days or more. In 1988, that number had decreased to 5.3%. Although costs increase from 1979 to 1983, they have remained relatively stable since 1983. When this increase in costs is plotted as a function of the consumer price index[12] (Fig. 3), a measurement of inflation, we see that despite the rising incidence of CE, the mean patient cost to society in 1979 dollars is less in 1988 than it was in 1979.

Complex Patients

We defined patients with one or more PECs as complex patients. Forty-eight per cent of the patients (5379) patients were defined as complex (48%). Table 1 demonstrates the relative incidence of the various PECs. Figure 4 demonstrates that age and the incidence of complex patients increases over time.

Table 2 demonstrates the effect of PECs on mortality rate, stroke rate, length of stay, and cost. There were no significant differences in mortality rate, stroke, or length of stay as a function of PEC. The intensity of services rendered in PEC-positive patients during their hospital stay, however, accounts for approximately $700 increased cost for PEC-positive patients ($p = 0.0001$).

The distribution of patients with PECs by physician volume suggests that over time complex patients are increasingly referred to HVPs. This suggests an effective triage mechanism is developing, initiated either by the referring physician or the patient. During this period, however, there were still over 2700 (51.2%) complex patients who had their CE performed by a low-volume physician.

Volume/Quality

The 190 physicians annually performing CE over this 10-year period were stratified by volume. Figure 5 is a stacked histogram showing the distribution of patients to low-volume physicians (LVPs) over time, suggesting that LVPs are losing market share.

Table 3 demonstrates that mortality ($p < 0.05$) and

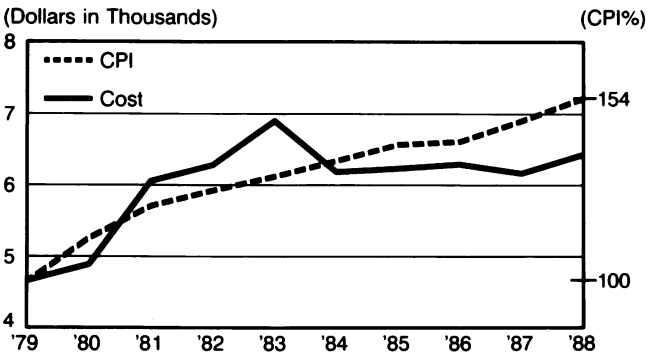

FIG. 3. Level cost curve for carotid endarterectomies for four years.

TABLE 2. *Outcome Indicators by the Presence of Pre-existing Conditions*

	Pre-existing Conditions		
	No	Yes	p value
N	5820	5379	
Mortality	132	99	0.11
(Column %)	(2.27)	(1.84)	
Stroke	216	199	NS
(Column %)	(3.71)	(3.70)	
Mean length of stay	11.4	11.07	0.105
Mean cost	$5,802	$6,526	0.0001

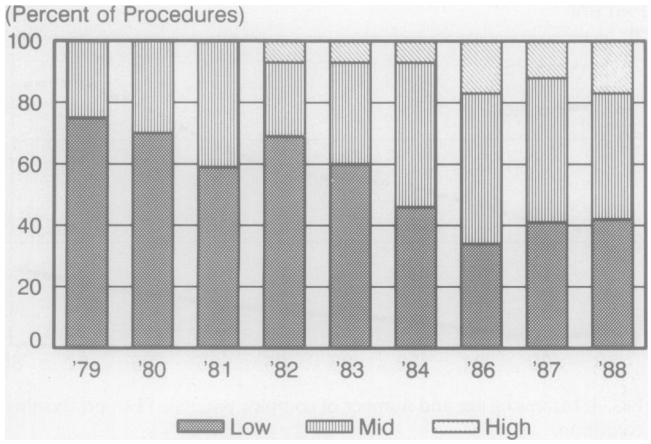

FIG. 5. Distribution of patients showing HVPs assuming a larger market share. The year 1985 is omitted because of double counting.

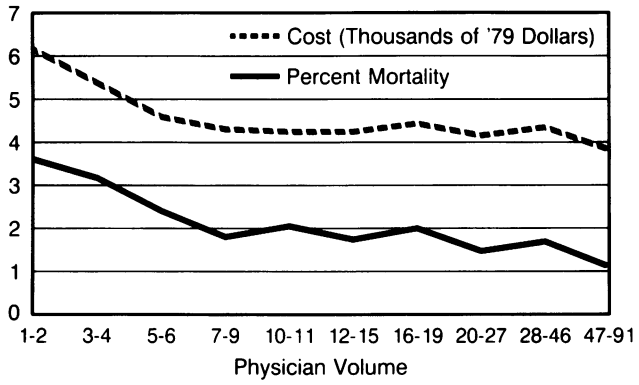

FIG. 6. Mortality rate and cost by decile of physician volume.

stroke rates ($p < 0.01$) decrease by 50% as a function of physician volume. In addition physician volume significantly ($p < 0.001$) lowers LOS and cost. Low-volume physicians increase the mean cost of operation by more than $1000.00.

Figure 6 presents outcome data on mortality rate and cost by decile of physician volume, excluding 1985 ($n = 9715$). Forty per cent of CEs were performed by physicians whose volume was less than 10 procedures a year. Mortality rate decreases precipitously until physician volume reaches nine CEs per year, and then mortality rate decreases more slowly. Hospital cost as a function of physician volume by decile suggests a minimum yearly volume of nine is required to be cost efficient.

To judge the relative influence of physician technique *versus* system efficiency on outcome, a similar analysis was performed using hospital volume. All hospitals performing carotid endarterectomy were analyzed by CE volume. Figure 7 is a stacked histogram depicting grouped hospital volume over time. There is an increasing trend for CE to be performed in higher-volume hospitals.

Table 4 presents outcome criteria by hospital volume for all patients and complex patients. There are no statistically significant differences between mortality rate and postoperative stroke rate on the basis of hospital volume. Increased hospital volume is associated with decreased length of stay ($p < 0.001$) and cost ($p = 0.05$).

TABLE 3. *Outcome by Physician Volume*

	Low	Mid	High	p-value L *vs* H
N				
Overall	5067	3876	772	
Complex	2289 (45.2)	1887 (48.7)	466 (60.4)	<0.001
Mortality (%)				
Overall	130 (2.6)	66 (1.7)	9 (1.2)	0.02
Complex	60 (2.6)	27 (1.4)	4 (0.9)	0.02
Stroke (%)				
Overall	203 (4.0)	145 (3.7)	16 (2.1)	0.008
Complex	100 (4.4)	68 (3.6)	8 (1.7)	0.007
Length of stay				
Overall	12.7	10.5	8.1	<0.001
Complex	13.1	9.9	7.9	<0.001
Cost				
Overall	$6531	$5746	$5520	<0.001
Complex	$7355	$5824	$5798	<0.001

Discussion

Historically outcome data for CE has emanated from a small group of surgeons interested in the procedure. This study examines CE performed by a large number of unselected surgeons over a 10-year period. This population-based approach is designed to define morbidity rate, mortality rate, LOS, and cost. It is only in using this methodology that policy decisions can be made regarding the efficacy of CE.

The data demonstrates that the incidence of CE increases steadily during a decade as operative indications expand to include older and more complex patients. Despite this increase in complexity, operative mortality decreases but postoperative stroke rate increases. It is spec-

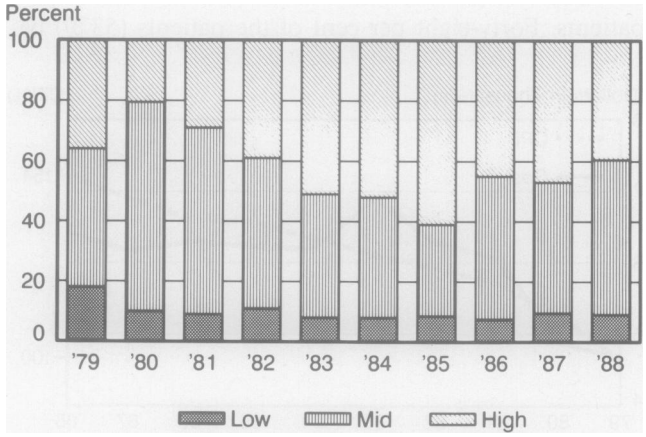

FIG. 7. Stacked histogram of hospital volume.

TABLE 4. *Outcome by Hospital Volume*

	Low	Mid	High	p-value L *vs* H
N				
	922	5,258	5,019	
Overall	420	2,372	2,587	
Complex	(45.6)	(45.1)	(51.5)	0.001
Mortality				
Overall	22 (2.4)	117 (2.2)	92 (1.8)	NS
Complex	5 (1.2)	50 (2.1)	44 (1.7)	NS
Stroke				
Overall	33 (3.6)	205 (3.9)	177 (3.5)	NS
Complex	19 (4.5)	98 (4.1)	82 (3.2)	NS
Length of stay				
Overall	12.9	12.2	10.0	<0.001
Complex	13.1	12.2	9.7	<0.001
Cost				
Overall	$6504	$6353	$5872	0.004
Complex	$6774	$6913	$6131	0.053

ulated that there is a correlation between the increase in stroke rate and the complexity of the patient population; however the data neither confirms or denies our speculation.

Traditionally, physicians have evaluated surgical procedures by clinical outcome. With increasing attention on resource allocation, CE also was analyzed by cost during the decade. Although both mean cost and the total cost increase, the increased total cost results from a growing number of patients undergoing CE. When adjusted for inflation, the mean cost per year for CE decreases during the decade. Increased operative incidence for less cost indicates increased provider productivity. Thus, despite increasing numbers of CEs performed and improved quality, as reflected by decreasing mortality, the cost per operation decreases. This demonstrates that physicians are providing better care for less hospital dollars, in other words, increased productivity. Contrary to political rhetoric, the medical community has improved both the productivity and efficiency of CE. This increased productivity occurred in a decade when total medical costs have continuously increased to 11% of the gross national product and is largely a result of physician efforts to decrease LOS.

Role of Physician Volume

The factors that impact outcome can be divided into two major components: physician and hospital. The physician component includes not only the technical ability of the surgeon but also the operative indication and preoperative health of the patient. Hospital-related issues range from hospital demographics and system efficiency to the skill of ancillary services. This study examines both physician and hospital volume as a proxy for these components. It is hypothesized that a spectrum exists for all vascular procedures. In certain operations, such as ruptured abdominal aortic aneurysm (which requires rapid access to the operating suite), the system component or hospital volume may be the most important determinant of outcome. In other operations, such as carotid endarterectomy, surgical technique may be the primary determinant of outcome.

For the mature, elective operation, physician volume is demonstrated to be an important outcome determinant. High-volume physicians have a mortality and postoperative stroke rate that is 50% less than their low-volume colleagues. It is surprising to demonstrate such a significant reduction in mortality rate as a function of physician volume because the mortality rate after CE is very low. Furthermore hospital costs were significantly less for HVPs. Those physicians that perform more CEs have significantly reduced mean LOS, thereby reducing the cost of hospitalization to society. This phenomenon is found in all patients, regardless of complexity.

These findings argue for the concentration of patients undergoing CE into the hands of HVPs. The data suggest that physician CE volume should exceed nine procedures a year to minimize both deaths and cost. The trend toward regionalized care is apparent in this data, suggesting that referring physicians are triaging more patients to both HVPs and hospitals. Although concentration of CE patients into high-volume 'regional practices' is at the expense of patient geographic and social convenience, both patient and payor outcome is improved. Consequently it is in the best interest of both the patient and payor to encourage regionalization, and physicians can expect this trend to continue.

Strengths and Limitations

The large patient population, representing all CE in a geographic area, the availability of cost data, and analysis of provider productivity from the dual perspective of patient and payor provide the unique perspective of this study. Because all CEs performed by all surgeons in a given area over a 10-year period were examined, sufficiently large patient numbers (11,199) allow resolution of the issue of morbidity rate and mortality rate in CE. Previous clinical research[13,14] reports outcome only by the physicians interested in CE. In contrast this study examined results of CE from the entire spectrum of surgical experience. From a policy perspective, this methodology provides a more stringent test of the operative risk than the analysis of selected experiences.

An additional strength of the study design is the definition of a subgroup of complex patients. Pre-existing condition influence on provider volume, clinical outcome, LOS, and cost affords a comprehensive examination of outcome from the perspective of both patient and payor. The lack of PEC effect on CE mortality was expected. We showed previously[15] that the effect of PEC on mortality in trauma patients is dependent on the magnitude of the

injury and the patient's physiologic reserve.[16] Carotid endarterectomy, unlike aortic reconstruction, for example, exerts relatively little metabolic demand on the patient, thus minimizing the PEC effect on mortality. The presence of PECs does, however, clearly increase the intensity of service provided to the patient.

Limitations of the study are acknowledged. This is a retrospective examination based on hospital discharge abstract data. Analysis is necessarily limited to in-hospital outcome, as longitudinal follow-up is unavailable. Thus definition of long-term stroke-free survival, impact on quality of life, and the creation of a true cost–benefit equation cannot be addressed.

The severity of individual PECs is not distinguishable by ICD-9-CM methodology, nor is the preoperative indication for surgical intervention. These factors inhibit further patient stratification by risk or complexity and are a recognized limitation of all studies based on hospital discharge abstract data. In addition our definition of postoperative stroke includes codes for both 'occlusion of cerebral arteries' and 'central nervous system complications resulting from procedure.'[9] The increased incidence of stroke over time may be a result of variations in operative indications or improved documentation of transient postoperative neurologic deficits.

Finally the study is limited by the standard population-based concerns addressed by Jencks and colleagues,[17] who suggest there is potential under-reporting of pre-existing disease or complications in patients with life-threatening conditions. Truncation of PEC and stroke data may occur when multiple acute conditions or complications take coding precedence. In this population, 75% of patients had four or fewer of the five available diagnosis fields used. It is, however, reasonable to assume that some under reporting of PECs exists and only those PECs severe enough to warrant documentation in the medical record are being identified. Thus estimates of the PEC effect on outcome may still be conservative.

In summary CE is an operation performed by a large number of surgeons with a variable yearly volume. Both patient and payor outcome is improved by concentrating CE patients in the hands of high-volume surgeons. While this trend is already evolving, the pace of this evolution can be expected to increase as payors recognize that regionalization of certain procedures lowers costs.

Conclusions

1. Carotid endarterectomy has a mortality rate of 2.1% and stroke rate of 3.7% over the decade in this population study.
2. Mortality rate decreased while postoperative stroke rate increased.
3. High-volume physicians significantly reduce mortality, postoperative stroke rate, and cost for patients undergoing CE, independent of patient complexity.
4. Payors can be expected to concentrate CE in the hands of HVPs.

The outcome criteria of this study include not only morbidity rate and mortality rate but costs. All providers need to realize that the resources for patient care are, and will continue to be, limited. We must take the initiative in the search for solutions.

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DISCUSSIONS

DR. MALCOLM O. PERRY (Nashville, Tennessee): This is an important study by Dr. Edwards and his associates and certainly a commendable effort. It is something that needs to be done and it's not very palatable to talk about regionalization among those of us who like to be independent in our activities. But it is something that we may all have to swallow, palatable or not.