Suboptimal Control of Atherosclerotic Disease Risk Factors After Cardiac and Cerebrovascular Procedures

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Background and Purpose—Undergoing a carotid endarterectomy, a coronary artery bypass graft, or a percutaneous coronary intervention provides an opportunity to optimize control of blood pressure and low-density lipoprotein.

Methods—Using Veterans Administration databases, we determined whether patients who underwent a carotid endarterectomy (n=252), coronary artery bypass graft (n=486), or percutaneous coronary intervention (n=720) in 2002 to 2003 at 5 Veterans Administration Healthcare Systems had guideline-recommended control of blood pressure and low-density lipoprotein in 12-month periods before and after a vascular procedure. Postprocedure control of risk factors across procedure groups was compared using χ² tests and multivariate logistic regression.

Results—The proportion of patients undergoing carotid endarterectomy who had optimal control of both blood pressure and low-density lipoprotein increased from 23% before the procedure to 33% after the procedure (P=0.05) compared with increases from 32% to 43% for coronary artery bypass graft (P=0.001) and from 29% to 45% for percutaneous coronary intervention (P=0.002). Compared with the carotid endarterectomy group, the percutaneous coronary intervention group was more likely to achieve optimal control of blood pressure (OR: 1.92, 95% CI: 1.42 to 2.59) or low-density lipoprotein (OR: 1.51, 95% CI: 1.01 to 2.26) and the coronary artery bypass graft group was more likely to achieve optimal control of blood pressure (OR: 1.53, 95% CI: 1.42 to 2.59). Postprocedure cardiology visits, increase in medication intensity, and greater frequency of outpatient visits were also associated with optimal postprocedure risk factor control.

Conclusions—Although modest improvements in risk factor control were detected, a majority of patients in each vascular procedure group did not achieve optimal risk factor control. More effective risk factor control programs are needed among most vascular procedure patients. (Stroke. 2007;38:929-934.)

Key Words: cardiac procedures ■ carotid prevention ■ secondary prevention

Because vascular procedures do not halt future development of atherosclerotic disease, guidelines recommend controlling atherosclerotic risk factors for patients who undergo them.1,2 In the United States in 2002, an estimated 134,000 patients underwent a carotid endarterectomy (CEA), 306,000 underwent coronary artery bypass grafts (CABG), and 640,000 underwent percutaneous coronary interventions (PCI).3

From a health systems perspective, reducing future atherosclerotic events in this population would make vascular procedures more cost-effective. These patients should be a promising group for such reductions. Preprocedure medical criteria have eliminated those with poor health or serious cognitive impairment. These patients have made a commitment to improve their health by risking possible perioperative mortality to reduce the future chance of atherosclerotic events. However, there are only a few studies about risk factor control after cardiac procedures in the United States4-5 and none after a CEA.

We studied whether patients who underwent a CEA, CABG, or PCI met guideline-recommended control of the atherosclerotic risk factors of blood pressure (BP) and low-density lipoprotein (LDL) after a vascular procedure. We hypothesized that patients undergoing cardiac procedures (CABG or PCI) would have better BP and LDL control compared with patients undergoing CEA because of greater availability of specialty programs and cardiologists among persons with a cardiac event.6
Methods

Setting and Study Population

The Veterans Administration Desert Pacific Healthcare Network encompasses 5 hospitals and 29 community-based clinics serving 1.2 million veterans residing in southern California and southern Nevada. The network maintains a database (called the Data Warehouse in this article) that contains demographic characteristics, utilization, and clinical data about Veterans Administration care within the network from 1999 to the present.

The study sample consisted of all patients who underwent the following vascular procedures between October 1, 2001, and September 30, 2003: a CEA (International Classification of Diseases, 9th Revision, Clinical Modification code 38.12), CAGB (International Classification of Diseases, 9th Revision, Clinical Modification codes 36.1 to 36.3), or PCI (International Classification of Diseases, 9th Revision, Clinical Modification code 36.0x or Current Procedural Terminology codes 92975, 92980 to 92984, 92995, and 92996). We excluded patients who underwent more than one type of procedure during this 2-year period. If patients underwent the same procedure more than once during the period (“repeat procedures”), we included only the most recent procedure.

Sample Characteristics

We extracted data on age, race/ethnicity (only available for 56% of the sample), and sex from the Data Warehouse. We determined date of death using the database and the Social Security Death Index. We extracted International Classification of Diseases, 9th Revision, Clinical Modification codes to identify patients with a history of myocardial infarction, angina, stroke, or transient ischemic attack (International Classification of Diseases, 9th Revision, Clinical Modification codes 410, 413, and 434 to 436) and to construct an adaptation of the Charlson Index.

Care Processes

We extracted the number and specialty of outpatient clinic visits. We eliminated visits related to procedures (such as an electroencephalogram) because it was unlikely that management of risk factors would occur during these encounters. Because the Data Warehouse does not contain inpatient visits, we could not determine whether patients were enrolled in inpatient cardiac rehabilitation programs.

Recent increases in a patient’s medication regimen are strongly associated with subsequent control of atherosclerotic risk factors. We extracted from the Data Warehouse all antihypertensive and antihyperlipidemic medications issued to our sample. The intensity of a patient’s medication regimen for a risk factor was considered to be increased if the dosage was increased or medication was begun for that risk factor.

Blood Pressure and Low-Density Lipoprotein Control

The time interval of 0 to 12 months before the date of a vascular procedure was called the “preprocedure period.” The time period of 3 to 15 months after the date of a vascular procedure was called the “postprocedure period,” because cholesterol levels may be transiently depressed for up to 2 months after an operation, the beginning of the postprocedure period was set at 3 months after the vascular procedure.

We extracted all BP (including both systolic blood pressure and diastolic blood pressure) and LDL values in a patient’s preprocedure and postprocedure periods. Values obtained during hospitalizations and the emergency room were excluded because they may not be representative of BP values when patients are not in the hospital. We used the average of the 2 most recent BP values during each time period; if there was only one BP measurement available, we used that value. We used guidelines in effect during the study period to define optimal BP and LDL control (systolic blood pressure ≤140 mm Hg, diastolic blood pressure ≤90 mm Hg, LDL ≤2.58 mmol/L [100 mg/dL]).

Analysis

Analyses were performed using SAS, version 9 (SAS Institute Inc) and Stata, version 9 (Stata Corp). We used 2-sample t tests and χ² tests to compare characteristics of patients undergoing different vascular procedures. We dropped from our analysis patients who were missing a BP or LDL measurement during either the preprocedure or postprocedure periods. We used χ² tests to examine improvements in BP and LDL from the preprocedure to the postprocedure period as dichotomous measures reflecting optimal control; we used paired t tests to examine them as continuous measures.

We constructed staged sets of logistic regression models to examine predictors of optimal BP and LDL control accounting for clustering by site where the procedure was performed using the Huber-White correction. The first models included only the type of vascular procedure. The second model added patient characteristics to the first model: age, history of atherosclerotic events, the Charlson Index, preprocedure control of risk factors, and the year the procedure was performed. The third model added postprocedure utilization variables to the second model: increased intensity of medication regimen; visits to specialty clinics; and total number of primary care, neurology, cardiology, and cardiac rehabilitation visits.

We performed the following sensitivity analyses. Optimal risk factor control was categorized using more lenient cutoffs: systolic blood pressure ≤145 mm Hg, diastolic blood pressure ≤95 mm Hg, and LDL ≤110 mg/dL. We compared BP control using the last single BP measure versus the average of the last 2 BP values in each time period.

To assess the likelihood that missing data could change our findings, we ran logistic models using data imputed by 2 different methods. First, we imputed suboptimal control of a risk factor for patients with missing values in either the preprocedure or postprocedure period. Second, we performed 5 iterations of a hot-deck imputation stratifying by age and Charlson Index.

We obtained approval for this project from the Veterans Administration Greater Los Angeles Healthcare System Institutional Review Board.

Results

During the study period, we identified 1787 vascular procedures that were performed on 1680 patients. For the 105 patients with repeat procedures of the same type, we included only the most recent procedure. We then excluded 142 patients who underwent more than one type of vascular procedure during the study period and 80 patients (11 CEA, 33 CABG, and 36 PCI, P=0.32) who died in the first 15 months after the vascular procedure. This yielded a final sample of 1458 patients: 252 CEA, 486 CABG, and 720 PCI. BP measurements in both preprocedure and postprocedure time periods were available for patients undergoing 225 CEA (89%), 427 CABG (88%), and 578 PCI (80%). LDL measurements in both time periods were available for 190 patients undergoing CEA (75%), 389 CABG (80%), and 527 PCI (73%).

Compared with cardiac procedure patients, patients undergoing CEA were older, had more comorbidity, were more likely to have had a cerebrovascular event, and less likely to have had a cardiac event (Table 1). Over 85% of the patients in each vascular procedure group had a postprocedure primary care visit. However, over 60% of patients undergoing CABG and those undergoing PCI had a postprocedure cardiology visit compared with only 17% of patients undergoing CEA with a postprocedure neurology visit.

Analyzing changes in risk factor measurements from preprocedure to postprocedure periods as continuous variables, we found improvements in systolic blood pressure, diastolic
blood pressure, and LDL values for each vascular procedure group except patients undergoing CEA who had improvement only in LDL values (Table 2). We also found improvements in overall BP (P's < 0.001) and LDL (P's < 0.01) for each vascular procedure when optimal risk factor control was analyzed as dichotomous variables (Figure). However, despite these improvements, less than half of all patients in each vascular procedure group (33% of CEA, 43% of CABG, and 45% of PCI) attained optimal control of both BP and LDL according to national guidelines by the end of the postprocedure period.

Compared with patients undergoing CEA, the PCI group was more likely to have postprocedure optimal control of BP and LDL, and the CABG group was more likely to have postprocedure optimal BP control (Table 3). After patient characteristics were added to the models, CABG and PCI remained significantly associated with postprocedure BP control. After utilization variables were added to the models, type of vascular procedure was no longer associated with optimal BP or LDL control. History of an atherosclerotic event, having a postprocedure cardiology visit, and a greater number of postprocedure visits were associated with optimal postprocedure BP control. An increase in cholesterol medication intensity and a greater total number of postprocedure visits were associated with optimal postprocedure LDL control.

In sensitivity analyses, 44% in the CEA group, 57% in the CABG group, and 59% in the PCI group met the more

### TABLE 1. Characteristics and Postprocedure Utilization of Patients Undergoing Vascular Procedures

<table>
<thead>
<tr>
<th>Procedure</th>
<th>CEA (n=252)</th>
<th>CABG (n=486)</th>
<th>PCI (n=720)</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean age, years±SD</td>
<td>68.7±9.2</td>
<td>64.5±9.2</td>
<td>62.7±9.6</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Male</td>
<td>246 (98)</td>
<td>482 (99)</td>
<td>713 (99)</td>
<td>0.14</td>
</tr>
<tr>
<td>White*</td>
<td>115 (82)</td>
<td>189 (75)</td>
<td>317 (74)</td>
<td>0.15</td>
</tr>
</tbody>
</table>

#### History of
- Myocardial infarction or angina: 56 (22) vs. 318 (65) vs. 572 (79) <0.001
- Stroke or transient ischemic attack: 122 (48) vs. 73 (15) vs. 99 (14) <0.001

#### Charlson Index
- Low (0 or 1): 22 (8) vs. 93 (19) vs. 189 (26) <0.001
- Medium (2–4): 133 (53) vs. 255 (52) vs. 344 (48)
- High (≥5): 97 (38) vs. 138 (28) vs. 187 (26)

#### Had at least one postprocedure
- Primary care visit: 229 (91) vs. 440 (91) vs. 623 (87) 0.05
- Cardiology visit: 35 (14) vs. 325 (67) vs. 449 (62) <0.001
- Neurology visit: 42 (17) vs. 36 (7) vs. 49 (7) <0.001
- Cardiac rehabilitation visit: 17 (7) vs. 65 (13) vs. 78 (11) 0.02

#### Mean no. of postprocedure outpatient visits±SD†
- 4.7±3.8 vs. 6.4±4.9 vs. 5.8±4.4 <0.001

#### Data are expressed as no. (%) unless otherwise specified. Postprocedure is the time period of 3 to 15 months after the vascular procedure.

*Race/ethnicity data was missing for 44% of the sample.
†Mean no. of visits included only primary care, cardiology, neurology, and cardiac rehabilitation outpatient visits.

### TABLE 2. Postprocedure Risk Factor Values and Changes From Preprocedure Values

<table>
<thead>
<tr>
<th>Procedure</th>
<th>CEA</th>
<th>CABG</th>
<th>PCI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Postprocedure Value</td>
<td>Change From Preprocedure</td>
<td>Postprocedure Value</td>
<td>Change From Preprocedure</td>
</tr>
<tr>
<td>Systolic blood pressure, mm Hg</td>
<td>136.9 (134.5 to 139.2)</td>
<td>−2.3 (−4.9 to −0.3)</td>
<td>131.6 (129.9 to 133.3)</td>
</tr>
<tr>
<td>Diastolic blood pressure, mm Hg</td>
<td>71.2 (69.7 to 72.6)</td>
<td>−0.4 (−1.7 to −0.0)</td>
<td>72.3 (71.4 to 73.3)</td>
</tr>
<tr>
<td>LDL, mmol/L</td>
<td>2.69 (2.57 to 2.81)</td>
<td>−0.16† (−0.29 to −0.04)</td>
<td>2.50 (2.42 to 2.58)</td>
</tr>
</tbody>
</table>

95% CI in parentheses. Postprocedure is the time period of 3 to 15 months after the vascular procedure; preprocedure is the time period time period of 0 to 12 months before the vascular procedure.

*P<0.05 by paired t tests comparing mean preprocedure versus postprocedure values.
†P<0.001 by paired t tests comparing mean preprocedure versus postprocedure values.
lenient criteria for optimal BP and LDL control (results not shown). Using the lenient criteria, patients undergoing cardiac procedure remained significantly associated with optimal BP and LDL control in the full set of multivariate logistic models. Using a single BP measure instead of an average of 2 BP measures, the only difference in significance among vascular procedure type was that CABG (versus CEA) now only trended toward significance ($P=0.06$). When we used both methods described for imputing data, the resulting logistic models yielded identical findings for the significance of type of vascular procedure as the original models.

Proportion of patients with optimal risk factor control in preprocedure and postprocedure periods. Error bars indicate 95% CIs. Preprocedure is the time period of 0 to 12 months before the vascular procedure; postprocedure is the time period of 3 to 15 months after the vascular procedure. $P<0.05$ by $\chi^2$ tests for all comparisons of optimal preprocedure versus optimal postprocedure overall BP, LDL, and combined overall BP and LDL control for each vascular procedure group.

![Graph showing proportion of patients with optimal risk factor control in preprocedure and postprocedure periods.](Graph)

**TABLE 3. Staged Logistic Models for Optimal Postprocedure Risk Factor Control**

<table>
<thead>
<tr>
<th></th>
<th>Model 1 OR [95% CI] From Model With Only Type of Procedure</th>
<th>Model 2 OR [95% CI] From Model 1 Plus Clinical Variables</th>
<th>Model 3 OR [95% CI] From Model 2 Plus Postprocedure Utilization Variables</th>
</tr>
</thead>
<tbody>
<tr>
<td>Blood pressure control</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CABG (CEA)</td>
<td>1.53 [1.10 to 2.12]*</td>
<td>1.36 [1.10 to 1.69]*</td>
<td>0.96 [0.71 to 1.30]</td>
</tr>
<tr>
<td>PCI (CEA)</td>
<td>1.92 [1.42 to 2.59]*</td>
<td>1.79 [1.44 to 2.21]*</td>
<td>1.30 [0.98 to 1.72]</td>
</tr>
<tr>
<td>Age</td>
<td>1.00 [1.00 to 1.01]</td>
<td>1.00 [0.99 to 1.01]</td>
<td></td>
</tr>
<tr>
<td>Medium Charlson Index (low)</td>
<td>1.06 [0.94 to 1.19]</td>
<td>0.97 [0.91 to 1.04]</td>
<td></td>
</tr>
<tr>
<td>High Charlson Index (low)</td>
<td>1.12 [0.90 to 1.39]</td>
<td>0.97 [0.87 to 1.08]</td>
<td></td>
</tr>
<tr>
<td>History of atherosclerotic event</td>
<td>1.23 [1.04 to 1.47]*</td>
<td>1.18 [1.03 to 1.35]*</td>
<td></td>
</tr>
<tr>
<td>Blood pressure medication increase†</td>
<td>1.07 [0.90 to 1.28]</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Outpatient cardiac rehabilitation†</td>
<td>1.31 [0.98 to 1.75]</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Outpatient cardiology visit†</td>
<td>1.51 [1.13 to 2.00]*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Outpatient neurology visit†</td>
<td>0.73 [0.52 to 1.03]</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total outpatient visits‡</td>
<td>1.36 [1.07 to 1.75]*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>LDL control</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CABG (CEA)</td>
<td>1.40 [0.94 to 2.09]</td>
<td>1.37 [0.85 to 2.21]</td>
<td>1.29 [0.89 to 1.88]</td>
</tr>
<tr>
<td>PCI (CEA)</td>
<td>1.51 [1.01 to 2.26]*</td>
<td>1.42 [0.95 to 2.12]</td>
<td>1.39 [1.00 to 1.94]</td>
</tr>
<tr>
<td>Age</td>
<td>1.00 [1.00 to 1.01]</td>
<td>1.00 [1.00 to 1.01]</td>
<td></td>
</tr>
<tr>
<td>Medium Charlson Index (low)</td>
<td>1.06 [0.70 to 1.61]</td>
<td>1.06 [0.76 to 1.48]</td>
<td></td>
</tr>
<tr>
<td>High Charlson Index (low)</td>
<td>1.05 [0.63 to 1.73]</td>
<td>1.00 [0.64 to 1.54]</td>
<td></td>
</tr>
<tr>
<td>History of atherosclerotic event</td>
<td>1.16 [1.00 to 1.36]</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cholesterol medication increase†</td>
<td>2.03 [1.42 to 2.89]*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Outpatient cardiac rehabilitation†</td>
<td>0.75 [0.55 to 1.02]</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Outpatient cardiology visit†</td>
<td>1.09 [0.97 to 1.21]</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Outpatient neurology visit†</td>
<td>1.30 [0.81 to 2.10]</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total outpatient visits‡</td>
<td>1.29 [1.16 to 1.45]*</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Reference group in parentheses. All models account for clustering by site of procedure. Models 2 and 3 are adjusted for preprocedure control and year of procedure.

*OR $P$ value $<0.05$.
†The time period of 3 to 15 months after the vascular procedure.
‡Logarithmic transformation of (total postprocedure outpatient visits+1) was entered in the model.
Discussion

Although we detected modest improvements in BP and LDL control, a majority of patients in each vascular procedure group did not attain optimal control of BP and LDL in the year after a vascular procedure. Studies on vascular procedures have typically used outcomes such as 30-day mortality, which are important measures of quality. However, they overlook the opportunity to improve control of underlying atherosclerotic risk factors, conditions that patients undergoing vascular procedure will need to manage for the rest of their lives.

Studies of BP and LDL control after cardiac procedures outside the United States have shown varying ranges of improvements in risk factor control.14–16 Our study demonstrates greater improvement in risk factor control among patients undergoing cardiac procedure compared with previous U.S. studies.4,5

Although there is a study of medication use after a CEA,17 there are no studies on risk factor control. We found that control of risk factors among patients undergoing CEA was not different from patients undergoing cardiac procedures after adjusting for clinical and utilization variables. This is a hopeful message because it suggests that control of risk factors among patients undergoing CEA may be improved if they obtained similar intensity of care as patients undergoing cardiac procedures.

Like in previous studies, a cardiology visit was associated with optimal postprocedure control in our models of BP control.18 We could not form any firm conclusion about a neurology visit’s effect because so few patients had such a postprocedure neurology visit. By assuming a similar responsibility for risk factor management as cardiologists, neurologists may improve risk factor control among patients undergoing CEA. One study reported that a stroke clinic staffed by a stroke neurologist and specialist nurses improved control of hypertension and hyperlipidemia.19 Another study reported that a stroke clinic did not improve risk factor control; however, in that study, the authors wrote that they rarely prescribed medications for risk factor control.20 Therefore, it is not surprising that this stroke clinic did not improve control of risk factors. Neurologists are more likely to address risk factor control than a CEA surgeon.21 In addition, implementation of new models of care delivery such as disease management programs and care teams have led to improved outcomes for other chronic conditions.22 We believe these interventions should be adapted for improving atherosclerotic prevention care and tested in randomized, controlled trials.

Although some clinicians may not apply the National Cholesterol Education Program guidelines to patients with asymptomatic carotid stenosis, these patients have a considerable risk of coronary disease and need effective atherosclerotic preventive care.23 A minority of patients undergoing patients may also possess intracranial stenoses and therefore, may be less tolerant of lower BPs than patients undergoing cardiac procedures. However, we do not believe these clinical scenarios account for the entire difference in risk factor control between patients undergoing a CEA versus a cardiac procedure.

Strengths and Limitations

A strength of this study is the collection of BP and LDL measurements on a large number of patients undergoing vascular procedures. In addition, because Veterans Administration care is usually not restricted by a patient’s ability to pay, our study diminishes financial barriers to accessing health care.

The study has the following limitations. Because there were missing data on race on 44% of our sample, we could not perform valid analyses on their impact on risk factor control. We did not have data on other risk factors such as smoking status nor did we have data on lifestyle counseling delivered during clinic visits. Although we do not have data on the extent of non-Veterans Administration care obtained by our sample, the presence of so many suboptimally controlled BP and LDL measurements indicates the need for better risk factor management, no matter where care was obtained. Finally, suboptimal risk factor control may not always reflect poor quality of care because some patients may have refractory BP and LDL levels despite aggressive attempts by providers to control them.

Regarding generalizability, most of the patients in the sample were older males, and the findings may not apply to younger and female patients. Although our data came from just one healthcare system, Veterans Health Administration care has been shown to be either as good as care delivered outside the Veterans Health Administration.24

Summary

Although we found differences in BP and LDL control across the vascular procedure groups, our study also demonstrated considerable room for improvement for all vascular procedure groups. Effective programs to manage atherosclerotic risk factors are needed among most patients undergoing vascular procedures, especially among patients undergoing CEA.

Acknowledgments

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Disclosures

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References


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In the article entitled “Suboptimal Control of Atherosclerotic Disease Risk Factors After Cardiac and Cerebrovascular Procedures” by Cheng et al,¹ the values in Table 3, under the “LDL control” section, have been displaced downward by one line. The results of “CABG (CEA)” have been incorrectly placed in the “PCI (CEA)” row, the “PCI (CEA)” results incorrectly placed in the “Age” row, and so forth, extending to the last row, in which the “Total outpatient visits” results are incorrectly placed in an undesignated row one line down. All values under the “LDL control” section should thus be moved one row up. The publisher regrets this error.

The corrected version of this article can now be viewed online at http://stroke.ahajournals.org.

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