Severity of Aortic Atheromatous Disease Diagnosed by Transesophageal Echocardiography Predicts Stroke and Other Outcomes Associated with Coronary Artery Surgery: A Prospective Study

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Advanced atheromatous disease of the thoracic aorta identified by transesophageal echocardiography (TEE) is a major risk factor for perioperative stroke. This study investigated whether varying degrees of atherosclerosis of the descending aorta, as assessed by TEE, are an independent predictor of cardiac and neurologic outcome in patients undergoing coronary artery bypass grafting (CABG). Intraoperative TEE of the descending aorta was performed on 189 of 248 patients participating in a randomized controlled trial of low (50-60 mm Hg) or high (80-100 mm Hg) mean arterial pressure during cardiopulmonary bypass for elective CABG. Aortic atheromatous disease was graded from I to V in order of increasing severity by observers blinded to outcome. Measured outcomes were death, stroke, and major cardiac events assessed at 1 wk and 6 mo. Nine of the 189 patients with TEE examinations had perioperative strokes by 1 wk. At 1 wk, no strokes had occurred in the 123 patients with atheroma Grades I or II, while the 1-wk stroke rate was 5.5% (2/36), 10.5% (2/19), and 45.5% (5/11) for Grades III, IV, and V, respectively (Fisher's exact test, P = 0.00001). For 6-mo outcome, advancing aortic atheroma grade was a univariate predictor of stroke (P = 0.00001) and death (P = 0.03). By 6 mo there were one additional stroke, three additional deaths, and one additional major cardiac event. Atheromatous disease of the descending aorta was a strong predictor of stroke and death after CABG. TEE determination of atheroma grade is a critical element in the management of patients undergoing CABG surgery.

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Coronary artery bypass grafting (CABG) prolongs life for patients with severe triple vessel or left main coronary artery disease (1,2). Stroke, however, remains one of the most devastating complications after this procedure (3). Overall postoperative cardiac morbidity has been declining over the past years, in part because of advances in anesthetic and surgical techniques. However, the incidence of neurologic complications has been largely unchanged, with stroke occurring in 1% to 5% of patients (4-6). Risk factors for perioperative stroke include increased age (4), previous cerebrovascular accidents, carotid stenosis (5), atrial fibrillation, patent foramen ovale and other intracardiac shunts (7), the presence of intracardiac thrombus, valvular disease, and atheromatous disease of the ascending thoracic aorta and aortic arch (6,8). Transesophageal echocardiography (TEE) was superior to chest radiograph and cardiac catheterization in detecting aortic atheromatous disease and atheroma correlated with the occurrence of stroke (9). Previous studies have demonstrated the significance of ascending aorta and arch atheroma in predicting stroke after cardiopulmonary bypass (CPB) (9,10). In elderly patients, risk of perioperative stroke...
was significantly increased when atheromata had mobile components (9). However, these studies did not prospectively evaluate neurologic outcome by observers blinded to intraoperative TEE results, or control for confounding variables.

The goal of this study was to determine whether atheromatous disease of the descending thoracic aorta, as diagnosed by TEE, is independently predictive of stroke and other morbidity or mortality in patients undergoing elective CABG. We also attempted to identify clinical predictors of atheroma grade. The study was performed in the context of a prospective, randomized, controlled trial which evaluated the effect of blood pressure management during CPB on cardiac and neurologic outcome (11). Patients were observed prospectively, evaluated preoperatively and postoperatively by blinded observers, and assessed for mortality, and cardiac and neurologic outcome at one week and six months after surgery (11).

Methods

Patient Eligibility and Baseline Neurologic Evaluation

Between October 1991 and February 1994, 248 patients undergoing elective multivessel CABG were enrolled in a study examining the influence of mean arterial pressure (MAP) during CPB on cardiac and neurologic morbidity and quality of life after CABG (11). Exclusion criteria included inability to complete neurologic testing, participation in other studies, and inability to return for follow-up evaluation. Preoperatively, all patients underwent detailed cardiologic and neurologic examinations by a study cardiologist and neurologist blinded to blood pressure management. Detailed demographic, cardiac, and neurologic characteristics were compiled. Symptom duration was the time from the onset of anginal symptoms to the time of surgery. The Charlson comorbidity score, a measure of comorbid illness, with a higher score representing a greater burden of comorbidity (12), was also calculated for each patient. Institutional review board approval and informed, written consent were obtained.

TEE Examination

TEE evaluation of the descending thoracic aorta was performed intraoperatively after anesthetic induction and intubation on a cohort of 189 patients from the 248-patient study group, based on availability of TEE equipment, the ability to insert the TEE probe, and the absence of contraindications to TEE, (e.g., esophageal disease). All examinations were performed with either monoplane or biplane 5 MHz TEE probes (Acuson, Mountain View, CA) and Acuson 128 XP® systems (Acuson) and recorded on VHS tapes for later off-line interpretation. Aortic pathology was graded off-line, based on transverse images of the descending thoracic aorta just distal to the arch and complemented by longitudinal images when obtainable. Aortic grade was determined by the consensus evaluation of two anesthesiologists experienced in TEE, blinded to intraoperative blood pressure management, using an increasing scale from I to V, according to the following criteria (10): Grade I, normal to mild intimal thickening; Grade II, severe intimal thickening without protruding atheroma; Grade III, atheroma protruding less than 5 mm; Grade IV, atheroma protruding greater than or equal to 5 mm; Grade V, atheroma of any size with mobile components. The reproducibility of this scale has been demonstrated (13).

Intraoperative Course and Management

In the parent study, patients were randomly assigned on arrival to the operating room to one of two MAP strategies during CPB: low (50–60 mm Hg) or high (80–100 mm Hg) MAP group. Subsequent analysis of the data from the parent study demonstrated that patients were balanced with respect to demographics and perioperative management except for MAP during CPB (11). All hemodynamic variables were downloaded every 10 s from a Marquette 7000® monitor (Marquette, Milwaukee, WI) to a laptop computer. All operative events, pharmacological agents, and CPB variables were recorded on-line by a research assistant using a locally developed program that was synchronized with Marquette downloading. Anesthesia was induced with thiopental (1–2 mg/kg) and fentanyl (25 μg/kg). Pancuronium provided muscle relaxation. Anesthesia was maintained with a combination of the following: fentanyl boluses (1–5 μg/kg, to a total of 50–70 μg/kg), midazolam boluses (1 mg) and/or isoflurane (pre- and post-CPB periods only).

Perfusion techniques used during CPB were identical for both groups and are detailed elsewhere (11). Nonpulsatile CPB, membrane oxygenation, 40-μ blood filter, systemic cooling to 30–32°C, and α-stat pH management were common features of perfusion. A centrifugal or a roller pump was used, based on availability. Flow rates were predetermined at 1.6 and 2.4 L min⁻¹ m⁻² during cooling and warming, respectively. Pump flow was constant except for transient alterations to facilitate surgical exposure. Target MAP on CPB for the intervention group MAP was 80–100 mm Hg and for the control group 50–60 mm Hg. If the MAP increased above target level, norepinephrine or metaraminol was infused. The surgeons were blinded to the descending aortic atheroma grade, as the classification was performed later, off-line.
There were no differences in technical aspects of the CABG procedure between the high and low pressure groups; operative mortality, aortic cross clamp time, duration of CPB, and number of grafts did not differ (11).

Follow-up and Outcome Definition

The study cardiologist evaluated patients on postoperative Days 1 or 2, and 7, and the neurologist evaluated patients preoperatively, and on postoperative Days 2 and 7. Both were blinded to the intraoperative management and the TEE atheroma grades. Standardized blinded examinations were also performed at 6 mo postoperatively.

Stroke was defined as a fixed, focal neurologic deficit (12). Death was any which occurred within 6 mo after surgery. Major cardiac events included myocardial infarction, pulmonary edema, adult respiratory distress syndrome, low flow state/cardiogenic shock, or cardiopulmonary arrest (11).

Statistical Analysis

In order to ascertain whether selection bias might have occurred, the characteristics of the 189 patients who had TEE examinations performed and those of the 59 patients who did not have TEE performed were compared using large-sample \( \chi^2 \) or \( t \)-testing as appropriate to the distribution of these variables.

For the main analysis, the relationship between the principal outcomes and atheroma grade was analyzed in a univariate fashion using standard \( \chi^2 \) testing for a 2 \( \times \) 5 contingency table, and Fisher’s exact test when more than 50% of cells had expected counts that were less than 5. A \( \chi^2 \) test for linear trend of proportions was used to test the quantitative association between atheroma grade and outcome.

Clinical variables of interest listed in Table 2 were assessed for their value as predictors of outcome and atheroma grade using similar methods. To determine whether atheroma grade remained an independent predictor of outcomes, variables identified as predictive of outcome in the univariate analysis were incorporated into standard multivariate logistic regression analysis (14).

Statistical analyses were done using SAS software for PC, version 6.08 (SAS Institute, Cary, NC) and all \( P \) values were two-sided.

Results

Baseline Characteristics of Patients Evaluated by TEE

The demographics on the 189 study patients who had TEE performed are presented in Table 1. Analysis of demographics for patients who had TEE and those who did not have TEE revealed no statistically significant differences in the baseline characteristics presented in Table 1 with the single exception of cardiac symptom duration. Patients who had TEE performed had cardiac symptoms for a mean of 5.7 yr (median = 2, range 0–40 yr) versus a mean of 3.8 yr (median = 1, range 0–25 yr) for those patients without TEE (\( P = 0.04 \)).

TEE Diagnosed Atheroma Distribution and Outcomes

Regarding the frequency distribution of atheroma of the descending thoracic aorta as graded by TEE, the majority of patients (123/189, or 65%) had mild to moderate aortic disease (Grades I and II). Fewer patients had advanced atheroma grades; 19%, 10%, and 6% had Grades III, IV, and V, respectively (Figure 1).

At 1 wk, there were seven deaths, nine strokes, and nine major cardiac events. Atheroma grade predicted stroke (\( P = 0.00001 \)) but did not predict the occurrence of death (\( P = 0.18 \)) or major cardiac events (\( P = 0.16 \)).

Stroke rate increased with severity of atheroma grade (\( P < 0.00005 \), test for trend) (Figure 2). No strokes occurred by 1 wk in patients with atheroma Grades I and II. All observed strokes occurred in patients with advanced atheromatous disease (Grades III, IV, and V). Collectively, 9 of 66 (13.6%) of these patients had strokes perioperatively. The stroke rate was 5.5% and 10.5% for Grades III and IV, respectively. Five of 11 patients (45.5%) with mobile atheroma of the descending aorta (Grade V), sustained a stroke after CABG.

As of 6 mo postsurgery, there were five additional outcomes. These included one stroke on postoperative Day 9 in a patient with a Grade II aorta, one myocardial infarction diagnosed 1.5 mo postoperatively, and three deaths—one from multisystem failure, one from the complications of stroke on postoperative Day 4, and one from lung cancer. Atheroma grade predicted the 6-mo outcomes of stroke (\( P = 0.00001 \)), and death (\( P = 0.028 \)) but did not predict the occurrence of major cardiac outcomes at 6 mo (\( P = 0.16 \)).

Independence of Atheroma Grade as a Predictor of Neurologic Outcome

All preoperative demographic and clinical factors in Table 1 were examined to determine whether they were univariate predictors of neurologic outcome at 1 wk (and 6 mo). Age (\( P = 0.07 \)), comorbidity score (\( P = 0.03 \)), and diabetes mellitus (\( P = 0.004 \)) were statistically significantly associated with the occurrence of stroke at 1 wk when assessed in a univariate fashion. In a multivariate logistic regression analysis incorporating these three factors and atheroma grade,
atheroma grade remained an independent predictor of the risk of stroke (P = 0.0008) within 1 wk after surgery, even when these univariate clinical predictors of outcome were considered simultaneously.

Similarly, at 6 mo, comorbidity score (P = 0.05) and diabetes mellitus (P = 0.008) were associated with the occurrence of stroke. A multivariate logistic analysis incorporating these two variables and atheroma grade identified atheroma grade as an independent predictor of stroke at 6 mo postoperatively (P = 0.0001).

Clinical Predictors of Advanced Aortic Atheroma Grade

To ascertain whether patients with advanced atheromatous grades could be identified a priori according to baseline clinical or demographic characteristics, profiles of patients across the atheroma grades were compared (Table 2). Analysis across the atheroma groups for all features reported in Table 1 showed the following to be univariate predictors: age (P = 0.04), cardiac symptom duration (P = 0.01), history of previous angioplasty (P = 0.036), previous focal neurologic deficit (P = 0.02), history of decompensated congestive heart failure (P = 0.05) symptomatic peripheral vascular disease (P = 0.004), and higher comorbidity scores (P = 0.02). The atheroma groups did not differ by gender, dialysis, ejection fraction, or the presence of left main coronary artery disease. In a multivariate regression analysis, these factors account for 22% (multiple R² = 0.218) of the variability in TEE-determined atheroma grade.
TEE Atheroma Grade and MAP During CPB

Of the 189 TEE-evaluated patients, 88 had been assigned to low MAP and 101 to high MAP during CPB. The two groups were similarly managed throughout the CPB period except with respect to MAP during CPB. As intended in the overall trial, MAP during CPB was 59.2 ± 5.4 mm Hg versus 81.8 ± 7.8 in the low and high MAP groups, respectively.

Analysis was performed on the demographics for the high and low blood pressure management groups and no statistically significant differences were demonstrated (11). There was no statistically significant difference in type of pump used and aortic atheroma grade (P = 0.1) (11). Pre- and postbypass periods of hypotension were also analyzed, and did not differ according to atheroma grade or MAP group.

Perioperative stroke rate was associated with both atheroma grade as noted above and MAP management as previously reported (11) (Fig. 3). Two of 30 patients with advanced aortic disease (Grades III, IV, and V) managed during CPB at high MAP had strokes compared with 7 of 36 managed with low MAP. Four of six (66.7%) patients with Grade V atheroma had strokes when managed at low pressure and one of five (20%) had strokes when managed at high MAP during CPB; however, none of these comparisons reached statistical significance. Of note, the additional stroke included as a 6-mo outcome occurred on postoperative Day 9 in a patient with a Grade II aorta, managed at high pressure.

Discussion

The exact pathophysiology linking severity of atheromatous disease of the thoracic aorta with stroke incidence associated with CABG remains unclear (15). Embolization of atheromatous material has been suggested as an explanation. Atheroemboli have been found in cortical arterioles adjacent to infarcts in patients dying after CABG (16). Several studies have demonstrated a correlation between aortic disease and stroke rates after cardiac surgery (8,10). However, these studies were either retrospective or did not have blinded assessment of neurologic outcome.

The methodological strengths of this study include its prospective controlled nature, with outcome assessment performed by observers blinded to intraoperative blood pressure management and aortic atheromatous grade. In addition, baseline and follow-up neurologic and cardiac outcomes were assessed in a uniform fashion by a neurologist and cardiologist, respectively. Cardiac and neurologic follow-up at one week was completed on 100% of patients and on 96% of patients at six months (11).

TEE examinations were performed on only 189 of 248 patients enrolled in this trial, primarily because of availability of the TEE machine. Nonetheless, we attempted to determine whether those who had TEE differed systematically from those without it. Analysis of patient demographics in this study revealed that those who had TEE performed differed only with respect to symptom duration.

The ascending aorta and arch are the common sites for cannulation and manipulation during cardiac surgery and can be evaluated echocardiographically. In this study, TEE-diagnosed advanced atheromatous disease of the descending aorta was an independent predictor of stroke and death. Examination of the stroke rate by atheroma grade prompts reconsideration of current practice. We have previously demonstrated the reproducibility of TEE assessment of aortic
atheromatous disease (13). This supports the widespread applicability of this technique across centers and specialties. Many centers have made intraoperative TEE a routine part of management of CABG patients (17). The utility of TEE as a screening tool for aortic atheroma has also been demonstrated (18).

While severity of aortic disease increases as a function of age and duration of cardiac symptoms, there are insufficient reliable predictors of atheroma grade. Patients with higher atheroma scores were older, had a longer duration of cardiac symptoms, increased incidence of previous major neurological events, and higher comorbidity scores. These findings are consistent with other reports in which age, hypertension, diabetes, peripheral vascular disease, and history of neurologic events correlated with advanced aortic atheromatous disease (9,10,19). Importantly, patients in this study with Grade V aortic disease had only an 18.2% incidence of symptomatic peripheral vascular disease (Table 2).

Complete imaging of the thoracic aorta is not possible by TEE even with bi- or omniplane scanning (20). In contrast, the descending aorta can be completely imaged even with monoplane scanning. Studies examining the correlation between descending aortic atheromatous disease and disease of the aortic arch and ascending aorta have conflicting results. Some studies indicate good correlation between the three aortic segments (9,21), while one recent abstract found a very poor correlation between descending aortic disease and ascending aortic disease assessed by epiaortic imaging techniques (22). Nonetheless, clinically significant discrepancies between the two segments are rare; it is unusual to find severe disease in the ascending aorta or aortic arch and little pathology in the descending aorta. Similarly, patients without disease in the descending aorta rarely have TEE-detected disease of the ascending aortic sections by epiaortic scanning (21). Thus, TEE of the descending aorta can be a valuable screening tool for aortic pathology. Furthermore, TEE has been found 100% sensitive for atheroma of the ascending aorta but with a specificity

### Table 2. Baseline Preoperative Clinical Characteristics Across the Five Aortic Atheroma Grades

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Grade I (n = 43)</th>
<th>Grade II (n = 80)</th>
<th>Grade III (n = 36)</th>
<th>Grade IV (n = 19)</th>
<th>Grade V (n = 11)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (yr, mean ± sd)*</td>
<td>59.7 ± 9.0</td>
<td>65.4 ± 8.7</td>
<td>71.1 ± 7.1</td>
<td>68.3 ± 9.4</td>
<td>73.5 ± 6.3</td>
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<tr>
<td>Males</td>
<td>79.1</td>
<td>80.0</td>
<td>83.3</td>
<td>57.9</td>
<td>90.9</td>
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<tr>
<td>Symptom duration (yr, mean ± sd)*</td>
<td>3.4 ± 5.6</td>
<td>5.2 ± 7.5</td>
<td>8.1 ± 9.5</td>
<td>6.1 ± 7.5</td>
<td>9.3 ± 12.9</td>
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<td>History of previous angioplasty*</td>
<td>11.6</td>
<td>12.5</td>
<td>2.8</td>
<td>5.3</td>
<td>0.0</td>
</tr>
<tr>
<td>Ejection fraction (% , mean ± sd)</td>
<td>48.3 ± 12.1</td>
<td>49.5 ± 13.5</td>
<td>47.6 ± 10.7</td>
<td>40.5 ± 14.3</td>
<td>49.3 ± 14.5</td>
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<tr>
<td>Left main coronary artery disease</td>
<td>14.0</td>
<td>11.3</td>
<td>16.7</td>
<td>5.3</td>
<td>9.1</td>
</tr>
<tr>
<td>Previous myocardial infarction</td>
<td>39.5</td>
<td>47.5</td>
<td>38.9</td>
<td>63.2</td>
<td>27.3</td>
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<tr>
<td>Congestive heart failure*</td>
<td>4.7</td>
<td>7.6</td>
<td>11.1</td>
<td>15.8</td>
<td>9.1</td>
</tr>
<tr>
<td>Valvular heart disease (aortic or mitral)</td>
<td>2.3</td>
<td>3.8</td>
<td>8.3</td>
<td>5.3</td>
<td>0.0</td>
</tr>
<tr>
<td>Preoperative major focal neurologic deficit*</td>
<td>4.7</td>
<td>3.8</td>
<td>16.7</td>
<td>10.5</td>
<td>0.0</td>
</tr>
<tr>
<td>Comorbidity index*</td>
<td></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0-1</td>
<td>69.7</td>
<td>57.5</td>
<td>66.7</td>
<td>15.8</td>
<td>36.4</td>
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<tr>
<td>2-3</td>
<td>25.6</td>
<td>25.0</td>
<td>16.6</td>
<td>68.5</td>
<td>54.6</td>
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<tr>
<td>&gt;4</td>
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<td>17.6</td>
<td>16.7</td>
<td>15.8</td>
<td>45.5</td>
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<td>61.1</td>
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<td>54.5</td>
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<tr>
<td>Diabetes</td>
<td>16.3</td>
<td>20.1</td>
<td>19.4</td>
<td>31.6</td>
<td>9.1</td>
</tr>
<tr>
<td>End organ dysfunction</td>
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<td>8.8</td>
<td>11.1</td>
<td>15.8</td>
<td>9.1</td>
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<td>Renal dysfunction</td>
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<td>11.1</td>
<td>5.3</td>
<td>0.0</td>
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<tr>
<td>Dialysis</td>
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<td>1.3</td>
<td>2.8</td>
<td>5.3</td>
<td>0.0</td>
</tr>
<tr>
<td>COPD/asthma</td>
<td>7.0</td>
<td>10.0</td>
<td>11.1</td>
<td>10.5</td>
<td>18.2</td>
</tr>
<tr>
<td>Symptomatic peripheral vascular disease*</td>
<td>11.6</td>
<td>17.5</td>
<td>16.7</td>
<td>52.6</td>
<td>18.2</td>
</tr>
</tbody>
</table>

Total n = 189; each entry is percent of n for each group unless otherwise specified.
COPD = chronic obstructive pulmonary disease.
* P < among atheroma grades.
rate of 60% (18), and significant plaque detected anywhere in the thoracic aorta is a very sensitive screening tool for significant plaque in the ascending aorta (18). This may explain the poor correlation found by Guzzetta et al. (22).

Identification of patients with advanced atheromatous disease of the descending thoracic aorta should prompt detailed examination of the ascending aorta and aortic arch, preferably with epiaortic scanning (23). Detection of advanced disease in these segments in the vicinity of aortic cannulation and cross-clamp application levels warrants reconsideration of the risks of the proposed procedure. Previously, modifications in anesthetic and surgical techniques to lessen stroke incidence have been attempted but not validated. These modifications include alternate aortic cannulation sites and cannulae (9), “no touch,” single aortic cross-clamp techniques (24), circulatory arrest, and aortic atherectomy (10,25).

Our data suggest that patients with mobile atheroma (Grade V) appear to represent a particularly vulnerable subset for developing stroke after CABG. Re-examination of the risk-benefit ratios of surgery versus medical management of these patients is warranted. In addition, patients with severe aortic atheromatous disease who require CABG procedures may benefit from modifications in surgical techniques directed at reducing stroke risk. These technical modifications (e.g., circulatory arrest, aortic atherectomy), may in turn increase risk, but may prove to be the best option since conventional management itself carries such a high risk of stroke.

While many modifications in surgical technique have been proposed, performance of CPB at higher MAP may be an easily achievable alternative without significant drawbacks. The optimal range of MAP during CPB however, remains controversial. Proponents of low MAP during CPB stress a long history of safe practice (26). Hypothetically, high MAP during CPB may predispose to turbulence and embolization in the presence of aortic atheromatous disease. Other studies have also demonstrated the feasibility of increasing MAP while not adversely affecting patient outcome (27). While a concern of higher MAP particularly during the cross-clamp period is the potential for cardiac warming and wash out of cardioplegic solution because of enhanced collateral flow, the previously reported study confirmed that higher MAP during CPB can be achieved without increased surgical or technical difficulty, while diminishing cardiac and neurologic morbidity and mortality (11).

In this study, one of five patients with Grade 5 atheroma managed at high MAP developed stroke, while four of six similar patients managed at low MAP developed stroke. The data suggest the utility but do not prove the importance of managing patients with advanced aortic atheromatous disease at higher MAP during CPB. Although based on a small number of patients, which precluded statistical significance, these findings support the need for additional study in larger populations to define whether higher MAP during CPB is beneficial to patients with advanced atheromatous disease.

The importance of maintaining MAP within the normal autoregulatory range on cardiac and renal outcomes has been demonstrated in studies of noncardiac surgery (28). Higher MAP (closer to the right-shifted autoregulatory range), while potentially more mechanically traumatic, may improve cerebral perfusion and lessen the likelihood of hypoperfusion injury. Higher cerebral perfusion pressure may improve collateral blood flow to the territory of vessels occluded by emboli thus attenuating hypoperfusion injury. In addition, some degree of cerebral protection may be afforded by higher perfusion pressures, lessening impact on “watershed” areas. These pressures more closely approximate those wherein cerebral autoregulation is preserved. Importantly, no patients with Grade I or II aortic atheroma suffered an adverse outcome. This may reflect a protective effect of normal vasculature and a vulnerability of patients with diseased vasculature.

In conclusion, this study demonstrates that atheroma grade of the descending aorta is a strong independent risk factor for stroke within one week of CABG surgery and for both stroke and death within six months postoperatively. While increased MAP during CPB has been shown to be generally beneficial for cardiac and neurologic outcome (11), in particular, we note that patients with advanced atheromatous disease of the aorta may benefit from increased perfusion pressures. TEE determination of atheroma grade is a critical element in the management of patients undergoing CABG surgery.

References


