

## Mild to Moderate Atheromatous Disease of the Thoracic Aorta and New Ischemic Brain Lesions After Conventional Coronary Artery Bypass Graft Surgery

George Djaiani, MD, FRCA; Ludwik Fedorko, MD, PhD; Michael Borger, MD, PhD;  
David Mikulis, MD; Jo Carroll, RN; Davy Cheng, MD, MSc; Keyvan Karkouti, MD, MSc;  
Scott Beattie, MD, PhD; Jacek Karski, MD

**Background and Purpose**—The presence of new ischemic brain infarcts, detected by diffusion-weighted magnetic resonance imaging (DW-MRI), have been reported in considerable number of patients after cardiac surgery. We sought to determine the role of proximal thoracic aortic atheroma in predicting embolic events and new ischemic brain lesions in patients undergoing conventional coronary revascularization surgery.

**Methods**—Transesophageal echocardiography and epiaortic scanning was performed to assess the severity of aortic atherosclerosis in the ascending aorta and the aortic arch. Patients were allocated to either low-risk group, (intimal thickness  $\leq 2$  mm), or high-risk group (intimal thickness  $> 2$  mm). Transcranial Doppler was used to monitor the middle cerebral artery. DW-MRI was performed 3–7 days after surgery. The NEECHAM Confusion Scale was used for assessment and monitoring patient consciousness level.

**Results**—Patients in the high-risk group were considerably older;  $71 \pm 6$  (n=38) versus  $67 \pm 6$  (n=72) years,  $P=0.004$  and were more likely to have impaired left ventricular function. Confusion was present in 6 (16%) patients in the high-risk group and 5 (7%) patients in the low-risk group. Patients in the high-risk group had a three-fold increase in median embolic count, 223.5 versus 70.0,  $P=0.0003$ . DW-MRI detected brain lesions were only present in patients from high-risk group, 61.5 versus 0%,  $P<0.0001$ . There was significant correlation between the NEECHAM scores and embolic count in the high-risk group;  $r=0.63$ ,  $P<0.001$ .

**Conclusions**—The findings of this investigation suggest that mild to moderate atheromatous disease of the ascending aorta and the aortic arch (intimal thickness  $> 2$  mm) is a major contributor to ischemic brain injury after cardiac surgery. (*Stroke*. 2004;35:e356-e358.)

**Key Words:** aortic diseases ■ brain infarction ■ brain ischemia ■ cardiac surgery ■ magnetic resonance imaging

The presence of new brain infarcts detected by MRI has been reported in almost one third of patients after coronary artery bypass graft (CABG) surgery.<sup>1–4</sup> The purpose of this study was to determine the role of proximal thoracic aortic atheroma (ascending aorta and aortic arch) in predicting cerebral embolic events and new ischemic brain infarcts in patients undergoing CABG surgery.

### Methods

#### Study Population and Management Strategies

After institutional research board approval, informed consent was obtained from 110 patients  $> 60$  years of age scheduled for CABG surgery. Patients with history of stroke, claustrophobia, atrial fibrillation, and symptomatic carotid artery disease were excluded. Anesthetic and cardiopulmonary bypass (CPB) management was standardized.

#### Thoracic Aorta Assessment

Intraoperative transesophageal echocardiography and epiaortic scanning was used to evaluate proximal thoracic aorta. Normal aorta was defined as intimal thickness  $\leq 2$  mm (grade 0). Atheroma was classed as  $> 2$  to 4 mm (grade 1),  $> 4$  mm (grade 2), and mobile atheroma (grade 3). Patients with grade 1 to 3 atheroma were allocated to high-risk group and patients with grade 0 atheroma to low-risk group.

#### Cerebral Emboli Detection

Using transcranial Doppler, the middle cerebral artery was monitored continuously from 2 minutes before cannulation of the aorta to 2 minutes after aortic decannulation. The technique of detection and analysis of embolic hits was used as described previously.<sup>5</sup> The embolic load (sum of embolic hits) was calculated for 2 time periods: first, 1 minute before and 2 minutes after surgical interventions (aortic cannulation and decannulation, cross-clamp application and removal, CPB start and end, and start of cardiac ejection), and second, embolic load during entire CPB.

Received March 8, 2004; final revision received March 25, 2004; accepted March 30, 2004.

From the Department of Anesthesiology (G.D., L.F., J.C., K.K., S.B., J.K.), Division of Cardiac Surgery (M.B.), and Neuroradiology (D.M.), Toronto General Hospital, University Health Network, University of Toronto, Canada; and the Department of Anesthesia and Perioperative Medicine (D.C.), University of Western Ontario, London, Ontario, Canada.

Correspondence to Dr George Djaiani, Department of Anesthesiology, Eaton North 3-410, Toronto General Hospital, 200 Elizabeth St, Toronto, Ontario M5G 2C4, Canada. E-mail george.djaiani@uhn.on.ca

© 2004 American Heart Association, Inc.

Stroke is available at <http://www.strokeaha.org>

DOI: 10.1161/01.STR.0000138783.63858.62

## MRI Scanning

MRI was performed 3 to 7 days after surgery. New ischemic lesions were identified as regions of signal hyperintensity on diffusion-weighted imaging (3 orthogonal gradient direction;  $b=1000$  s/mm<sup>2</sup>) and signal hypointensity on the apparent diffusion coefficient maps.

## Consciousness Assessment and Monitoring

The NEECHAM Confusion Scale<sup>6</sup> was used for assessment and monitoring of patient consciousness level preoperatively (baseline) and postoperatively daily (days 1 to 5).

## Statistical Analysis

The emboli count was analyzed with Mann–Whitney *U* test, and the association between atheroma and MRI brain infarcts was assessed using a 2×2 contingency table. One-way ANOVA was used to compare the NEECHAM scores. A *P* value <0.05 was considered significant.

## Results

### Demographic Data

Patients in the high-risk group were considerably older ( $71 \pm 6$  [n=38]) versus  $67 \pm 6$  [n=72] years;  $P=0.004$ ) and were more likely to have impaired left ventricular (LV) function (26 versus 11%;  $P=0.041$ ).

### Aortic Atheroma Characteristics

The mean thickness of atheroma/intima was  $4.8 \pm 1.9$  and  $1.4 \pm 0.6$  mm in the high- and low-risk groups, respectively ( $P<0.00001$ ). Eleven patients presented with grade 1/grade 2 atheroma in the ascending aorta. Twenty-three patients had grade 1/grade 2 atheroma restricted to the aortic arch with normal ascending aorta. Grade 3 atheroma was identified in 4 patients (1 ascending aorta and 3 aortic arch). Surgical management was modified in these 4 patients. Distal arch cannulation with conventional CPB was performed in 2 patients, and beating heart surgery without CPB was achieved in the other 2 patients.

### MRI Findings

A total of 50 (45%) patients underwent MRI investigation. In patients who had MRI, the overall prevalence of new ischemic brain lesions was 16%; however, new lesions were found only in the high-risk group (Table). Half of these patients had a single 3- to 12-mm lesion, and the other half presented with multiple 3- to 15-mm lesions. Four patients with new brain lesions had the atheroma restricted to aortic arch. Pre-existing lacunar infarcts were present in 3 and 4 patients in the high- and low-risk groups, respectively ( $P=0.63$ ). One patient with pre-existing infarct had a new brain lesion.

### Transcranial Doppler Findings

Adequate transcranial Doppler signal was acquired in 24 and 52 patients from the high- and low-risk groups, respectively ( $P=0.328$ ). The high-risk group had a 3-fold increase in embolic events during CPB (Figure 1).

### Assessment of Consciousness

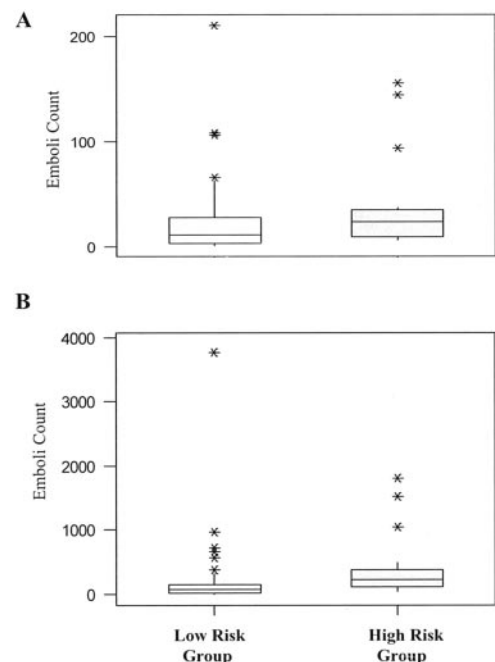
Confusion was identified in 6 (16%) and 5 (7%) patients in the high- and low-risk groups, respectively (Figure 2). None of the patients had any clinically significant metabolic changes that would justify the altered level of consciousness.

### New Ischemic Brain Lesions as Identified by Diffusion-Weighted MRI

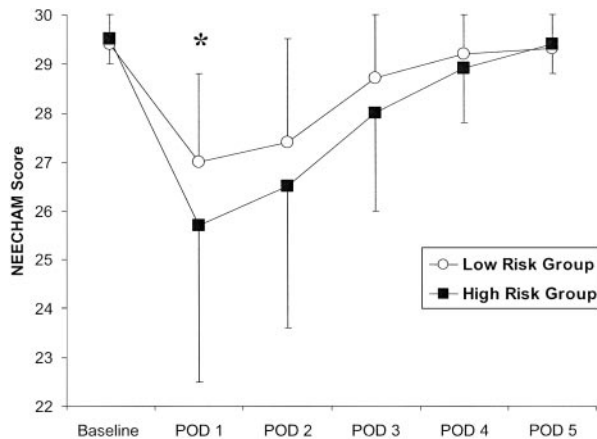
	Low-Risk Group (n=72)	High-Risk Group (n=38)	<i>P</i> Value
MRI performed	37 (52)	13 (35)	0.086
MRI infarcts			
Present	0 (0)	8 (61)	<0.0001
Absent	37 (100)	5 (39)	
MRI not performed	35 (48)	25 (65)	0.086
Mental status change	14 (19)	18 (47)	0.002
Confusion	4 (6)	5 (13)	0.36
Claustrophobia	10 (14)	12 (31)	0.12
Delirium	0 (0)	1 (2.6)	0.90
Other	21 (29)	7 (18)	0.33

"Other" reasons for not performing MRI included presence of pacing wires, patient refusal, and unavailable MRI slot at allocated time. Data are expressed as n (%).

One patient in the high-risk group had a clinical stroke with a lesion in the motor cortex of the left hemisphere. There was a significant correlation between the NEECHAM scores and embolic count in the high-risk group only ( $r=0.63$ ;  $P<0.001$ ). Patients with mobile atheroma had good clinical outcomes and no neurological sequelae. Postoperative morbidity and hospital length of stay were comparable between the 2 groups.



**Figure 1.** Comparison of embolic events during CPB. The box plot displays the interquartile range representing the 25th and 75th percentiles. A line across the box is the median. Whiskers represent the lowest and highest observations inside the region. Outliers are plotted with asterisks. A, Median emboli count is 24.0 and 12.0 during surgical interventions in the high- and low-risk groups, respectively ( $P=0.023$ ). B, Median emboli count is 223.5 and 70.0 during entire CPB in the high- and low-risk groups, respectively ( $P=0.0003$ ).



**Figure 2.** Comparison of NEECHAM scores. POD indicates postoperative day. \* $P=0.01$ .

## Discussion

The new brain infarcts were found in 8 patients ( $n=6$  grade 1 and  $n=2$  grade 2 atheroma). Four of these patients had the atheroma restricted to aortic arch. Proximal thoracic atheroma was associated with increased intraoperative embolic load, a change in postoperative mental status, and development of acute ischemic brain infarcts. The prevalence of these brain infarcts in patients with atheroma exceeded 60%. These findings suggest that mild to moderate atheroma of the proximal thoracic aorta was a major contributor to ischemic brain injury after cardiac surgery. The surgical procedure was altered in 4 patients with mobile atheroma. All of these patients had good clinical outcomes and no neurological sequelae.

Patients in the high-risk group presented for surgery on average 4 years later, most likely accounting for the observed difference in the degree of atherosclerosis in the thoracic aorta between the 2 groups. Furthermore, these patients were more likely to have impaired LV function preoperatively. Advanced age and impaired cardiac function have been recognized previously as independent predictors of neurological complications after cardiac surgery.<sup>7,8</sup> Our results suggest that these predictors may simply represent a surrogate measure of the degree of atheromatous changes of the thoracic

aorta, which has not been assessed consistently in the previous studies.

In conclusion, this investigation demonstrates that a patient population at increased risk of suffering new ischemic brain lesions as a result of heart surgery can be identified reliably before surgery by means of detailed comprehensive echocardiography. At present, it is unclear, whether the choice of alternative surgical, endovascular, or medical therapy would result in better neurological outcomes in patients with mild and moderate aortic atherosclerosis. However, the absence of new MRI-identified infarcts in the low-risk group suggests that for patients with no significant atheromatous disease, routine CABG with CPB is a safe and effective management strategy. Patient stratification based on the aortic atheromatous burden should be addressed in future trials designed to tailor treatment strategies to improve long-term outcomes of coronary heart disease and reduce the risks of perioperative neurological injury.

## References

1. Vanninen R, Aikio M, Kononen M, Partanen K, Tulla H, Hartikainen P, Paranen J, Manninen H, Enberg P, Hippelainen M. Subclinical cerebral complications after coronary artery bypass grafting: prospective analysis with magnetic resonance imaging, quantitative electroencephalography, and neuropsychological assessment. *Arch Neurol*. 1998;55:618–627.
2. Bendszus M, Reents W, Franke D, Mullges W, Babin-Ebell J, Koltzenburg M, Warmuth-Metz M, Solymosi L. Brain damage after coronary artery bypass grafting. *Arch Neurol*. 2002;59:1090–1095.
3. Restrepo L, Wityk RJ, Grega MA, Borowicz L Jr, Barker PB, Jacobs MA, Beauchamp NJ, Hillis AE, McKhann GM. Diffusion- and perfusion-weighted magnetic resonance imaging of the brain before and after coronary artery bypass grafting surgery. *Stroke*. 2002;33:2909–2915.
4. Goto T, Baba T, Matsuyama K, Honma K, Ura M, Koshiji T. Aortic atherosclerosis and postoperative neurological dysfunction in elderly coronary surgical patients. *Ann Thorac Surg*. 2003;75:1912–1918.
5. Borger MA, Peniston CM, Weisel RD, Vasiliou M, Green RE, Feindel CM. Neuropsychologic impairment after coronary bypass surgery: effect of gaseous microemboli during perfusionist interventions. *J Thorac Cardiovasc Surg*. 2001;121:743–749.
6. Neelon VJ, Champagne MT, Carlson JR, Funk SG. The NEECHAM Confusion Scale: construction, validation and clinical testing. *Nurs Res*. 1996;45:324–330.
7. Newman MF, Kirchner JL, Phillips-Bute B, Gaver V, Grocott H, Jones RH, Mark DB, Reves JG, Blumenthal JA. Longitudinal assessment of neurocognitive function after coronary artery bypass surgery. *N Engl J Med*. 2001;344:395–402.
8. Djaiani GN, Phillips-Bute B, Blumenthal JA, Newman MF. Chronic exposure to nicotine does not prevent neurocognitive decline after cardiac surgery. *J Cardiothorac Vasc Anesth*. 2003;17:341–345.