Choice of Hemodynamic Support During Coronary Artery Bypass Surgery for Prevention of Stroke

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Abstract: The objective of this study was to evaluate a protocol involving cerebrovascular accident (CVA) risk evaluation and choose adequate hemodynamic support that prevents major CVA. For evaluation of CVA risk, we undertook head computed tomography (CT), magnetic resonance imaging (MRI), magnetic resonance angiography (MRA), chest CT, carotid artery Doppler echo, carotid artery MRA, and echo scanning of ascending aorta during surgery. Cerebrovascular specialists did the physical examinations and reading of images. Hemodynamic support (chemical arrest on pump, on-pump beating, or off pump) was chosen according to the result of risk evaluation. We retrospectively studied 92 cases before (group A; 1997 October to 1998 November) and 91 after (group B; 1998 November to 2001 January) starting protocol. We also studied urgent cases (group C; 9 cases; 1997 October to 2001 January) in which we did not use the protocol. When adequate hemodynamic support was chosen, major CVA (modified Rankin scale grades 3, 4, and 5) incidence decreased from 6.6% (six case; group A) to 0% (p < .05; group B). There were three major CVA cases in group C (p < .05 vs. group B), in which the ascending aorta was clamped. Our protocol eliminated major CVA associated with elective coronary surgery. We need simpler evaluation, however, when we undertake urgent surgery. Keywords: coronary artery, surgery, cardiopulmonary bypass, off pump, cerebrovascular accident.

In coronary artery bypass grafting (CABG), cerebrovascular accident (CVA) is the most serious complication (1,2). Especially, CVA during CABG results in long hospital stay, large cost, and poor quality of life (1). To prevent CVA during surgery, we started preoperative risk evaluation of CVA in November 1998. Based on CVA risk evaluation, we changed hemodynamic support during CABG. Until October 1998, we undertook CABG with chemical arrest using cardiopulmonary bypass (conventional CABG), but major CVA happened in six cases. On the contrary, we have had no major CVA cases since starting preoperative CVA evaluation, although we have to use an off/on-pump beating technique in the high/moderate-risk patient group.

The objectives of this study, therefore, were 1) to show advantage of our CVA evaluation methods to prevent major CVA and 2) to speculate a mechanism of CVA during CABG. To achieve these objectives, we retrospectively studied 92 cases before and 91 after starting CVA risk evaluation. During the study period, the same two surgeons performed surgery using hemodynamic support according to the CVA evaluation. We also studied urgent cases (group C; nine cases) in which we did not have enough time to use the protocol.

MATERIALS AND METHODS

Between October 1997 and January 2001, 192 patients underwent CABG. Since November 1998, we started preoperative risk evaluation for CVA during surgery. We divided our 192 patients into three groups. Group A was 92 who underwent CABG before starting CVA risk evaluation (October 1997 to November 1998). Group B was 91 patients who underwent CABG after starting CVA risk evaluation (November 1998 to January 2001). Group C was nine urgent cases without risk evaluation during that time (October 1997 to January 2001).

Patient Background

The details of patients in each group are shown in Table 1. There was no statistical significance among groups in each index.

Evaluation of CVA Risk

We undertook head computed tomography (CT), magnetic resonance imaging (MRI), magnetic resonance angiography (MRA), chest CT, carotid artery Doppler echo,
carotid artery MRA, and echo scanning of ascending aorta during surgery. Cerebrovascular specialists performed physical examinations and reading of images. Our evaluation consists of ascending aortic lesion and carotid/intracranial vascular lesion imaging. We evaluated atherosclerotic lesion with chest CT and echo scanning of ascending aorta. We use head CT, MRI, MRA, carotid artery Doppler echo, and carotid artery MRA for evaluation of the carotid/cerebral vascular lesion. We divided our patients into three groups: high, moderate, and low risk for CVA (3,4). Briefly, we regarded high risk as when we recognized more than 75% of stenosis in any carotid, vertebral, or middle cerebral artery. We regarded moderate risk as when arterial stenosis was more than 50% but less than 75%. When vascular stenosis was less than that but old cerebral infarction was recognized, we regarded this as moderate risk. When vascular stenosis was less than that above and there was no significant cerebral infarction, we regarded this as low risk.

Hemodynamic Support
According to the results of CVA risk evaluation, we selected different hemodynamic support. When both carotid/cerebral vascular and ascending aortic lesions were positive, off-pump CABG or on-pump beating CABG with subclavian artery cannulation was selected. Use of cardiopulmonary bypass depends on hemodynamic condition during surgery. When only the ascending aorta lesion was positive, we avoided cross-clamp of the ascending aorta. We operated with a beating heart technique regardless of cardiopulmonary bypass. Thus, off-pump CABG or on-pump CABG with subclavian artery cannulation was selected. When carotid/cerebral vascular disease was diagnosed as moderate or high risk, and the ascending aorta was intact, we used pulsatile cardiopulmonary bypass with cross-clamp of the ascending aorta (conventional CABG). If neither the vascular or ascending aortic lesion was detected, we did not use pulsatile cardiopulmonary bypass with cross-clamp of the ascending aorta (conventional CABG). Our strategy of hemodynamic support is summarized in Figure 1.

Surgical Technique
The left internal thoracic artery (LITA) was anastomosed to the left anterior descending artery (LAD) as long as the LITA was available. The right coronary artery and circumflex branches were anastomosed to the great saphenous vein or the radial artery graft. Proximal anastomosis depends on the ascending aortic lesion. When there is no lesion in the ascending aorta, the proximal site of vein graft or radial artery was anastomosed to the ascending aorta with cross-clamp of the aorta and cardiac arrest. When any lesion of the ascending aorta was detected, a proximal site graft was anastomosed to the right internal thoracic artery (RITA) in an end-to-end manner. We applied nontouch technique to the ascending aorta, which included subclavian arterial cannulation against an ascending aortic lesion. During this study, the same two surgeons performed the operations.

Statistics
We compared the incidence of major CVA during surgery between groups A, B, and C. Major CVA was defined as more than grade 3 on the modified Rankin scale (5–7). We also compared hemodynamic support methods between groups A and B (incidence conventional CABG, off-pump CABG, on-pump beating CABG, and pulsatile cardiopulmonary bypass with cross-clamp). Number of grafts, operation times, and cardiopulmonary bypass times were compared between groups A and B. In group C, we calculated total cost during admission between CVA and non-CVA patients. Statistical analyses were based on the guidelines described by Wallenstein et al. (8). Gaussian-distributed variables were expressed as means ± SD and were subjected to Student t test. Binomially distributed variables, such as the incidence of stroke, were compared using the χ² test for a 2 × n table.

RESULTS
Incidence of Stroke
After starting our strategy against stroke during sur-
gery, major CVA (modified Rankin scale grades 3, 4, and 5) incidence decreased from 6.6% (six cases; group A) to 0% \((p < .05; \text{group B})\). There were three major CVA cases in group C \((p < .05 \text{ vs. group B})\) that had surgery at the same period of this study. Group C had no time to evaluate CVA risk for urgent surgery. There were two minor CVAs (scores 1 and 2) in groups A and B and one in group C (no statistical significance). The results are summarized in Table 2.

Hemodynamic Support

Because 61 cases in group B (91 cases) were regarded as low risk for both carotid/cerebral vascular stenosis and ascending aortic lesion, these 61 patients had conventional CABG. Nine patients in group B had severe carotid/cerebral vascular stenosis and were diagnosed as high risk. All these 21 patients had off-pump CABG. On the contrary, in group A (92 cases), 79 patients had conventional CABG without any evaluation for CVA. Five patients had on-pump beating CABG and eight patients underwent off-pump CABG. There were, however, no scientific reasons for choosing beating heart CABG in group A. In group C (nine cases), eight patients underwent conventional CABG for time saving and only one patient had off-pump CABG. Major CVAs occurred only during conventional CABG in groups A and C. The changes of hemodynamic support among groups A, B, and C was significant \((3 \times 3 \chi^2 \text{ test}, p < .05)\), as shown in Table 3.

Graft Number, Operation Time, and Mortality

As shown in Table 4, there was no statistical significance among groups in graft numbers and operation time. In groups B and C, there were no hospital deaths despite three major CVA cases. Three patients died in group A. One was because of a major CVA, one was caused by bleeding shock, and one was caused by cardiogenic shock.

Cost of CVA

We compared cost during hospital admission between CVA (three patients) and non-CVA cases (six patients) in group C (note: eight of nine patients underwent conventional CABG). CVA patients required 7,538,660 ± 500,210 yen/patient, but non-CVA patients required only 3,702,190 ± 801,440 yen/patient. The difference was statistically significant \((p < .05)\). On the other hand, the cost of CVA risk evaluation was only 100,150 yen/patient. The cost of CVA patients is because of the long stay in the intensive care unit and repeated brain imaging such as head CT/MRI.

DISCUSSION

Morbidity of Off-Pump CABG and Conventional CABG

In our institute, off-pump CABG is more common technique for coronary surgery. Cardiopulmonary bypass is used only when intracardiac procedure such as valve replacement is necessary. Off-pump CABG is theoretically less harmful than conventional CABG as cardiopulmonary bypass is unnecessary (9). It is still unclear, however, that morbidity of the off-pump CABG is less than conventional CABG (10,11). Indeed, in our institute, the only significant difference between off-pump and conventional CABG was found in the amount of bleeding (12). Mid- and short-term results of off-pump CABG are as satisfactory as conventional CABG (13), but long-term results are not available at this moment (11).

Mechanism of Major CVA

As shown in Figure 1 and Table 3, we applied off-pump CABG to moderate- and high-risk groups not only for ascending aortic lesions but also for vascular lesions. Major CVA during surgery was 0% after starting the protocol. This indicates that even small debris disseminated on clamping or declamping of the ascending aorta may be quite dangerous when patients have a vascular lesion in

<table>
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<th>Table 2. CVA incidence during surgery.</th>
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<td>Modified Rankin Scale</td>
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<td>1, 2 (minor CVA)</td>
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\*p < .05 vs. group A.  
†p < .05 vs. group B, \(3 \times 3 \chi^2\).
the neck and brain. It is known that hypoperfusion of the brain causes watershed brain infarction, and dissemination of debris results in multiple infarction (12). Because we had no watershed brain infarction, combination of dissemination of debris and intracranial vascular lesion may play a more important role than neck lesion (blood flow decrease at carotid artery results in watershed infarction) (4). It should be noted that the incidence and degree of intracranial vascular lesion is quite different among races (4). Intracranial lesion is more common in Asian and African populations than in European populations (4). On the contrary, the importance of a carotid lesion for CVA during CABG was more pronounced in European populations (2). Our strategy against CVA may be useful for Asian and African people only. This is one of the reasons why our off-pump CABG prevented major CVA, although previous studies did not show any statistical significance (10,11).

**Should We Move From Conventional CABG to Off-Pump CABG?**

Conventional CABG is technically easier than off-pump CABG. Hemodynamics are not needed during surgery, and the myocardium is completely quiet. However, conventional CABG without preoperative risk evaluation of CVA (group A) resulted in a high incidence of major CVA (6.5%). The brain infarction was multiple in all six patients, indicating that debris disseminated to the brain during surgery (14). Makino mentioned that debris disseminates even on declamping of ascending aorta (4). We started this project to prevent CVA during CABG with Makino and coworkers in November 1998 (3,4). We evaluated both vascular and ascending aortic lesions. MRA is the most important method for detection of vascular lesions, and chest CT is the most important method for detection of ascending aortic lesions (4). In elective surgery, we had enough time for both imaging examinations and careful reading by the specialists before the surgery. The cost was acceptable, as described above—only 2.7% of the total cost during admission. The result was quite satisfactory and we eliminated major intraoperative CVA.

In the mean time, we got used to the off-pump CABG technique. Although beating heart surgery (no touch technique to ascending aorta) was quite useful even on pump, we have not used cardiopulmonary bypass in CABG since 2001 to save costs. One of the greatest advantages of off-pump CABG is that we do not have to worry about operating time. In conventional CABG, cross-clamp time and cardiopulmonary bypass time must be watched. In off-pump CABG, duration of time is not important. Once the initial bypass grafting (most of initial grafting is RITA/LITA to LAD) is finished, hemodynamics become much more stable. We can take more time for the multiple grafting until total revascularization, even in urgent cases.

**Limitation of This Study and Our Strategy**

This study was a retrospective study. To indicate the risk factors of major CVA during surgery, we used a prospective and randomized study (11,15). Statistics should be simpler. We should compare, between groups, cross-clamping the ascending aorta and beating heart technique. However, when we started our trial for CVA prevention, we did not know the precise risk factors. Now we know that subclavian cannulation and pulsatile cardiopulmonary bypass with cross-clamping of the aorta are not necessary any more (14). We can operate with the off-pump technique in these patients. Even when cardiopulmonary bypass is necessary, cannulation to the ascending aorta is safe when a good spot is found by intraoperative echo scanning of the ascending aorta.

A limitation of our study is that long period prognosis of off-pump CABG is still not known (11). In order to investigate long period prognosis between conventional and off-pump CABG, we are organizing a prospective study, comparing graft patency in both CABG techniques in low-risk patients in our evaluation (11,15). It should be noted, however, that prospective studies with large numbers of patients are quite few in coronary bypass surgery (11). A recent review (15) pointed out that the study budget for coronary surgery is not enough. Different from a homograft, because a graft for coronary bypass is not available on market, no sponsor supports a prospective study (15). Even in our next prospective study, examination before surgery is limited. Because the medical insurance system in Japan is quite unique, we can still undertake brain MRIs and chest CTs as routine examination before the coronary surgery. Furthermore, indication of coronary surgery and intervention is not clear in Japan. Japanese surgeons must operate on any risky patients, resulting in high morbidity and mortality. Our preoperative evaluation is quite effective to eliminate CVA but may not be necessary in other countries who keep to the indication of coronary intervention and surgery.

**REFERENCES**