Introduction

Off-pump coronary artery bypass grafting (OPCAB) has been reported to be effective to prevent complications associated with cardiopulmonary bypass, and to be superior to conventional coronary artery bypass grafting (CABG) with cardiopulmonary bypass. However, the incidence of complications and the mortality rate have been reported to be extremely high in patients who underwent emergency conversion to surgery with cardiopulmonary bypass due to intraoperative hemodynamic deterioration. Therefore, this inappropriate situations should be avoided. Particularly, when OPCAB is intended to perform in high-risk patients such as with severe stenosis of the left main coronary artery (LMCA) or left ventricular dysfunction, the preventive measure should be undertaken to perform OPCAB in a stable condition so as to promote the better outcome of the surgery. For such high-risk patients, elective intra-aortic balloon pumping (IABP) therapy has been reported as a strategy to improve the outcomes of CABG with cardiopulmonary bypass. The effectiveness of elective IABP in OPCAB has also been reported recently, but its use-
fulness has not been sufficiently evaluated. In the present study, we will focus to evaluate on the effectiveness of elective IABP in high-risk OPCAB patients intentionally and prospectively introduced and compared with low-risk OPCAB patients who were operated without IABP.

**MATERIALS AND METHODS**

From October 2002 to September 2006, total of 143 patients were received isolated coronary artery bypass surgery. During this period, all isolated CABG were performed with the intention to treat without cardiopulmonary bypass. We preoperatively selected the patients who underwent surgery by the elective insertion of IABP under the criteria described below.

Inclusion criteria for elective IABP are as follows.
1. Patients with more than 75% stenosis of LMCA necessitating bypass grafting to the circumflex artery
2. Patients with left ventricular dysfunction with an ejection fraction of less than 35%, necessitating bypass grafting to the circumflex artery

Patients who met the following criteria described below were excluded from this study.
1. Patients with thoracic and/or abdominal aneurysm.
2. Patients with moderate to severe aortic insufficiency
3. Patients with arteriosclerosis obliterans expected to be exacerbated by IABP catheter insertion.
4. Patients with acute myocardial infarction

Among the total of 143 patients, thirty patients underwent elective IABP (Group E), and 113 did not require elective IABP (Group C). Surgery was performed under midline sternotomy in all patients. In patients who underwent elective IABP, the left or the right femoral artery was punctured after harvesting the internal thoracic artery and an IABP catheter was inserted, guided by transesophageal echography. After insertion of the balloon catheter, heparin was intravenously administered at 150 units/kg. The details of coronary artery bypass grafting technique were as follows. For distal anastomosis, a suction-type stabilizer (Acrobat; GUIDANT, Minneapolis, MN; or Octopus 2; Medtronic, Minneapolis, MN) was used. For anastomosis of the circumflex artery (CX) and the right coronary artery (RCA), a heart positioner (X- pose; GUIDANT, Minneapolis, MN; or Starfish; Medtronic, Minneapolis, MN) was used. For anastomosis of the left anterior descending artery (LAD) or the right coronary artery, an external shunt tube (Coronary perfusion catheter; SUMITOMO BAKELITE, Tokyo, Japan) was inserted to the distal side of the coronary artery. After completing all distal anastomoses, heparin was neutralized by intravenous administration of protamine. When cardiopulmonary bypass was used due to hemodynamic deterioration during OPCAB, extracorporeal circulation was established through ascending aortic cannulation and single venous cannulation. In patients in whom OPCAB was converted, on-pump beating CABG was performed. The IABP catheter was removed after surgery in the ICU.

Corart BP1 (Aisin Seiki Co., Kariya, Japan) was used as the driving unit for IABP, and Sensor Balloon P1 (Aisin Seiki Co.) as the balloon catheter. A balloon catheter with a capacity of 32 ml or 40 ml was selected depending on the patient’s height. IABP catheter insertion was monitored with the SONOS5500 (PHILIPS, Eindhoven, Netherlands) echocardiography system using a T6210 transesophageal echo probe (PHILIPS).

**STATISTICS**

Continuous variables are presented as the mean ± SD and were compared by Student’s t test. The chi-square test (when all expected cell counts were 5 or more) or Fisher’s exact test (when any expected cell count was 4 or less) was used to determine the significance of differences in categorical variables. All statistical tests were two-tailed, and a p value of less than 0.05 was considered significant. Statistical calculation was performed using SPSS (Version 11.5; SPSS, Chicago, Ill.).

**RESULTS**

**Preoperative characteristics**

The age at operation was significantly younger in Group E than in Group C. The percentage of diabetic patients was significantly higher in Group E, but no significant difference was observed in the percentage of diabetic patients using insulin. The percentage of patients with unstable angina was significantly higher in Group E (Table 1).

**Number and reasons for performing elective IABP**

In Group E, the reasons for performing elective IABP were severe stenosis of the LMCA in 21, left ventricular dysfunction in 7, and severe stenosis of the LMCA concomitant with left ventricular dysfunction in 2 patients.

**Operative outcomes**

Table 2 shows the operative outcomes. There was no significant difference in the number of distal anastomoses between groups. The percentage of patients in whom
OPCAB could be completed also showed no significant difference. Conversion to surgery with cardiopulmonary bypass was observed in 4 patients undergoing elective IABP. No patient undergoing emergency conversion had received continuous cardiac massage until starting cardiopulmonary bypass. The postoperative course of these conversion cases was uneventful. All 4 patients had lesions in the LMCA and severe stenosis in the proximal right coronary artery, and cardiopulmonary bypass was established due to hemodynamic deterioration during manipulation associated with distal anastomosis. No significant difference was noted in the duration of ICU stay, the number of patients on a respirator for 24 hours or longer after surgery, hospital mortality, or the frequency of postoperative complications between groups. No complication associated with IABP catheter insertion, IABP driving, or IABP catheter removal was noted.

**Duration of postoperative IABP**

In all Group E patients, the IABP catheter was removed in the ICU on the day of surgery.

**DISCUSSION**

The concept of application of elective IABP were widely discussed and they were reported as useful in CABG with cardiopulmonary bypass before OPCAB became a common practice. Elective IABP in severely ill patients is expected to be useful for improving the OP-
CAB completion rate as well as avoiding emergency conversion; however, whether elective IABP is appropriate as a supportive measure for the management of ischemia or the hemodynamic deterioration associated with manipulation during OPCAB in severely ill patients remains unclear. Also, whether the use of IABP increases invasiveness in OPCAB is another matter of concern. The rarity of IABP complications in preventive use is also a major point of interest.

The indications for elective IABP should be strictly restricted, because complications associated with IABP are possible and a balloon catheter is economically expensive. In this series, severe LMCA stenosis and left ventricular dysfunction (EF < 35%) necessitating bypass grafting to the circumflex artery were regarded as basic indications of elective IABP. Gutfinger et al. reported that the indication of elective IABP in CABG with cardiopulmonary bypass were, emergency CABG for failed PTCA, marked LMCA stenosis (≥ 70%), left ventricular dysfunction (LVEF ≤ 40%), unstable angina refractory to medical therapy, and emergency re-operation. Similar conditions have been reported as indications of elective IABP in OPCAB. Since IABP increases coronary artery blood flow due to diastolic augmentation, it is expected to prevent decreases in coronary artery blood flow during OPCAB in patients with unstable angina having severe LMCA stenosis or severe stenosis of proximal coronary arteries. It is also expected to reduce the cardiac load and mitral regurgitation due to systolic unloading and to prevent hemodynamic deterioration during OPCAB in patients with ventricular dysfunction.

Concerning the evaluation of the usefulness of elective IABP, Suzuki et al. and Kim et al. reported that the outcomes of high-risk OPCAB with elective IABP were comparable to those of low-risk OPCAB, and that elective IABP was an effective strategy for the safe execution of OPCAB. In regarding to hospital mortality and the incidence of postoperative complications, our present study showed the outcome was similar between the groups that received elective IABP and the group that did not, although the condition was more severe in the first group. Christenson et al. underwent a prospective randomized study on the usefulness of elective IABP and found out that the frequency of conversion to surgery with cardiopulmonary bypass was significantly lower, and the duration of both the ICU stay and hospital stay was shorter in the group that elective IABP was applied. According to our results, conversion was observed in 4 severely ill patients who underwent elective IABP, and the conversion rate was similar to that in the group that did not undergo elective IABP. All patients who underwent elective IABP and conversion to surgery with cardiopulmonary bypass had severe stenosis in the proximal right coronary artery as well as the LMCA. In patients with such coronary artery lesions, the hemodynamics is considered likely to deteriorate due to marked ischemia during manipulations associated with OPCAB, even with IABP. In our series, the conversion rate was not low, because we converted to surgery with cardiopulmonary bypass before the hemodynamics became seriously deteriorate and we intended to avoid emergency conversion; as the consequence, no patient underwent emergency conversion under continuous cardiac massage before starting cardiopulmonary bypass.

We inserted the IABP catheter for elective IABP after harvesting the internal thoracic arteries. In many reports of elective IABP, the balloon catheter was inserted before the induction of anesthesia. There are the following advantages of balloon catheter insertion after graft harvesting. They are, the internal thoracic artery graft can be harvested quickly with a small volume of hemorrhage, and the catheter is inserted under general anesthesia, the patient does not feel pain or anxiety on catheter insertion. On the other hand, the problems of catheter insertion after graft harvesting include the uncertainty of whether the catheter can be inserted safely into an appropriate position without radiographic guidance. Concerning to this, transesophageal echography clearly shows the position of guidewire and the tip of balloon catheter. Therefore, this is a useful method for safe insertion of the IABP catheter.

Concerning to the duration of IABP, the IABP catheter could be removed in the ICU on the day of surgery in all patients, and there were no complications associated with IABP. According to the study conducted by Cohen et al on the large number of patients including those patients received medical treatment for acute myocardial infarction, major complications of IABP were observed in 11% of patients. The low incidence of IABP complications in our study is considered to be related to the fact that the IABP catheter was inserted while the hemodynamics of patient was stable and that IABP could be removed in a short period of duration.

**Conclusions**

The outcomes of OPCAB using elective IABP in high-
risk patients, such as those with marked LMCA stenosis and left ventricular dysfunction, were similar to those of OPCAB in low-risk patients, suggesting the usefulness of elective IABP in OPCAB. In elective IABP, the IABP catheter could be removed in early postoperative period and the complications related to IABP were rare.

REFERENCES