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Preventive Use of Intra-Aortic Balloon Pump in Patients Undergoing High-Risk Coronary Artery Bypass Grafting: A Retrospective Study

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Background: Coronary artery bypass grafting (CABG) is an important therapeutic measure for CHD patients. The patients who score more than 12 EuroSCORE points cannot achieve good results because of their low cardiac output and delicate left ventricular function. Therefore, use of an intra-aortic balloon pump (IABP) is essential for coronary surgical patients in the peri-operative period. At present, there is no unified standard about when to insert an IABP. This study aimed to compare the short-term clinical outcomes of the IABP inserted in the preoperative condition with its use in the emergency condition for extremely high-risk patients.





Material/Methods: IABP support time, respirator support time, and ICU stay time were significantly shorter (all $p < 0.05$) in the preoperative IABP group compared to the emergency IABP group, and the rates of low cardiac output syndrome (LCOS), acute myocardial infarction, and acute kidney injury in the preoperative group were also significantly lower in the preoperative IABP group (all $p < 0.05$). There were no significant differences in IABP-related complications and the mortality ($p = 0.106$) between two groups.

Results: Compared to the emergency IABP group, the IABP support time, respirator support time and ICU stay time were significantly lower in the preoperative IABP group (all $p < 0.05$), and the rates of LCOS, acute myocardial infarction, and acute kidney injury in the preoperative group were also significantly lower (all $p < 0.05$). There were no significant differences in IABP-related complications and the mortality ($p = 0.106$) between the 2 groups.

Conclusions: For high-risk patients with CABG, preoperative IABP insertion is a safe and effective measure.

MeSH Keywords: **Coronary Artery Bypass • Coronary Disease • Intra-Aortic Balloon Pumping**

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Background

According to WHO research, in the past 10 years, coronary heart disease (CHD) has been the leading cause of death in the world and China has the second-largest number of CHD patients. Although remarkable improvements have been achieved in the management of CHD, the burden of this worldwide disease remains high [1]. There is no doubt that CHD has become a serious public health problem in China.

Options for treatment of CHD include drug therapies, percutaneous coronary intervention (PCI), and coronary artery bypass grafting (CABG). Interventions, baseline characteristics, and even gene polymorphism have impacts on the prognosis [2]. With the development of coronary interventional therapy and the popularity of PCI, patients who are undergoing CABG are older and may suffer from more common comorbidities like diabetes mellitus and chronic renal failure, more severe coronary lesions like left main (LM) coronary lesion, chronic total occlusion, and multi-vessel lesion. These comorbidities and severe lesions lead to high risk of cardiac surgery [3,4]. Recently, the European system for cardiac operative risk evaluation (EuroSCORE) has been widely used in risk evaluation of cardiac surgery. EuroSCORE divides cardiac operative risk into 3 levels: low-risk (0–2 points); intermediate-risk (3–5 points), and high-risk (≥ 6 points) [5]. Nowadays, operative complications and mortality of high-risk patients are close to those of most patients. The patients who get more than 12 points in EuroSCORE cannot get good results because of their low cardiac output and delicate left ventricular function. Therefore, the usage of an intra-aortic balloon pump (IABP) is essential for coronary surgical patients in the preoperative period [6,7].

IABP has become the most widely used left ventricular assist device since it was first reported in 1968 [8]. Due to diastolic inflation and systolic deflation, coronary blood flow is increased and afterload is decreased, translating into augmentation of oxygen supply and lowering of oxygen demand, thus providing circulatory support for patients with hemodynamic instability and facilitating the functional recovery of stunned myocardium [9,10].

In several randomized controlled trials (RCTs), IABP's preoperative initiation and peri-operative usage have been shown to reduce the mortality rate in CABG patients who are considered to be at high risk (those undergoing repeat CABG, those with a left ventricular ejection fraction $< 30\%$, or those with left main CAD) despite its known associated vascular complications. It was recommended as a class IIa (level of evidence B) indication in the American College of Cardiology Foundation/American Heart Association (ACC/AHA) guidelines [11]. However, we still have no unified standard about when

to insert an IABP recently. The present study aimed to compare the short-term clinical outcomes of the IABP inserted in the preoperative condition with it in the emergency condition for extremely high-risk patients.

Material and Methods

Data source and population of patients

From October 2011 to January 2014, a total of 96 patients who had undergone CABG combined with IABP insertion were analyzed retrospectively. The EuroSCOREs of all 96 patients were more than or equal to 12 points. According to the time of IABP insertion, these 96 patients were divided into 2 groups: the preoperative IABP group (58 patients) and the emergency IABP group (38 patients). The demographics were documented, including age, gender, hypertension, smoking, diabetes mellitus, hyperlipidemia, and chronic renal failure. Data on IABP support time, intensive care unit (ICU) stay time, hospitalized days, and respirator support time were collected. We also make comparisons according to factors such as whether their LVEF were $\leq 40\%$, whether the LM coronary was stenosed, and their NYHA classification. We recorded the usage of vasoactive agents and the rates of low cardiac output syndrome, acute myocardial infarction, IABP related complications, acute kidney injury, and mortality.

Standard for the insertion and extraction

The insertion in the preoperative IABP group: patients with severe multi-vessel lesions whose EuroSCORE were more than or equal to 12 points combined with at least 2 of the following items: LVEF $\leq 40\%$, LM lesion $\geq 90\%$, left anterior descending (LAD) proximal subtotal occlusion, drug-refractory unstable angina pectoris, and PCI-related complications.

The insertion in the emergency IABP group: during the operation, patients suffered from hypotension, ST-segment elevation in electrocardiogram, repeated ventricular fibrillation, no improvements in hemodynamics when dopamine dosage $\geq 15 \mu\text{g}/\text{kg}\cdot\text{min}$, and they cannot be isolated from cardiopulmonary bypass. After the operation, symptoms of shock were present in patients, like cold limbs, oliguria, mental confusion, blood pressure (BP) $< 80 \text{ mmHg}$, mean arterial pressure (MAP) $< 60 \text{ mmHg}$, and cardiac index (CI) $< 2.0 \text{ L}/\text{m}^2\cdot\text{min}$.

IABP would be extracted if: 1) dopamine dosage was less than $5 \mu\text{g}/\text{kg}\cdot\text{min}$ and the patient is hemodynamically stable without dopamine; 2) CI $> 2.5 \text{ L}/\text{m}^2\cdot\text{min}$; 3) MAP $> 70 \text{ mmHg}$; 4) peripheral circulation was stable and blood volume was sufficient; 5) urine volume $> 1 \text{ ml}/\text{kg}\cdot\text{h}$; 6) The respirator data was extracted and the result of blood gas analysis was normal.

Table 1. Baseline characteristics.

Characteristic	Preoperative IABP (n=58)	Emergency IABP (n=38)	P-value
Age (years)	65.38±12.43	68.18±9.48	0.240
Gender (M/F)	30/28	21/17	–
Hypertension (% , n)	58.6 (34)	65.8 (25)	0.430
Hyperlipidemia (% , n)	82.8 (48)	81.6 (31)	0.544
Diabetes mellitus (% , n)	65.5 (38)	84.2 (32)	0.264
Chronic renal failure (% , n)	3.4 (2)	7.9 (3)	0.324
Tobacco use (% , n)	65.5 (38)	55.3 (21)	0.373
LVEF (≤40%)	56.9 (33)	50.0 (19)	0.428
NYHA classification			
III (% , n)	24.1 (14)	21.1 (8)	0.490
IV (% , n)	75.9 (44)	78.9 (30)	0.512
LM coronary disease (% , n)	62.1 (36)	60.5 (23)	0.539

LVEF – left ventricular ejection fraction; LM – left main.

The insertion of IABP

An 8-Fr catheter was inserted via percutaneous common femoral artery and the balloon was 34 ml or 40 ml. Transesophageal echocardiography and X-ray were taken to make sure that the balloon was in the right position. All the related IABP complications were recorded in detail, including severe limb ischemia, IABP-related death, severe hemorrhage, and balloon rupture and malfunction. We intended to anticoagulate at the speed of 20 ml/h with the use of low molecular weight dextran.

Definitions

Hypertension was defined as systolic blood pressure/diastolic blood pressure ≥140/90 mmHg in the supine position, or the use of antihypertensive medication. Diabetes mellitus was identified by a fasting plasma glucose ≥7.0 mmol/L, or random plasma glucose ≥11.1 mmol/L, or if patients received therapy with insulin or oral medications for diabetes. Hyperlipidemia was defined as the presence of total cholesterol ≥5.7 mmol/L, or LDL ≥3.6 mmol/L, or HDL <1.04 mmol/L, or current lipid-lowering medication use. Chronic renal failure meant creatinine ≥5 mg/dL. Tobacco use, either at time of the interview or in the past, was recorded. LCOS was defined as CI < 2.5 L/m²*min. If patient peak creatinine at 72 hours after the operation was at least 1.5 times the basic creatinine before the operation, we defined it as acute kidney injury. The diagnosis of acute myocardial infarction was according to the Third Universal Definition of Myocardial Infarction [12].

Statistical analysis

Results are expressed as mean ± standard deviation (SD) for continuous variables and frequencies for categorical variables. Differences between groups were checked by nonparametric test and chi-square test for continuous and categorical variables, respectively. An alpha value of 0.05, corresponding to a p value <0.05, served as the criterion for establishing statistical significance. Statistical analysis was performed with SPSS19.0 and STATA12.0.

Results

Baseline characteristics

We collected data from 96 patients who underwent CABG (mean age 66.49±11.39, 45 female patients and 51 male patients). According to the time to insert IABP, 58 patients were assigned to the preoperative IABP group and the other 38 patients were assigned to the emergency IABP group. The comparison between the baseline information and previous medical history of the 2 groups is shown in Table 1. There were no significant differences of the possible factors that may contribute to CHD such as hypertension, hyperlipidemia, diabetes mellitus, or tobacco use in the 2 groups. Similarly, there were no significant differences in age, chronic renal failure, LVEF, LM coronary disease, or NYHA classification.

Table 2. Hospitalization characteristics.

	Preoperative IABP (n=58)	Emergency IABP (n=38)	P-value
IABP time (h)	31.12±5.27	44.95±7.14***	0.000
Respirator time (h)	5.53±1.23	8.53±2.74***	0.000
ICU days (d)	1.83±0.65	2.11±0.65*	0.044
Hospitalized days (d)	11.55±2.51	12.47±2.28	0.069
LCOS (% , n)	3.4 (2)	15.5 (9)**	0.009
cardiopulmonary bypass	5.2 (3)	15.5 (9)*	0.021
Vasoactive agent			
Dopamine (% , n)	20.9 (12)	32.8 (19)*	0.028
Epinephrine (% , n)	15.5 (9)	39.7 (23)**	0.001
AKI (% , n)	5.2 (3)	13.8 (8)*	0.038
IABP complication (% , n)	0 (0)	0 (0)	–
AMI (% , n)	5.2 (3)	13.8 (8)*	0.038
Perioperative death(% , n)	3.4 (2)	8.6 (5)	0.106

IABP – intra-aortic balloon pump; ICU – Intensive Care Unit; LCOS – low cardiac output syndrome; AKI – acute kidney injury; AMI – acute myocardial infarction. * p<0.05; ** p<0.01; *** p<0.001.

Hospitalization characteristics

Patients in these 2 groups had different hospitalized conditions (Table 2). In the preoperative IABP group, they did not extract IABP until 31.12±5.27 hours after insertion and 44.95±7.14 hours after insertion in the emergency IABP group, and there were several significant differences between them (p=0.000). The result showed a statistical difference in respirator support time and ICU stay time between groups (p=0.000 and p<0.05). In spite of this, duration of hospital stay was similar (p>0.05). The incidence rate of LCOS was higher in the emergency IABP group (9; 15.5%) than in the preoperative group (2; 3.4%), and the p value was 0.009. The amounts of dopamine and epinephrine used were also statistically different (p=0.028 and p=0.001). After the operation, 3 patients presented AKI in the preoperative group and the amount was less than that in the emergency group (8; 13.8%). The result of postoperative AMI was the same as postoperative AKI. Neither group had IABP-related complications and there were no perioperative deaths.

Discussion

CABG is an effective surgical procedure for patients with severe coronary disease. However, high benefits are associated with high risk, especially for older patients with hypertension,

diabetes mellitus, chronic obstructive pulmonary disease, and other comorbidities. Thus, all influencing factors should be taken into consideration and comprehensive clinical treatment methods must be introduced, including better electrocardiograph monitoring, respirator support, and IABP insertion. IABP is the most common assisted measure in the Department of Cardiac Surgery. The main effects of IABP are reduction of ventricular afterload, improvement of diastolic coronary perfusion, and enhancement of subendocardial perfusion, and it can increase cardiac output and improve cardiac function; therefore, it is most beneficial for patients with CABG [13,14]. Although IABP was recommended as a class IIa (level of evidence B) indication in guidelines for CABG [11], we still have questions about the time to insert IABP. The most important contribution of this study was the demonstration of the differences between preoperative and emergency IABP insertion in high-risk patients undergoing CABG.

In our study, we can easily find that patients accepting preoperative IABP had shorter IABP support time, respirator support time, and ICU stay time than patients in the emergency group. In fact, not only the important indicators discussed above, but also the mortality and the morbidities of LCOS, AKI, and AMI are superior to the emergency IABP group and all of them had statistically significant differences (all p<0.05). This means that preoperative IABP insertion can bring more

benefits for those high-risk patients during their hospitalization than emergency IABP insertion.

Specifically, IABP support time, respirator support time, and ICU stay time were all shorter in patients who had preoperative IABP insertion than inpatients with emergency IABP insertion. This shows that proactive IABP insertion can protect cardiac function better and promote recovery more quickly. Patients who accepted proactive insertion had a more stable course of hospitalization. The amount of dopamine and epinephrine used in the preoperative group was less than that in the emergency group, because earlier insertion of IABP stabilizes hemodynamics, reduces the usage of vasoactive agents, and increases the blood supply of important organs like the heart and lungs. All patients in the proactive group completed surgery successfully with the assistance of IABP [15–17]. Those high-risk patients often had multi-vessel lesions or/and left main artery lesions, and more than 1 artery needed revascularization. Surgeons may turn over the heart to deal with the left circumflex artery, posterior descending branch, and posterior branch of the left ventricle. This may lead to decreased BP and even ventricular fibrillation, particularly in off-pump CABG, which necessitates changing to cardiopulmonary bypass. In our study, this condition appeared twice in the preoperative group and 9 times in the emergency group ($p=0.021$). This may indicate that proactive insertion can stabilize the hemodynamics when we turn over the heart and reduce myocardial oxygen consumption. Thus, preoperative IABP insertion can help patients receive off-pump CABG successfully [18]. With the addition of the effects in shortening the ICU stay time and respirator support time, IABP does a great job during the perioperation period. Proactive IABP insertion can play a more effective role in high-risk patients.

Whether will it bring us more severe complications when we pay more attention to the benefits? LCOS is a clinical condition caused by a transient decrease in systemic perfusion secondary to myocardial dysfunction. The outcome is an imbalance between oxygen delivery and oxygen consumption at the cellular level, which leads to metabolic acidosis. It is observed most commonly in patients after cardiac surgery, and it is also the most important cause of death [19]. Two patients presented LCOS in preoperative IABP, compared to 9 patients in the emergency IABP group ($p=0.009$). Therefore, preoperative IABP can protect cardiac function better. According to the latest definition of acute myocardial infarction, by arbitrary convention, cardiac troponin (cTn) values $>10^{*99}$ th percentile upper reference limit (URL) during the first 48 h following CABG, occurring from a normal baseline cTn value (<99 th percentile URL). In addition, either: 1) new pathological Q waves or new LBBB; 2) angiographically documented new graft or new native coronary artery occlusion; 3) imaging evidence of new loss

of viable myocardium or new regional wall motion abnormality, should be considered as diagnostic of a CABG-related myocardial infarction. The incidence rate of CABG-related myocardial infarction was 5.2% ($n=2$) in the preoperative IABP group and 13.8% ($n=8$) in the emergency IABP group. The incidence rate of AKI was the same as CABG-related myocardial infarction. However, there was no IABP-related complication in the 2 groups and the difference in perioperative mortality rate between the 2 groups was not statistically significant. We can still say that preoperative insertion is a safe choice compared with emergency insertion in high-risk patients.

Another important factor that we cannot ignore is the expense of IABP. Despite the reimbursement of their basic social medical insurance, CABG is too expensive for most patients in China, as is IABP. Considering the cost of IABP, the decision should consider the balance of cost, risk, and benefits. As a result, it is not necessary to broaden the scope of applications infinitely. All the findings in our study were not only a great help for us to decide when to use IABP in the future, but also a demonstration that preoperative IABP insertion can reduce the risk of CABG and works best for patients who with than 12 points in EuroSCORE. And for the prevention of related IABP complications, we should extract the pump when the patient is hemodynamically stable.

Several limitations of this study should be recognized. The size of the sample of our study was small. In addition, we only focused on their hospitalizations, which may have an influence on the evaluation of preoperative IABP's risk and benefits in high-risk patients. Because of the improvement of PCI, we have few cases of acute myocardial infarction (AMI). Furthermore, we cannot see the benefit of IABP in AMI patients with severe mechanical complications like severe mitral regurgitation, left ventricular aneurysm, and acute inter-ventricular septum perforation. We did not calculate the expense of hospitalization, so we could not calculate the cost-benefit ratio of IABP. Despite the limitations of our approach, the study results provide us with effective proof that preoperative IABP insertion is a safe and effective measure for high-risk patients undergoing CABG.

Conclusions

For high-risk patients undergoing CABG, preoperative IABP insertion is a safe and effective measure.

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