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Clinical Practice of On-pump Beating-heart Coronary Artery Bypass Grafting at Tri-Service General Hospital

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Background: Current cardioplegic techniques cannot consistently avoid myocardial ischemic damage in high-risk patients undergoing coronary artery bypass grafting. Alternatively, revascularization without cardiopulmonary bypass is not always technically feasible. Beating-heart surgery with cardiopulmonary bypass support but without aortic cross-clamping may be an acceptable alternative. **Methods:** From April 2005 to August 2006, 70 patients underwent coronary artery bypass grafting through pump-supported, noncross-clamped beating-heart surgery. Among the patients, 74.3% were men and 25.7% were women. The mean age was 68±11.4 years. Preoperative left ventricular ejection fraction was 50.0%±15.5%. **Results:** Revascularization of 204 distal anastomoses (2.87 grafts/patient) was completed; 11.4% involved quadruple bypass, 68.6% involved triple bypass, and 20% involved double bypass. The mean operation time was 278 ± 62 minutes, and the mean bypass time was 61.0±26.3 minutes. The hospital mortality rate was 1.4%. The median postoperative ventilation time was 48±30 hours, the median intensive care unit stay was 4.1±2.3 days, and the mean total hospital stay was 12.8±4.7 days. Postoperative complications included acute renal failure (2.8%; all recovered after medical treatment), cerebrovascular events (1.4%), and reoperation for hemostasis (5.7%). One patient died during the hospital stay because of severe low cardiac output with multiple organ failure. **Conclusions:** On-pump beating-heart coronary artery bypass grafting may eliminate intraoperative global myocardial ischemia and may be an acceptable surgical option. This procedure avoids the myocardial injury associated with aortic cross-clamping and allows safe and complete coronary revascularization.

Keywords: coronary artery bypass grafting; cardioplegic techniques; revascularization; cardiopulmonary bypass

INTRODUCTION

The coronary artery bypass grafting (CABG) with cardiopulmonary bypass (CPB) technique was developed in 1966 by Dr. John Heysham Gibbon. CPB with aortic cross-clamping and cardioplegic arrest remains the gold standard, but several unwanted effects related to aortic cross-clamping and CPB remain of concern for certain high-risk patients.[1] Current clinical practice offers at least 3 types of procedure from which the surgeon can choose: 1) CABG with CPB on an arrested heart (arrested-ONCAB); 2) CABG with CPB with an empty beating heart (beating-ONCAB); and 3) off-pump CABG (OPCAB).

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Arrested-ONCAB provides the surgeon with excellent visualization of a motionless field. However, this procedure employs CPB, manipulation of the aorta for cannulation, cross-clamping, global ischemia, and usually hypothermia — all of which have associated morbidities.

Beating-ONCAB also provides the surgeon with excellent visualization of the displaced heart and the hemodynamic stability afforded by CPB. This procedure does not use aortic cross-clamping and thus requires less aortic manipulation than arrested-ONCAB. In beating-ONCAB, global myocardial ischemia and cardioplegic arrest are avoided, and the degree of hypothermia is moderate. There is mild motion of the heart, but regional stabilization is achieved easily with modern devices.

OPCAB avoids the use of CPB with its associated morbidities. It also maintains normothermia and minimizes aortic manipulation. However, hemodynamic instability can be a problem during cardiac displacement, especially in critical patients. Many surgeons are uncomfortable with this technique. Moreover, OPCAB has yet to demonstrate long-term graft patency rates equivalent to

Table 1 Preoperative Data*

Parameter (n = 70)	Value
Age, y	68±11.4 (range, 45-86)
Men, n (%)	52 (74.3)
Diabetes, n (%)	33 (47.1)
Ejection fraction(EF) <30%, n (%)	6 (8.5)
Preoperative EF, %	50±15.5
Intra-aortic balloon, n (%)	4 (5.7)
Creatinine >1.6 mg/dL, n (%)	13 (18.5)
Cardiogenic shock, n (%)	2 (2.8)
Emergent operation, n (%)	18 (25.7)

*Data are presented as the mean ± SD as indicated.

Table 2. Intraoperative Data*

Parameter (n = 70)	Value
No. of grafts/patient, n	2.87 ± 0.55
Left internal mammary artery, n (%)	32 (45.7)
Left anterior descending, n (%)	64 (91.4)
Diagonal, n (%)	12 (17.1)
Marginal branches of circumflex, n (%)	50 (71.4)
Right coronary, n (%)	35 (50)
Double bypass, n (%)	14 (20)
Triple bypass, n (%)	48 (68.6)
Quadruple bypass, n (%)	8 (11.4)
Bypass time, min	61 ± 26.3
Operation time, min	278 ± 62

*Data are presented as the mean ± SD as indicated.

those of ONCAB.

Despite the major advances in myocardial protection over the past decade, postoperative adverse events related to intraoperative ischemia have not been eliminated completely. Even continuous warm-blood cardioplegia, which is expected to keep the heart in an aerobic environment, does not completely prevent some degree of postoperative stunning,[2] possibly because the myocardial edema intrinsic to the diastolic state of the arrested heart can cause cardiac dysfunction. Conversely, keeping the heart beating, even with reduced contractility such as under β-blockade, is associated with less myocardial edema and better function.[3]

The aim of this study was to evaluate the performance and outcome of the on-pump beating-heart total myocardial revascularization technique. We assessed postoperative ventilation time, hematocrit (Hct), mortality, complications, length of stay in the intensive care unit (ICU), and total hospital stay.

Materials and Methods

From April 2005 to August 2006, 70 patients who underwent on-pump beating-heart surgery at Tri-Service General Hospital were included in our study. Patients receiving operations included emergency cases and patients in cardiogenic shock. Of these 70 patients, 74.3% were men (52/70), and 25.7% were women (18/70). The average age was 68±11.4 years. The average Hct was 35.93% ± 5.05%. The mean preoperative left ventricular (LV) ejection fraction (EF) was 50.32%±15.53%. Overall, 8.5% (6/70) of the patients had an EF <30%. Eighteen cases were emergency operations, 4 patients had an intraaortic balloon pump inserted before the operation, and 2 patients received CPR before the operation (see Table 1).

All patients were approached through a median sternotomy. One patient had the intraaortic balloon pump inserted after induction of anesthesia because of lower cardiac output syndrome with a cardiac index <2 L/min/m^2 in the presence of low systemic arterial pressure and high pulmonary pressure. CPB was performed via cannulation of the ascending aorta and using a two-stage right atrium—inferior vena cava cannula. Heparin was given at a dose of 300 U/kg to achieve a target activated clotting time (ACT) of >450 s. A standard circuit using Bard tubing set was used, which included a 40-mm filter, a roller pump, and a hollow fiber membrane oxygenator. Nonpulsatile flow was employed. The core temperature was allowed to drift, usually to 37°C. During bypass, Hct, ACT, line pressure, blood gases, and the patient's parameter values (arterial blood pressure, central venous pressure, temperature, and dieresis) were monitored. Revascularization was done sequentially, starting with the left internal thoracic artery to the left anterior descending artery. The saphenous vein graft was anastomosed distally to the target coronary vessel. Once all the coronary artery anastomoses were performed, a single side-biting clamp was applied to the aorta for the proximal vein graft anastomoses.

Initial results were assessed primarily on the clinical outcome of the patients and included hospital mortality, perioperative myocardial infarction (defined as the appearance of a new Q-wave or a peak creatine phosphokinase (CPK)-MB fraction >10% of the total CPK), requirement for inotropic agents or intraaortic balloon pump support, occurrence of stroke, and the durations of the ICU stay and postoperative hospital stay. Early mortality was defined as death within 30 days after the operation or death in the hospital after 30 days if a patient was still in the hospital 30 days after the operation. Ventilation time was defined as the duration of mechanical ventilation from the time of admission to the ICU until extubation.

Table 3. Postoperative Results*

Parameter (n = 70)	Value
Ventilation time, h	48 ±30
Intra-aortic balloon, n (%)	5 (7.1)
Cerebrovascular event, n (%)	C1 (1.4)
Acute renal failure, n (%)	1 (1.4)
Reoperation for hemostasis,n (%)	4 (5.7)
Bleeding in first 24 hr, mL	426 ±172
Intensive care unit stay, d	4.1±2.3
Hospital stay, d	12.8±4.7
Hospital mortality, n (%)	1 (1.4)
Preoperative hematocrit, %	35.9±5.1
Postoperative hematocrit, %	29.2±2.4

*Data are presented as the mean ± SD as indicated.

RESULTS

The intraoperative data are listed in Table 2. Revascularization was as complete as was deemed possible and comprised 204 distal anastomoses with a mean number of distal grafts per patient of 2.87±0.55. The bypass system allowed either complete or partial cardiopulmonary support. The mean operation time was 278±62 minutes. The mean bypass time was 61±26.3 minutes. Overall, 11.4% (8/70) of the patients received a quadruple bypass, 68.6% (48/70) received a triple bypass, and 20% (14/70) received a double bypass. The mean volume of bleeding in the first 24 hours was 426±172 mL. Postoperative Hct was 29.2%± 3.4%. The mean hospital stay was 12.8±4.7 days, and the mean ICU stay was 4.1±2.3 days. Complications occurred in 8 (11.4%) of the patients (Table 3): reoperation for mediastinal bleeding occurred in 4 (5.7%) patients; a nonreversible neurologic event occurred in 1 (1.4%) patient; increased ventilation >48 h occurred in 8 (11.4%) patients; and acute renal failure occurred in 1 (1.4%) patient despite adequate medical treatment. There was one cardiac-related death in a 78-year-old man who underwent an emergency operation for unstable angina that was complicated by congestive heart failure requiring balloon pump support. Despite an uneventful triple bypass procedure, the patient ultimately died 12 days after the operation from a low cardiac output state that persisted postoperatively.

Our hospital's rates of hemodialysis, cerebrovascular event, and hospital mortality were lower than those reported in other studies in the USA.[4] We noted longer durations of the ICU stay and hospital stay, and ventilator time, but no significant differences in the rates of postoperative intra-aortic balloon insertion compared with data from other studies.

DISCUSSION

Myocardial revascularization has evolved partly from the techniques of angioplasty and stenting, and partly from surgical techniques involving various arterial and venous conduits. Some patients require surgical revascularization, especially those who go into cardiogenic shock. The early results of emergency conventional CABG for acute myocardial infarction are generally poor.[4,5,6,7] These poor results can be attributed to the patient's poor status or operative procedures associated with extracorporeal circulation and cardioplegic arrest, which induce ischemic injury and reperfusion injury to the myocardium. Keeping the heart beating is associated with less myocardial edema and better function.[8] It also offers a low risk of systemic hypoperfusion during surgery and, as a consequence, superior renal protection, as demonstrated by a low incidence of postoperative renal complications.[5]

Because cardioplegic arrest can trigger inflammatory responses, aortic cross-clamping should be avoided in unstable patients with acute myocardial infarction. However, this initial advantage of OPCAB has to be evaluated carefully from the long-term results showing a higher rate of reoperation in patients receiving OPCAB compared with those undergoing CPB in cases of acute myocardial infarction and LV dysfunction.[9-11] These adverse results of OPCAB can be attributed to the incomplete revascularization, which may result in part from the difficulty of performing distal anastomoses on the circumflex branches via a sternotomy. The other reason may be that tilting the heart reduces venous return and decreases cardiac output, which can be compensated partly by raising the preload or adjunct inotropic support, or both, when completing the anastomosis.[12,13] However, raising the preload in patients with poor heart function is usually rapidly followed by heart failure.

Considering the various factors mentioned above, our surgical approach was based on 2 main objectives: first, we tried to use CPB and aortic cross-clamping for as short a time as possible to decrease myocardial ischemia; second, we used CPB to help maintain stable hemodynamic conditions to compensate for the decrease in cardiac output that occurs during completion of the distal anastomosis. CPB compensated for the decrease in cardiac output, and coronary perfusion was maintained. Hemodynamic conditions were stable throughout the operation in our patients. Besides, if stabilization is not optimal for performing a good anastomosis, cardioplegia can be given easily to allow revascularization of the difficult region, followed or preceded by revascularization of the other regions by unclamping the aorta to decrease aortic cross-clamping.

On-pump beating-heart CABG has excellent results in reducing the CPB time. Significantly less bleeding (<1000 mL) and surgical revision for bleeding has been noted and this was attributed to longer CPB time in patients undergoing conventional CABG.[5] Perrault et al demonstrated less release of troponin Ic, a cardiac-specific marker of tissue damage, using the on-pump beating-heart technique compared with conventional CABG.[14] They also found a 3-fold increase in the postoperative myocardial content of mRNA coding for heat shock protein (HSP) 70, reflecting the preserved ability of the beating heart to display an appropriate adaptive response to surgical stress, whereas the arrested heart seems to lose this capacity.

CONCLUSION

We have applied CABG on a beating heart with extracorporeal circulation in our practice to further decrease the mortality and morbidity related to surgical revascularization. Numerous corisk factors, such as urgency, cardiogenic shock, complications from angioplasty, and recent myocardial infarction may not be risk factors with this technique.[6] The postoperative course was simplified markedly because few patients presented with low cardiac output after surgery. On-pump beating-heart CABG may be the method of choice for patients with impaired LV function or acute ongoing ischemia because myocardial ischemia is reduced with this technique.[4] The results of this study need to be confirmed by other larger, long-term studies.

Limitations

Several limitations of this study should be addressed. First, our investigation was retrospective. Second, the patients undergoing conventional CABG were from a former series, whereas the on-pump beating-heart CABG was performed in the past decade, and there is a historical difference in technique and outcome, even though the operations were performed by the same surgeon. Third, the number of patients was small and the period of study was short. Further studies are needed to confirm our results.

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