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Role of Left Main Coronary Artery Stenosis on Intraoperative Conversion and Mortality in Off-Pump Coronary Artery Bypass

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Background: Intraoperative conversion is a major threat in off-pump coronary artery bypass (OPCAB). The conversion rate depends on patient selection and surgeon experience. Previous studies have demonstrated the feasibility of OPCAB for patients with left main coronary artery stenosis (LMCAS) ≥ 50%. However, no studies have focused on the role of LMCAS ≥ 90%. We sought to assess the impact of LMCAS ≥ 90% on the conversion rate and mortality in OPCAB.

Methods: We conducted a retrospective review of 1055 consecutive unselected patients undergoing OPCAB between 2000 and 2012. The patients in our study were divided into 3 groups by the severity of LMCAS.

Results: LMCAS was < 50% in 704, 50-90% in 266, and ≥ 90% in 85 patients. LMCAS was not associated with major postoperative complications and hospital mortality, although preoperative cardiogenic shock was present in 6.3%. Overall, the conversion rate was 10.1%:11.4% in LMCAS < 50%, 5.6% in LMCAS 50-90%, and 14.1% in LMCAS ≥ 90%. Operation status, cardiogenic shock, left ventricular ejection fraction < 30% and operation before 2007 were noted as independent predictors of conversion. The overall hospital mortality rate was 5.1%: 4.8% in LMCAS < 50%, 4.5% in LMCAS 50-90%, and 9.4% in LMCAS ≥ 90%. Operation status, cardiogenic shock, left ventricular ejection fraction < 30% and intraoperative conversion were observed to be independent predictors of mortality. However, LMCAS did not predict either conversion or hospital mortality.

Conclusions: LMCAS ≥ 90% was not an independent predictor of intraoperative conversion or hospital mortality in OPCAB.

Key Words: Conversion • Left main coronary artery stenosis • Off-pump coronary artery bypass

INTRODUCTION

Coronary artery bypass graft (CABG) surgery has traditionally been performed with the use of cardiopulmonary bypass. The technique of operating on a beating heart or off-pump coronary artery bypass (OPCAB) was developed to decrease postoperative complications and mortality.[1,2] In OPCAB surgery, one of the major intraoperative complications is hemodynamic deterioration, which can occur during displacement of the heart to expose the target vessels. It requires urgent or emergency intraoperative conversion to a pump for CABG. However, intraoperative conversion is associated with adverse outcomes.[3-9]

Significant left main coronary artery stenosis (LMCAS) ≥ 50% has been recognized as a risk factor among patients undergoing CABG and also a predictor of intra-

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operative conversion.[3-9] Nevertheless, recent studies have demonstrated that OPCAB can be safely performed in patients with LMCAS ≥ 50%.[10-17] However, none of previous studies have focused on the role of LMCAS ≥ 90% on the rate of intraoperative conversion and hospital mortality in OPCAB. The purpose of this study was to assess the impact of LMCAS ≥ 90% on the conversion and mortality in OPCAB.

MATERIALS AND METHODS

Patients

This was a retrospective, observational, cohort study of prospectively collected data. We included all consecutive unselected patients undergoing OPCAB by a single surgeon (Ron-Bin Hsu) between December 2000 and September 2012 at the National Taiwan University Hospital. No patient was excluded from OPCAB because of the pattern of coronary artery disease, cardiogenic shock or the emergency status of surgery. Patients who underwent simultaneous valvular or aortic surgery were excluded. Intention-to-treat data were obtained in the present study, and OPCAB cases that were converted to on-pump procedures remained in this investigation.

All data were collected by retrospective chart review. The local institutional medical ethics committee approved the study and waived the need for informed consent.

Operation

Beginning in December 2000, we started treating all patients with coronary artery disease with coronary artery bypass grafting without the use of cardiopulmonary bypass or OPCAB. As described previously,[18] the surgery was performed through a median sternotomy. The heparin dose is two-thirds of the standard dose for cardiopulmonary bypass, and the target activated clotting time is more than 350 seconds. This is partially reversed with a one-half the calculated protamine dose after the completion of coronary anastomosis. Cardiopulmonary bypass was on standby without priming the pump. The operation was converted to on-pump beating heart coronary artery bypass if there was hemodynamic compromise during the procedure.

Definition

Emergency surgery patients were defined as unstable patients with cardiogenic shock or acute coronary syndrome requiring immediate operation. Urgent patients were defined as patients with cardiac conditions who were kept in the hospital before surgery. Elective patients were defined as clinically stable patients who were discharged home while waiting for surgery. Cardiogenic shock was defined as persistent shock even with the use of inotropic infusion and intra-aortic balloon pumping. The completeness of revascularization was identified by comparing the number of distal anastomoses with the number of diseased coronary arteries. Revascularization index was defined as the ratio of the number of distal anastomoses and the number of diseased vessels. If the number of distal anastomoses equaled the number of diseased vessels, the revascularization index was 1.[18]

Statistical analysis

A total of 1055 consecutive patients underwent OPCAB. Patients were divided into 3 groups by the severity of LMCAS: < 50% in 704, 50-90% in 266, and ≥ 90% in 85 patients. Data of baseline patient characteristics, operative details, perioperative outcomes, blood transfusion and conversion were compared between the three groups. SPSS 20.0 for Windows was used for analysis, and categorical variables were reported as the percentage of patients in the subgroup. Continuous variables were presented as mean ± standard deviation. Comparison between the groups was performed using the Chi-squared test, Fisher's exact test, and the Mann-Whitney test. A p value below 0.05 was considered significant. A multivariate logistic regression analysis was performed on variables which were considered as risk factors in the univariate analysis with a p value less than 0.05.

RESULTS

Patients

There were 845 males and 210 females with the median age of 67 years (range, 26 to 91) enrolled in our study. Clinical and demographic characteristics were shown in Table 1. The mode of surgical intervention was

elective in 768 patients, urgent in 185 patients and emergency in 102 patients (10%). The percentage of preoperative cardiogenic shock was 6.3%. The overall hospital mortality rate was 5%:0.4% in elective cases, 8.6% in urgent cases, and 33% in emergency cases. The major causes of in-hospital death were severe cardiogenic shock in 30 patients, severe sepsis in 20 patients, ischemic stroke in 2 patients, ventricular tachycardia/fibrillation in 1 patient, and aortic rupture in 1 patient. Among 102 emergency cases, 17 patients had severe cardiogenic shock requiring extracorporeal membrane oxygenation before operation. Shock patients underwent on-pump beating heart CABG under either partial cardiopulmonary bypass or extracorporeal membrane oxygenation, and 13 of them (76%) died of persistent shock after operation. The overall conversion rate was 10% (107/1055).

LMCAS

As shown in Table 1, clinical and demographic data were compared between the 3 groups. There were negligible differences in sex, number of diseased vessels, number of distal anastomosis, revascularization index, perioperative blood transfusion, postoperative stroke, and postoperative infection. Old age, emergency operation, left ventricular ejection fraction < 30%, cardiogenic shock and operation after 2007 were more commom in patients with LMCAS ≥ 90%. The overall conversion rate was 10.1%:11.4% in LMCAS < 50%, 5.6% in LMCAS 50-90%, and 14.1% in LMCAS ≥ 90%. Overall hospital mortality rate was 5.1%:4.8% in LMCAS < 50%, 4.5% in LMCAS 50-90%, and 9.4% in LMCAS ≥ 90% (Table 1).

Hospital mortality

On multivariate logistic regression analyzing all the variables listed in Table 1, left ventricular ejection fraction < 30%, intraoperative conversion, operation status, cardiogenic shock and postoperative bloodstream infection and postoperative ventricular tachycardia were independent predictors of hospital mortality (Table 2). LMCAS did not predict hospital mortality.

Conversion

As shown in Table 3, clinical and demographic data were compared between patients with and without intraoperative conversion. Old age, LMCAS ≥ 90%, emergency operation, cardiogenic shock, left ventricular ejection fraction < 30% and operation before 2007 were more frequent in patients with intraoperative conversion. Patients with intraoperative conversion received

Table 1. Clinical and demographic characteristics of 1055 patients undergoing off pump coronary artery bypass: comparison between groups of LMCAS < 50%, LMCAS 50-90% and LMCAS ≥ 90%

Groups Case number	LMCAS < 50% N = 704	LMCAS 50-90% N = 266	LMCAS ≥ 90% N = 85	Total N = 1055	p value
Age in years	64.8 ± 10.9	67.8 ± 10.6	67.8 ± 10.3	65.8 ± 10.9	< 0.001
Male sex	81.4%	77.4%	77.7%	80.1%	0.33
Operation after 2007	49.3%	58.7%	55.3%	52.1%	0.03
LVEF < 30%	16.1%	9.8%	16.5%	14.5%	0.04
Conversion	11.4%	5.6%	14.1%	10.1%	0.01
Emergency	10.1%	5.6%	18.8%	9.7%	0.002
Cardiogenic shock	7.4%	2.3%	9.4%	6.3%	0.006
Number of diseased vessels	2.8 ± 0.5	2.9 ± 0.4	2.7 ± 0.4	2.8 ± 0.5	0.06
Number of distal anastomoses	3.4 ± 1.1	3.5 ± 0.9	3.3 ± 0.8	3.4 ± 1.0	0.06
Revascularization index	1.2 ± 0.3	1.2 ± 0.3	1.2 ± 0.3	1.2 ± 0.3	0.37
Blood transfusion	56.1%	61.3%	62.4%	57.9%	0.24
Sternal wound infection	2.4%	2.3%	1.2%	2.3%	0.77
Bloodstream infection	2.8%	2.6%	0.0%	2.6%	0.10
Stroke	1.0%	1.1%	2.45%	1.1%	0.61
Ventricular tachycardia	2.6%	1.9%	2.4%	2.37%	0.82
Hospital mortality	4.8%	4.5%	9.4%	5.1%	0.17

LMCAS, left main coronary artery stenosis; LVEF, left ventricular ejection fraction.

Table 2. Independent risk factors of hospital mortality by multivariate logistic regression

Variables	Odds ratio	95% confidence interval	p value
Age	1.00	0.96-1.04	0.96
Male sex	0.53	0.18-1.55	0.25
Number of diseased vessels	3.19	0.05-209.56	0.59
LMCAS			
< 50%	1		0.13
50-90%	2.57	0.78-8.52	0.12
≥ 90%	3.30	0.83-13.12	0.09
LVEF < 30%	8.28	2.67-25.72	< 0.001
Conversion	3.09	1.10-8.66	0.03
Number of distal anastomoses	0.38	0.007-19.27	0.63
Operation after 2007	1.84	0.64-5.27	0.26
Revascularization index	0.22	0.04-1.40	0.11
Operation status			
Elective	1		0.004
Urgent	22.61	3.61-141.67	0.001
Emergent	13.44	1.54-117.12	0.02
Cardiogenic shock	8.30	1.81-38.02	0.006
Blood transfusion	1.63	0.27-9.70	0.59
Sternal wound infection	1.01	0.09-10.84	1.00
Bloodstream infection	272.21	39.39-1881.39	< 0.001
Stroke	7.72	0.70-85.62	0.10
Ventricular tachycardia	7.15	1.51-33.85	0.01

LMCAS, left main coronary artery stenosis; LVEF, left ventricular ejection fraction.

Table 3. Clinical and demographic characteristics of 1055 patients undergoing off pump coronary artery bypass: comparison between patients with and without conversion

Group	No conversion	Conversion	p value
Case number	948	107	
Age in years	65.6 ± 10.74	68.0 ± 11.8	0.03
Male sex	79.9%	82.2%	0.61
Operation after 2007	54.5%	30.8%	< 0.001
LMCAS			0.01
< 50%	65.8%	74.8%	
50-90%	26.5%	14.0%	
≥ 90%	7.7%	11.2%	
Emergent	5.9%	43.0%	< 0.001
LVEF < 30%	9.7%	57.0%	< 0.001
Cardiogenic shock	2.3%	41.1%	< 0.001
Number of diseased vessels	2.8 ± 0.5	2.8 ± 0.4	0.71
Number of distal anastomoses	3.5 ± 1.0	2.9 ± 0.9	< 0.001
Revascularization index	1.2 ± 0.3	1.0 ± 0.3	< 0.001
Blood transfusion	53.5%	97.2%	< 0.001
Sternal wound infection	1.9%	5.6%	0.02
Bloodstream infection	1.9%	8.4%	< 0.001
Stroke	0.8%	3.7%	0.03
Ventricular tachycardia	2.0%	5.6%	0.02
Hospital mortality	2.3%	29.9%	< 0.001

LMCAS, left main coronary artery stenosis; LVEF, left ventricular ejection fraction.

less bypass grafts and more blood transfusion. Furthermore, intraoperative conversion was associated with increased rates of sternal wound infection, bloodstream infection, stroke, ventricular tachycardia and hospital mortality. On multivariate logistic regression analysis (Table 4), the independent predictors of conversion were operation status, cardiogenic shock, left ventricular ejection fraction < 30% and operation before 2007. LMCAS ≥ 90% was a significant predictor of intraoperative conversion.

DISCUSSION

This is the first study addressing the impact of LMCAS ≥ 90% on the rate of intraoperative conversion and hospital outcome in OPCAB. This study summarizes an 11-year experience of a single surgeon who performed these OPCAB procedures. The present cohort included both emergency and cardiogenic shock patients that were often excluded by previous OPCAB studies. There are 3 important findings: 1) intraoperative conversion was associated with significantly worse morbidity and mortality; 2) operation status, cardiogenic shock, poor heart function and surgeon experience were independent predictors of conversion; 3) LMCAS ≥ 90% was not an independent predictor of hospital mortality or conversion.

Conversion

There is a wide variability in the rate of intraoperative conversion during OPCAB. The conversion rate was 0 to 13.3% in previous randomized controlled trials of OPCAB performed in non-emergency patients.[4] The conversion rate depends on surgeon experience.[3-9,19] The successful performance of OPCAB is more dependent on the surgical experience than on pump CABG is because of the inherent difficulties in performing a delicate anastomosis on a beating heart.[2,19-22] In addition, the conversion rate also depends on patient selection. Patients with preoperative cardiogenic shock usually required an immediate life-saving support during CABG. Previous studies addressing the conversion often excluded emergency cases and were associated with a low percentage (< 1%) of shock patients.[3-9,19-22] In this study, we included cases of emergency (9.7%) and cardiogenic shock (6.3%). The overall conversion rate of 10.1% was intermediate. The use of "Operation" before 2007 was as an independent predictor of conversion. Our data reinforces the impact of cumulative surgeon experience in reducing intraoperative conversion.

LMCAS

In early development of off-pump technique, LMCAS ≥ 50% was a contraindication of OPCAB.[15,16] The surgical risk was high in patients with LMCA stenosis ≥ 75%,

Table 4. Independent risk factors of intraoperative conversion by multivariate logistic regression

Variables	Odds ratio	95% confidence interval	p value
Age	1.02	0.99-1.04	0.23
Male sex	1.49	0.77-2.90	0.24
Number of diseased vessels	2.13	0.22-20.73	0.52
LMCAS			
< 50%	1		0.38
50-90%	0.64	0.33-1.27	0.20
≥ 90%	1.16	0.50-2.70	0.73
Number of distal anastomoses	0.85	0.11-6.59	0.88
Revascularization index	0.95	0.003-284.94	0.99
Operation status			
Elective	1		0.001
Urgent	3.37	1.74-6.54	< 0.001
Emergent	2.31	0.88-6.04	0.09
Cardiogenic shock	9.91	3.47-28.30	< 0.001
LVEF < 30%	4.43	2.56-7.69	< 0.001
Operation after 2007	0.24	0.12-0.45	< 0.001

LMCAS, left main coronary artery stenosis; LVEF, left ventricular ejection fraction.

unstable angina, recent myocardial infarction, re-operative CABG, and left ventricular ejection fraction < 30%.[3-9,23,24] Displacement of the heart to expose target vessels during OPCAB may impair cardiac function and induce severe hypotension.[25] Severe hypotension is detrimental to a patient with LMCAS ≥ 90%. Myocardial ischemia may aggravate with surgical manipulation. Patients would become unstable and require intra-aortic balloon pump support[23,24] or emergency cardiopulmonary bypass.[3-9]

With the improvements that have been made in technology and hemodynamic management, patients with significant LMCAS can undergo OPCAB safely.[10-17] Nevertheless, most of the previous studies have been performed in experienced centers and with patient selection.[3,10-17] Data from the real-world registry showed that LMCAS was associated with a high risk of intraoperative conversion.[6] In this study, LMCAS was not an independent predictor of hospital mortality and intraoperative conversion. We believed that the sequence of coronary artery anastomoses is important for a successful OPCAB. Anastomosis to the left anterior descending artery is performed first followed by right coronary artery and the left circumflex artery. The left internal mammary artery to left anterior descending artery anastomosis requires only slight cardiac displacement and provides immediate flow to ischemic myocardium during the subsequent inferior and lateral wall revascularization.

Study limitation

Several limitations of our study should be recognized. First, this study was retrospective, spanning more than a decade, and encompassed a small patient population. Thus the results were subject to selection bias. Additionally, many potential confounding variables are not included in this study. The OPCAB technology also continued to evolve and change during the study period. Because we had only 85 patients with LMCAS ≥ 90% and 107 patients converted, the statistical power for further subgroup analysis was impossible. Second, the timing and status of intraoperative conversion were not clearly described in this study. Early and elective conversion is associated with a lower risk of mortality and morbidity.[9] Third, the long-term outcomes including graft patency and major adverse cardiovascular events were not assessed. The long-term risk of LMCAS is not assessed in this study. However, this is the first study addressing the impact of LMCAS ≥ 90% on the rate of intraoperative conversion and hospital outcome in OPCAB.

CONCLUSIONS

LMCAS ≥ 90% was not an independent predictor of intraoperative conversion or hospital mortality in OPCAB.

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