original article

Surgery for chronic total occlusion of the left main coronary artery

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BACKGROUND AND OBJECTIVES: Chronic total occlusion of the left main coronary artery (LMCA) is a rare condition, and the information on surgical experiences is limited. Although total occlusion of the LMCA is accompanied by well-developed collateral circulation, the condition of circulation is unstable during manipulation of the heart. We report our experience with revascularization in cases with total occlusion of the LMCA using the on-pump beating-heart (OnP-BH) technique.

DESIGN AND SETTING: Retrospective case review of patients treated at The First Affiliated Hospital of China Medical University over a 10-year period (1999 to 2009).

PATIENTS AND METHODS: The on-pump coronary artery bypass grafting with the beating heart was applied to 8 patients with chronic total occlusion of the LMCA. The extracorporeal circulation period, intubation duration, intensive care unit stay period, discharge period, preoperative and postoperative treatments, and follow-up were observed.

RESULTS: The mean extracorporeal circulation period was 80.4 (19.7) minutes. The mean intubation duration was 13.0 (4.6) hours. The mean intensive care unit stay period was 3.2 (0.7) days, and the mean discharge period was 16.8 (3.3) days. No perioperative myocardial infarction occurred. The mean follow-up period was 50.9 (34.8) months. All patients were asymptomatic, and no deaths were recorded during the follow-up period. The results of echocardiography showed improvement in the left ventricular function.

CONCLUSIONS: The OnP-BH myocardial revascularization seems to be a valid alternative for chronic total occlusion of the LMCA.

Involvement of the left main coronary artery (LMCA) is observed in approximately 5% to 8% of patients with coronary artery lesions detected by coronary angiography.[1] Because of the fatal hemodynamic consequences of the LMCA occlusion, chronic total occlusion of the LMCA is rarely seen in the cardiovascular clinic.[2] Acute occlusion is invariably fatal; however, survival is possible if the patient reaches the hospital in time. Patients usually present with acute myocardial infarction, cardiogenic shock, or sudden cardiac death. Chronic total occlusion presents with angina, myocardial infarction, or congestive heart failure.[3] The incidence of total occlusion of the LMCA in the reported series ranged from 0.04% to 0.43% of all patients who underwent cardiac catheterization.[4,5] We report eight patients with chronic total occlusion of the LMCA who underwent on-pump coronary artery bypass grafting (CABG) with a beating heart in our institution between 1999 and 2009.

PATIENTS AND METHODS

Eight patients (2 females and 6 males) with ages in the range of 41-73 years (mean [SD] age, 58.4 [10.8] years) were included in the study. The percentage of patients in this group who required CABG in our department was 0.26% (8/3 073). The clinical data were collected from the patients' records (**Table 1**). Each patient had a dominant right coronary system and a total occlusion of the LMCA with well-developed collateral filling from the right coronary artery (RCA) (**Figures 1-3**). One patient whose left ventricular ejection fraction (LVEF) was 36% only had sparse collaterals. Apart from the LMCA occlusion, 4 patients had significant obstructive lesions in the RCA or its major branches. Of the 8 cases, the collateral pathways of the left anterior descend-

ing (LAD) artery were acute marginal branches of the RCA in 4 patients, conus branches of the RCA from the Vieussen loop in 2 patients, and a septal branch from the posterior descending artery of the RCA in 2 patients. The collateral pathways of the left circumflex coronary artery were obtuse marginal branches from the posterior descending of the RCA in 4 patients, the posterior left ventricular artery of the RCA in 1 patient, the distal part of the RCA in 1 patient, and no collateral in 2 patients. The sources of collateral filling in 4 patients with severe stenosis of the RCA were the proximal part of RCA stenosis in 1 patient and the distal part of RCA stenosis in 3 patients. Echocardiography demonstrated markedly depressed left ventricular ejection fraction (LVEF) in all 4 patients with severe stenosis of the RCA and in 2 patients with normal RCA. LVEFs of the other 2 patients were well preserved. Preoperative creatine kinase MB, troponin T, and troponin I of all 8 patients were normal. Low-molecular heparin was applied in all 8 patients and stopped 1 day before surgery. In all patients, β-blockers were routinely given orally until the morning of surgery. All operations were performed through a median sternotomy incision under general anesthesia. One patient planned for the on-pump beating-heart CABG (OPCAB) procedure had to be converted to the on-pump beating-heart (OnP-BH) surgery because of hemodynamic instability during cardiac manipulation. OPCAB was applied to all other 7 patients. Cardiopulmonary bypass with the beating heart was established through standard aortocaval cannulation using a roller pump and membrane oxygenator. The systemic temperature was kept

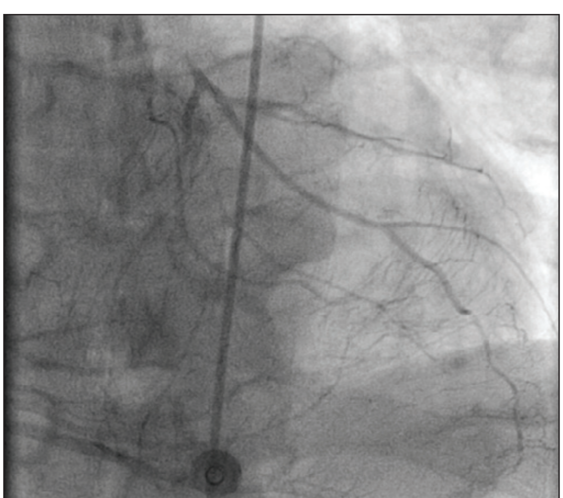

Figure 1. Selective coronary angiography in right anterior oblique projection showing total occlusion of the left main coronary artery.

Table 1. Preoperative data of patients with chronic total occlusion of the left main coronary artery.

Age/Sex	45/M	61/M	73/M	55/F	67/M	41/M	63/F	62/M
Risk factors	Smoking	Smoking, hypercholesterolemia	Family history	Hypercholesterolemia	Smoking	Family history	Smoking, hypercholesterolemia	Smoking, hypercholesterolemia
Associated diseases	Hypertension, DM	COPD	Hypertension	Hypertension, DM			DM	Hypertension
Previous history of MI	–	+	+	–	+	–	+	+
Electrocardiogram	Ant. ischemia	AMI	AMI	Ant. ischemia	AMI	Normal	AMI	AMI
Coronary angiography	LMCA, 100%	LMCA, 100%; RCPD artery', 60%	LMCA, 100%; RCA, 80%	LMCA, 100%	LMCA, 100%; RCA, 70%	LMCA, 100%	LMCA, 100%	LMCA, 100%; RCPD, 80%
Dominance	RCS	RCS	RCS	RCS	RCS	RCS	RCS	RCS
Echocardiography EF (%)	55	36	24	46	34	60	27%	41%

AMI: Anterior myocardial infarction, Ant: anterior, COPD: chronic obstructive pulmonary disease, EF: ejection fraction, F: female, LMCA: left main coronary artery, M: male, MI: myocardial infarction, RCA: right coronary artery, RCPD: right coronary posterior descending, RCS: right coronary system, + :present, – :absent.

Table 2. Operative and postoperative data of patients with chronic total occlusion of left main coronary artery.

Age/Sex	45/M	61/M	73/M	55/F	67/M	41/M	63/F	62/M
Extracorporeal circulation period (minutes)	75	113	96	82	92	71	51	63
Intubation duration (hours)	9	21	11	16	17	11	7	12
Operation	CABG × 2 LITA-LAD A-CxOM	CABG × 4 LITA-LAD A-D1-CxOM RITA-RCPD	CABG × 4 LITA-LAD A-D1-CxOM RITA-RCPD	CABG × 3 LITA-LAD A-D1-CxOM	CABG × 4 LITA-LAD A-D1-CxOM RITA-RCPD	CABG × 3 LITA-LAD A-D1-CxOM	CABG × 2 LITA-LAD A-CxOM	CABG × 3 LITA-LAD artery A-CxOM RITA-RCPD
Postoperative complications	–	IABP	–	–	VA	–	–	–
Discharge time (days)	17	23	15	18	18	17	12	14
Intensive care unit stay period (days)	3	5	3	3	3	3	3	3
Control angiography	+	–	–	–	–	–	-	-
Follow-up period (months)	110	61	68	50	71	32	12	3
Late mortality	–	–	–	–	–	–	–	-
Echocardiography EF (%)	65	56	31	55	42	65	38%	50%

EF: Ejection fraction, CABG: coronary artery bypass grafting, CxOM: obtuse marginal branch of circumflex artery, D: diagonal artery, IABP: intra-aortic balloon pump, LAD: left anterior descending, LITA: left internal thoracic artery, F: female, M: male, RCPD: right coronary posterior descending, VA: ventricular arrhythmia, +: present, – : absent.

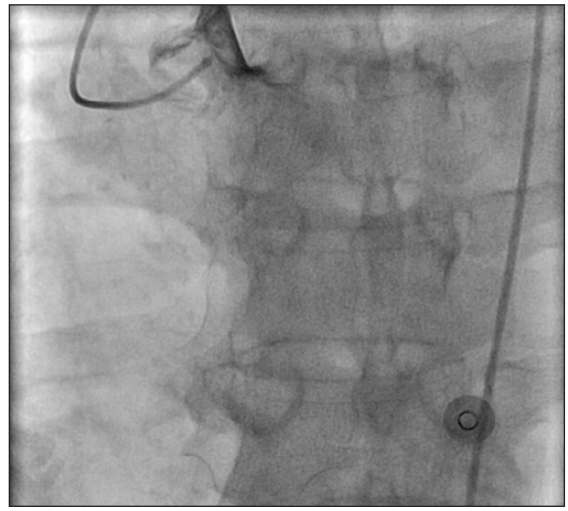

Figure 2. Selective coronary angiography in right anterior oblique projection showing total occlusion of the left main coronary artery.

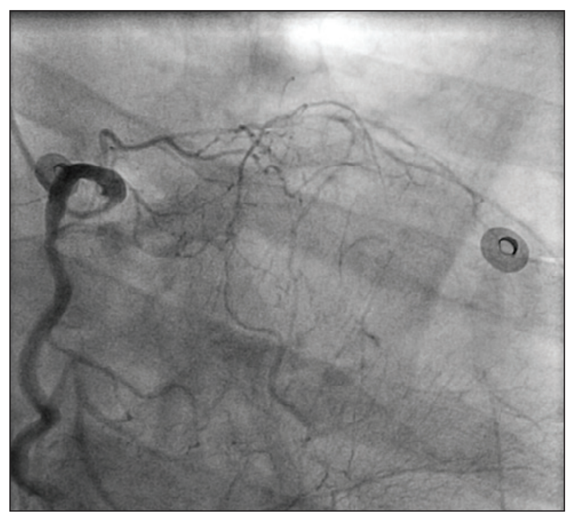

Figure 3. Selective coronary angiography in right anterior oblique projection showing total occlusion of the left main coronary artery.

between 34°C and 36°C. The flow of aortic perfusion was administered to hold above 2.4 L/m^2 per minute. Heparin was given at a dose of 300 IU/kg to achieve an activated clotting time (ACT) target of ≥500 seconds before commencement of cardiopulmonary bypass. On completion of all anastomoses, protamine was given to reverse the effect of heparin and return the ACT to pre-operative levels. Oxygen blowing was used to improve the visualization of the anastomotic region. When the coronary artery was opened, an intracoronary shunt was used in case of any relative electrocardiographic or hemodynamic instability or excessive bleeding, and

the anastomosis was then performed. The left internal thoracic artery (LITA) was used in 8 patients, and the distal end of the LITA was anastomosed with the LAD artery. The right internal thoracic artery was used in 4 patients with severe stenosis of the RCA. The radial artery (RA) was used in 7 patients, and the saphenous vein was used in 1 patient owing to a positive Allen test. The RAs of 7 patients were anastomosed to the obtuse marginal branch and the diagonal branch. The proximal saphenous vein of 1 patient was anastomosed to the obtuse marginal branch. The distal saphenous vein of this patient and the proximal RAs of 7 patients were anastomosed to the wall of the ascending aorta. For 1 patient with the collateral of LMCA from the proximal part of RCA stenosis, revascularization of the RCA was performed first, while revascularization of the left coronary artery was performed first in another 3 patients with the collateral of LMCA from the distal part of RCA stenosis. The nitrate, diltiazem, dopamine, milrinone, and prostaglandin E1 were applied intravenously after surgery. Aspirin (100 mg via nasogastric tube) was given to patients daily. On postoperative day 1, β-blockers were given intravenously in the ICU if the patient was unable to swallow pills. Accordingly, time of β-blocker withdrawal (if any) was minimized in the present series of patients. Postoperative prophylactic amiodarone (daily 200 mg orally was started on postoperative day 1) has been used routinely in all patients. An ACE inhibitor was used routinely in the patients, including those who were taking one preoperatively, who were in congestive heart failure, or who had low LVEF (≤35%), if hemodynamically tolerated (systolic blood pressure ≥100 mm Hg).

RESULTS

The mean extracorporeal circulation period was 80.4 (19.7) minutes. The mean intubation duration was 13.0 (4.6) hours. The mean intensive care unit stay period was 3.2 (0.7) days, and the mean discharge period was 16.8 (3.3) days. An intra-aortic balloon pump (IABP) was used in 1 patient who had sparse collaterals because of low cardiac output syndrome and removed 3 days after operation. In 1 patient, arrhythmia was detected, and it was controlled with an anti-arrhythmia agent. No perioperative myocardial infarction or mortality occurred. The mean follow-up period was 50.9 (34.8) months. All patients were asymptomatic and no deaths were recorded. The results of echocardiography showed an improvement in the LVEF (**Table 2**). One 45-year-old patient received coronary angiography in the 9th year after operation. The anastomotic stomas were all unobstructed. The other 7 patients did not receive control angiographies because they were not readmitted.

DISCUSSION

Patients with total occlusion of the LMCA have high mortality owing to the decreased blood supply of left ventricle by more than 75%, so these lesions are rarely demonstrated with coronary angiography, and survival depends on the existence of collateral circulation. In LMCA disease, the obstruction is also observed in other parts of the coronary artery tree,[6] and hence an urgent coronary bypass surgery is needed.[7] Although the collateral circulation only offers 10% of blood supply, it can prevent myocardial infarction of an ischemic myocardium and avoid myocardium irreversible necrosis or, as far as possible, decrease the lesion of necrosis, which suggests the possible beneficial effect of collateral circulation in preserving myocardial contractility in total occlusion of the LMCA.[8] The technical success of percutaneous coronary intervention for chronic total occlusions was only 64.9% to about 77.2%.[9-11] The restenosis rate of stenting in chronic coronary occlusion is 45% to 74%,[12] and the reocclusion rate of stenting in chronic coronary occlusion is 19% to about 26%.[13,14] With improvement in the perioperative management of patients undergoing CABG, early and late mortality after CABG in patients with LMCA stenosis had a decrease despite an increase in patient age and risk factors. CABG can obviously decrease the mortality of patients with stenosis of the LMCA.[15] In the absence of definitive data to the contrary, bypass surgery remains the standard of care for patients with the unprotected LMCA disease who are candidates suitable for surgery.[16-18] The committee of American College of Cardiology and American Heart Association considered that CABG was a class 1 recommendation for unstable angina patients with significant LMCA stenosis (greater than 50%).[19] The treatment of CTO of the LMCA is possible only through the cardiac surgery (insertion anastomoses) on branches of the left coronary artery. Because of the difficulties with crossing by chronic occlusion, percutaneous coronary intervention is not a recommended procedure. So CABG is considered to be the therapy of choice for this condition.[20-23] OPCAB and conventional CABG are frequently used nowadays. OPCAB provides the hope that this strategy would decrease perioperative morbidity, and possibly mortality, by eliminating cardiopulmonary bypass, but the fear concerning off-pump surgery has been that the difficulty of operating would lead to less complete and less effective revascularization at the time of surgery and worse long-term outcomes. Although total occlusion of the LMCA is accompanied by well-developed collateral circulation, the condition of circulation is unstable during manipulation of the heart. One patient

planned for the OPCAB procedure had to be converted to the OnP-BH surgery because of hemodynamic instability during cardiac manipulation. IABP was performed in this case and removed 3 days after operation. The patient was asymptomatic after a follow-up period of 61 months. On the other hand, ischemia-reperfusion injury occurs in the period of cardioplegic arrest. With conventional CABG, the procedure of operation is time-consuming, myocardial stunning produces arrhythmias, the function of endotheliocytes is suppressed, and necrosis of cadiocytes usually occurs. Hyperkalemia and anasarca may appear. Simultaneously, a well-distributed cardioplegic perfusate for an effective myocardial preservation is extremely complicated under conventional CABG in patients with total occlusion of the LMCA, especially with severe stenosis of the RCA. Shahian used antegrade cardioplegic perfusate for myocardial preservation.[21] Shiraishi operated on patients with total occlusion of the LMCA using intermittent antegrade cold blood cardioplegia.[24] Menasche claimed that myocardial areas distal to complete coronary artery occlusions are poorly protected by antegrade cardioplegia, and they suggested the use of retrograde cardioplegia for patients with totally occluded coronary arteries.[25] Others also agree that a combination of antegrade and retrograde delivery probably provides the most uniform distribution of cardioplegia.[26] However, all of the abovementioned cardioplegias do not result in a satisfactory effect. In patients of total occlusion of the LMCA who may poorly tolerate cardioplegic arrest, the OnP-BH surgery may be an acceptable alternative, associated with lower postoperative mortality and morbidity. The OnP-BH technique is a safe and convenient method for coronary artery bypass grafting.[27,28] Mizutani reported that OPCAB significantly reduced the duration of operation and cardiopulmonary bypass, total blood loss, and peak creatine kinase; and the number of patients requiring additional IABP support was significantly lower in the OPCAB group.[29] Miyahara also reported that OPCAB had lower postoperative mortality and morbidity than the conventional CABG. The stroke rate was significantly reduced in OnP-BH patients in comparison with that in conventional CABG patients.[30] The OnP-BH coronary surgery represents a merger of the standard on-pump surgery and the OPCAB technique. The absence of cardioplegic arrest and the hemodynamic stability guaranteed during extensive heart manipulation are the biggest benefits that can be derived from this technique, especially in cases of patients with total occlusion of the LMCA. In the present study, we have described our clinical experiences with the OnP-BH coronary surgery for patients with total occlusion of the LMCA. Normal temperature requires higher perfusion pressure, so the flow of aortic perfusion was administered to maintain a perfusion pressure above 2.4 L/m^2 body surface per minute and temperature greater than 34°C was maintained. Higher perfusion pressure injures formed elements of the blood, and the ratio of hemoglobinuria is increased after operation. Hemoglobinuria occurred in three cases but disappeared in 24 hours. In patients with total occlusion of the LMCA, the RCA is the vessel that actually perfuses the entire heart. Occlusion of the RCA before left coronary artery revascularization may be fatal, as the collateral flow to the left coronary system will also be compromised. Therefore, the left coronary artery revascularization was performed first, and the RCA bypass was done afterward. However, in patients with the left coronary system filled from the proximal part of the RCA lesion, the sequence of anastomosis is not important because the proximal part of the lesion still fills the collateral circulation when the RCA is clamped. Therefore, in the current group, although revascularization of RCA was performed first in one patient with the collateral of the LMCA from the proximal part of RCA stenosis, no cardiac infarction occurred during the preoperational period and the patient recovered well. Intracoronary shunt was very important in the case of patients with total occlusion of the LMCA, because the blood supply of the left coronary system wholly depended on the RCA even though the blood supply of the collateral circulation was sparse. When the revascularization of the RCA is performed under total occlusion of blood, a catastrophic result may occur. Thus, an intracoronary shunt should be promptly used in case of relative electrocardiographic or hemodynamic instability or excessive bleeding. Effective symptomatic relief is obtained by CABG, and revascularization may also improve prognosis in this subset of patients with coronary heart disease. Although the number of patients in our study was not enough for a statistical analysis and we did not have a control group, we obtained encouraging results using this strategy.

In conclusion, although further randomized clinical trials cannot be used to compare results derived using different surgical strategies undertaken to treat such small subgroups, we strongly believe that, on the basis of reported data and our surgical experience in this field, the OPCAB surgery, when not strictly contraindicated, can lead to acceptable short- and mid-term results and remains an attractive alternative to conventional myocardial revascularization and off-pump beating heart surgery in cases with total occlusion of the LMCA.

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