

Hybrid Coronary Revascularization for the Treatment of Left Main Coronary Artery Disease in High-Risk Patients

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ABSTRACT

Objective: Hybrid coronary revascularization is an alternative for treatment for high-risk patients with coronary artery disease. We evaluated the efficacy of staged hybrid coronary revascularization for the treatment of unprotected left main coronary artery disease in high-risk patients.

Methods: Patients with left main or proximal left anterior descending coronary artery stenosis who are not good candidates for percutaneous coronary intervention and who had suitable lesions in the right coronary and circumflex arteries were considered for staged hybrid therapy if they had poor left ventricular functions (ejection fraction <0.40) and comorbid illnesses. From January 2008 through December 2010, 11 patients (8 men, 3 women; mean age: 66.1 ± 9.1 years) were treated with off-pump coronary artery bypass grafting combined with staged percutaneous coronary intervention. Nine patients had left main coronary artery stenosis together with circumflex or right coronary artery stenosis, and 2 patients had proximal left anterior descending artery stenosis and right coronary artery stenosis.

Results: After off-pump coronary artery bypass grafting, procedure-related complications did not occur, and there was no in-hospital death. Coronary re-angiography after a median of 16 days revealed patent and functioning left internal mammary artery grafts in all patients. Applying subsequent percutaneous transluminal coronary angioplasty and occasional stenting ($n = 14$), a total of 14 lesions were treated successfully. Procedure related complications did not occur. All patients remained angina-free, and no stress electrocardiographic changes were recorded.

Conclusion: Our preliminary results indicate that a “staged hybrid” approach to the treatment of left main coronary artery disease in high-risk patients is safe and effective. Hybrid coronary revascularization enables complete revascularization and may be an alternative method of treating left main coronary artery disease in selected high-risk patients.

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INTRODUCTION

Hybrid coronary treatment is an alternative revascularization procedure that includes minimally invasive coronary artery bypass grafting (CABG) and percutaneous coronary interventions (PCI), especially for the treatment of high-risk patients with multivessel coronary artery disease [Murphy 2004; Reicher 2008; Bonatti 2010; Gao 2009]. Revascularization of the left anterior descending coronary artery (LAD) with the left internal mammary artery (LIMA) and percutaneous catheter treatment of other coronaries provide abstinence from cardiopulmonary bypass (CPB) and its side effects in this approach [Reicher 2008; Bonatti 2010]. In this method, bypass of the LAD is performed on the beating heart and the remaining coronaries are treated with percutaneous methods in patients who are high-risk candidates for CPB; hence, complete revascularization may be fashioned with attenuated risks [Murphy 2004; Vassiliades 2006; Holzhey 2008; Bonatti 2010]. Additionally, in this method there is minimal manipulation of the ascending aorta; thus, neurologic complications can be decreased [Reicher 2008]. Hybrid interventions may be preferred in patients with left main coronary artery (LMCA) disease and compromised left ventricular functions.

In this report, we aimed to assess the results of 11 hybrid interventions performed at our institution between 2008 and 2010.

PATIENTS AND METHODS

The study was approved by the institutional ethics committee, and consent was obtained from all patients for the design of retrospective and prospective chart analysis and clinical follow-up. Patients with LMCA lesions or proximal LAD lesions who are not amenable to PCI who have, however, various comorbidity factors and suitable right coronary artery (RCA) and circumflex coronary artery (Cx) lesions for PCI were selected for the treatment with hybrid revascularization method (Figure 1). The comorbidity factors are determined as low ejection fraction (<40%), history of recent myocardial infarction (<1 month), renal failure (creatinine >1.5), chronic obstructive pulmonary disease, peripheral artery disease, and neurologic dysfunction.

Between 2008 and 2010, 11 patients who underwent hybrid coronary revascularization were evaluated. Eight of them were men, and 3 were women. Mean age was

Table 1. Patient Demographic Data

Age, y	66.1 ± 9.1
Sex (Male/Female)	8/3
Body mass index > 25, n (%)	4 (36.3)
Mean ejection fraction, %	32.72
Mean creatinine level, mg/dL	1.7
Left main coronary artery lesion, n (%)	9 (81.8)
Risk factors	
Renal failure, n (%)	3 (27.2)
Current smoker, n (%)	6 (54.5)
Chronic obstructive pulmonary disease, n (%)	5 (45.4)
Hypertension, n (%)	8 (72.7)
Hypercholesterolemia, n (%)	5 (45.4)
Neurological dysfunction, n (%)	1 (9)
Previous myocardial infarction, n (%)	6 (54.5)
Diabetes mellitus, n (%)	5 (45.4)
Peripheral vascular disease, n (%)	2 (18.18)
Carotid artery stenosis, n (%)	1 (9)
Baseline medications	
Angiotensin converting enzyme inhibitor, n (%)	6 (54.5)
Aspirin, n (%)	10 (90.9)
β-Blocker, n (%)	11 (100)
Intravenous heparin, n (%)	8 (72.7)
Intravenous nitrates, n (%)	4 (36.3)

66.1 ± 9.1 years. Demographic data of the patients are presented in Table 1. In all patients, LIMA-LAD bypass was performed in an off-pump fashion, and the remaining revascularizations were treated with PCI. At least 1 (maximum 2) vessel was stented.

Anesthesia and Surgical Technique

All patients received 5 mg of oral diazepam for premedication. Intravenous lines and radial artery catheters were placed, and all patients were monitored by the BIS™ Monitoring System (A-2000™ Bispectral Index™, Aspect Medical Systems, Inc.; Newton, MA, USA).

Induction of anesthesia was achieved with intravenous fentanyl (3 µg/kg), propofol (2 mg/kg), and vecuronium (0.1 mg/kg). Intermittent boli of fentanyl and continuous inhalation anesthetics (isoflurane, rate of 4 L/minute in oxygen) were used for maintenance.

Operations were performed mostly through reversed-J inferior sternotomy up to the left third intercostal space. We did not perform the operation through a thoracotomy (minimally invasive direct coronary artery bypass graft–off-pump [MIDCAB-OP]) in order to perform a safer surgery because we may need to turn to CPB in an emergency situation. We used a mammary retractor to harvest the LIMA. Following pericardiotomy, intravenous heparin (1-1.5 mg/kg) was administered

to achieve a target activated clotting time of 300 seconds. The LAD was snared proximally and distally by using silicon loops with a blunt needle. The LAD was transiently occluded with the loops to evaluate the myocardial ischemic tolerance, then it was opened longitudinally. When not well tolerated or in case of suspicion, the chief surgeon did not hesitate to use intracoronary shunts. An anastomosis between the LIMA and the LAD was performed with a running 7.0 or 8.0 polypropylene suture. During the procedure, the mean arterial pressure was maintained above 65 mmHg by the administration of fluids and, if necessary, inotropic agents. After the completion of the anastomosis, heparin was antagonized with protamine sulfate. The postoperative anticoagulation regimen included unfractionated intravenous heparin (100 U/kg), aspirin (100 mg/day), and statin (20 mg/day) after extubation. After the third postoperative day, oral clopidogrel (75 mg/day) was started and continued at least one year.

Percutaneous Coronary Intervention

Percutaneous coronary interventions were performed after the operations. The femoral artery was cannulated with a 7F or 8F guiding catheter. The circumflex or right coronary artery (or both) underwent balloon dilation, followed by stent implantation until the desired arterial diameter was reached. Patients also received 250 mg/day ticlopidin in addition to aspirin and clopidogrel for 1 month.

Follow-Up

In-hospital death, use of blood and blood products, neurological complications (stroke, transient ischemic attack, or prolonged mental status changes), renal complications, prolonged ventilatory support (>24 hours), postoperative bleeding requiring re-exploration, and stays in the postoperative critical care unit and hospital were investigated during the early postoperative period. In the follow-up recurrence of angina, new myocardial infarction, re-interventions, and cardiac related death were determined. Patients were interviewed every 6 months, and in all patients either by telephone or during out-patient clinic visits. Control coronary angiographies were performed after the operations during the follow-up. Coronary angiograms were independently evaluated by cardiologists.

RESULTS

Preoperative Findings

There were 9 patients with LMCA lesion, 5 patients with LMCA and Cx lesions, 4 patients with LMCA, Cx, and RCA lesions, and 2 patients with proximal LAD and RCA lesions. Body mass index was above 25 in 4 patients (36.3%). Five of the patients (45.4%) were diabetic. Three patients (27.2%) had renal failure. There were 6 (54.5%) active smokers and 5 (45.4%) patients with chronic obstructive pulmonary disease. Hypertension and hypercholesterolemia were present in 8 (72.7%) and 5 (45.4%) patients, respectively. One patient had 80% carotid artery stenosis, and 1 patient had permanent neurologic dysfunction. There were 2 patients (18.1%) with peripheral arterial disease. In the history of 6 patients

Table 2. Significant Comorbidity Factors

Previous myocardial infarction, n (%)	6 (54.5)
Body mass index >25, n (%)	4 (36.3)
Left main coronary artery disease, circumflex coronary artery and right coronary artery lesion n (%)	4 (36.3)
Left ventricular dysfunction (ejection fraction < 30%), n (%)	4 (36.3)
Renal failure, n (%)	3 (27.2)
Chronic obstructive pulmonary disease, n (%)	5 (45.4)

there was previous myocardial infarction. Mean ejection fraction of the patients at the time of the operation was 32.72% (range, 25%-40%). Significant comorbidity factors are presented on Table 2. When reviewing the medications of the patients, 6 were on angiotensin converting enzyme inhibitors, 10 received aspirin, 8 were started intravenous heparin, 4 were started intravenous nitrates, and all received β -blockers and statins (Table 1).

Perioperative Findings

In all patients CABG, ie, LIMA-LAD bypasses, were performed on the beating heart without any complications. Conversion to CPB was not required. Intracoronary shunts were used 3 patients. Occlusion of the LAD led to arrhythmias in 2 patients, and for the remaining patient, reason was the desire of the surgeon. Otherwise electrocardiographic changes were not observed in the remaining patients. The coronary occlusion time was 17.4 ± 3.2 minutes (range, 12-21 minutes). Coronary occlusion was well tolerated with fluid replacement and low dose inotropic support ($5 \mu\text{g}/\text{kg}$ per minute dopamine in

2 patients) to maintain adequate arterial pressure. The operations lasted 85 to 180 minutes (mean 112 ± 44 minutes). After the operations, all the patients were transferred to the intensive care unit while still intubated, and they were extubated there electively. Mean duration of ventilatory support was 4.4 ± 1.9 hours (range, 2-7 hours). None of the patients required prolonged ventilation. Blood transfusion was performed in 3 patients (1 patient required 2 units of erythrocytes suspension, and 2 patients required 1 unit) when their hematocrit levels fell below 28%. None of the patients required re-exploration, and drainage from the chest tubes was measured to be 230 ± 190 mL, in average. The postoperative courses of the patients were uneventful, and intensive care unit stay was 14.7 ± 4.4 hours. All the patients were kept in the hospital until the PCI.

Percutaneous Coronary Interventions

At the second stage, together with PCI, LIMA-LAD grafts were checked minimum on the fourth postoperative day and maximum on the twenty-second postoperative day (mean, 16 days postoperative). All LIMA-LAD bypasses were found to be patent and well functioning (Figure 2). The PCI were coronary stents extending from LMCA to Cx in 4 patients, Cx stents in 5 patients, and RCA stents in 5 patients; hence, complete revascularization could be maintained (Figure 3). In addition to coronary interventions, the patient with carotid artery disease underwent carotid stenting at the time of PCI. After the PCI the patients were discharged from the hospital. Mean duration of hospital stays was 16.4 ± 4.2 days.

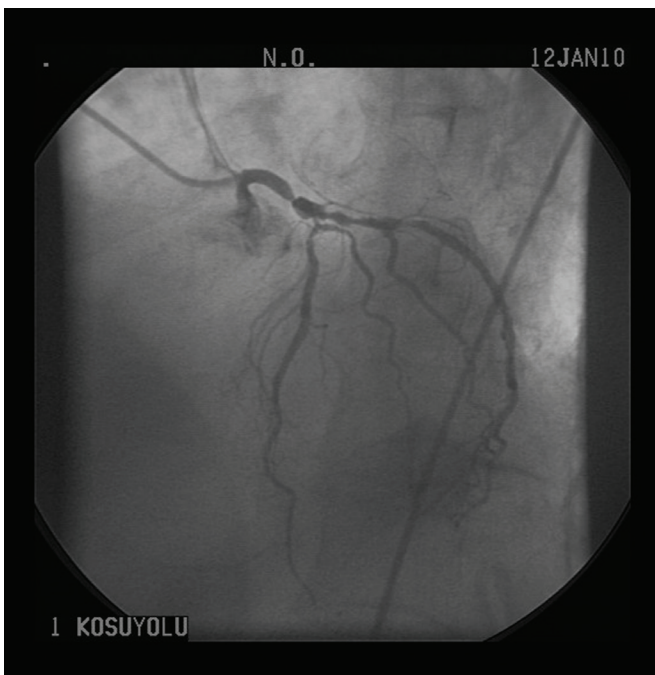


Figure 1. Preoperative Angiography.

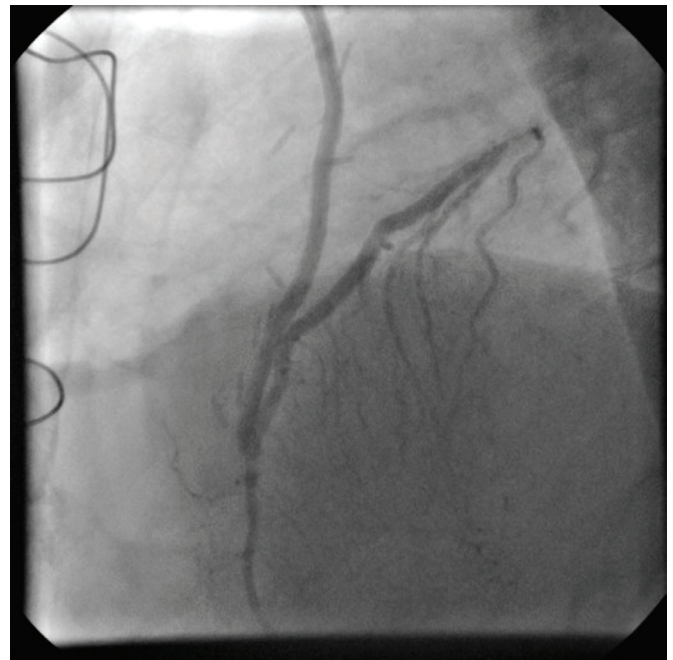


Figure 2. Control Coronary Angiography. Check of left internal mammary artery–left anterior descending coronary artery (LIMA-LAD) anastomosis at the time of percutaneous coronary intervention (PCI) for complementary complete revascularization.

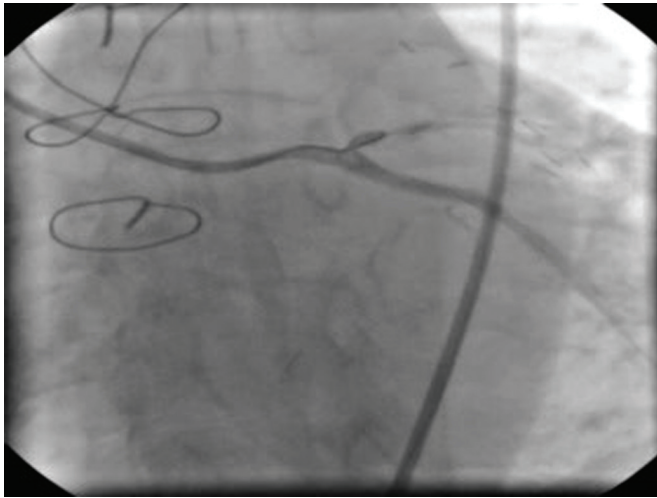


Figure 3. After Percutaneous Coronary Intervention (PCI) Angiography.

Follow-Up

Patients were followed-up for a minimum of 6 months and a maximum of 21 months (mean, 16 months). Seven patients were in New York Heart Association functional Class I, and 4 patients were in Class II at the time of first interview. Control echocardiographies indicated an increase in mean ejection fraction from 32.72% to 36.56%. None of the patients experienced major cardiovascular events such as mortality, myocardial infarction, re-intervention, and cerebrovascular event in the early postoperative period. In 2 patients, coronary angiographies after 8 and 11 months, respectively, indicated stenosis in the stents of Cx and RCA, and these patients required additional PCI and re-stenting. Otherwise all LIMA-LAD grafts were found patent and well functioning. During the subsequent follow-up visits, no new events were detected.

DISCUSSION

Coronary revascularization is still a challenge in the high-risk patient population in the current era. Literature lacks an established treatment strategy for these patients. Hybrid coronary intervention is among the options. It is a safe and effective alternative in selected patients with multivessel coronary artery disease and in the presence of various comorbidity factors [Cisowski 2002; Davidavicius 2005; Us 2006; Vassiliades 2006; Holzhey 2008; Del Giglio 2009; Jones 2010]. This technique is also quite feasible for LMCA lesions.

Recent advances in stent technology and increased experiences in percutaneous techniques favor patients to be considered for percutaneous interventions. However, the realistic aim and gold standard of coronary revascularization is still the LIMA-LAD anastomosis [Hulusi 2009]. Re-intervention rates after PCI both in the short- and long-run cannot be undervalued despite its similar rates for mortality and myocardial infarction with CABG [Us 2006]. On the other hand, combination of LIMA-LAD revascularization with PCI may

be applicable in high-risk patients. When reviewing the long-term results of the drug eluting stents, which are proposed as alternatives to conventional CABG, hybrid coronary revascularization may be applicable with low mortality and morbidity rates in operatively high-risk candidates with stenosis in different coronary arteries [Vassiliades 2006].

Hybrid coronary revascularization may sound like a very good treatment strategy for LMCA disease in high-risk patients; however, the method is not free from controversies. One of them regards to the ranking of the interventions. In the first option, the patients undergo LIMA-LAD revascularization followed by PCI. The major advantage of this approach is that it allows control of LIMA-LAD anastomosis. However, in the case of an interventional complication, a second operation may be required to prevent the complication. In the second option, CABG is preceded by PCI. In this respect, postoperative bleeding is a major concern. Additionally, in both options the patients undergo 2 major procedures in a short period of time. This may affect the psychology of the patients negatively. However, such a problem may be overcome by development of hybrid rooms in which both CABG and PCI can be performed simultaneously [Davidavicius 2005; Reicher 2008; Del Giglio 2009]. In our series we preferred CABG first and then after a certain period of time PCI is performed together with LIMA-LAD bypass control.

Coronary artery bypass grafting and full revascularization on the beating heart is another alternative for high-risk patients, ie, patients >70 years of age, with severe left ventricular dysfunction, having at least 1 comorbidity factor, with a history of cerebrovascular disease, with malnutrition, etc. On the other hand, especially in patients with severely deteriorated left ventricular functions, manipulation of the heart may lead to hemodynamic instability [Holzhey 2008; Jones 2010]. In such cases, execution of the LIMA-LAD anastomosis on the beating heart and then sequential hybrid procedure dramatically decreases the mortality and morbidity rates [Gao 2009]. In our cohort, off-pump CABG is generally well tolerated with fluid replacement and with low dose inotropic support in 2 patients.

The hybrid revascularization method is also advantageous in patients with calcified aortic wall because the method is devoid of aortic cannulation and proximal anastomosis [Reicher 2008].

CONCLUSION

Hybrid intervention requires critical patient selection as well as preoperative detailed patient examination, and only patients who definitely require such a procedure should receive this treatment. Additionally, surgery and cardiology teams should work in strict coordination from the initiation of this 2-stage therapy. It is a safe and effective alternative full revascularization procedure in selected patients with LMCA lesion and/or severe left ventricular dysfunction especially in the presence of comorbidity factors. Long-term follow-up results of multicenter studies are warranted in order to establish a standard accepted protocol in this highly challenging patient population.

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