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Clinical Outcome of Patients With and Without Renal Impairment Undergoing a Minimally Invasive LIMA-to-LAD Bypass Operation

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ABSTRACT

Purpose: Patients with renal impairment undergoing conventional coronary artery bypass grafting (CABG) have a significant risk of postoperative deterioration of kidney function. We investigated the outcome of patients with and without renal impairment treated by off-pump coronary artery surgery.

Methods: From January 1997 until January 2000, 158 consecutive patients (mean age 63 ± 9.8 years, 126 male, 32 female) underwent minimally LIMA-to-LAD bypass operations. The patients were divided into three groups: group I patients (n=133) had a preoperative creatinine of <1.3 mg/dL, group II patients (n=21) had a creatinine of ≥1.3 mg/dL, and patients of group III (n=4) required chronic dialysis due to terminal kidney dysfunction. Monitoring of the blood creatinine was performed during the entire hospital stay. A postoperative angiogram was performed in 113 of the 158 patients.

Results: All operations were performed without intraoperative complications. Postoperative angiograms revealed a patent LIMA-to-LAD bypass in all but one patient, who demonstrated a dissection of the left internal mammary artery (LIMA) graft. Mean creatinine value on admission was 1.0 ± 0.1 mg/dL in group I and 2.7 ± 1.9 mg/dL in group II. The maximal postoperative creatinine value was 1.1 ± 0.4 mg/dL in group I and 2.9 ± 2.7 mg/dL in group II. Neither hemofiltration nor hemodialysis was necessary in any patient of group I or group II during the postoperative course.

Conclusion: Minimally invasive LIMA-to-LAD bypass is a safe and effective procedure with low morbidity and no mortality in the first 158 patients. Preoperative renal impairment had no adverse effect on outcome or residual kidney function. Thus, higher doses of diuretics and hemofiltration/dialysis were not used, resulting in a cost reduction. Therefore, this approach may be worthwhile to consider in patients with significant renal impairment who have to undergo CABG.

INTRODUCTION

Minimally invasive coronary artery bypass grafting has been introduced into cardiac surgery in the last decade and has been proved to be a safe and effective technique for the cardiovascular patient [Benetti 1991, Buffolo 1996, Calafiore 1996a, Mariani 1997]. The most important advantage of minimally invasive operations is that cardiopulmonary bypass (CPB), with its multiple side effects [Andersen 1991] in virtually every organ system, can be avoided. Several authors have reported on the benefit to patients with severe concomitant disease, including renal impairment, who have avoided CPB [Izzat 1998, Riess 1998, Kappert 1999]. Patients with renal impairment undergoing conventional coronary artery bypass grafting (CABG) have an especially significant risk of postoperative deterioration of kidney function [Abel 1976, Hiberman 1979], which may result in an increased dependence on diuretics or even the use of hemofiltration/dialysis. This deterioration may prolong the postoperative hospital stay and increase costs. In this study we investigated the out-

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Table 1. Demographic data of patients with and without renal impairment undergoing minimally invasive LIMA-to-LAD bypass operation

	Patients [n]	Age [years]	Weight [kg]	Height [cm]	CAD [n]	LVEF [%]	Patients with concomitant disease [n]	Creatinine pre-op [mg/dL]
GROUP I					1 vessel: 53			
(creatinine < 1.3 mg/dL)	133	61.8 ± 9.7	80.1 ± 11.5	172.9 ± 7.8	2 vessel: 52	62.9 ± 15.1	32	1.0 ± 0.1
					3 vessel: 28			
GROUP II					1 vessel: 3			
(creatinine ≥ 1.3 mg/dL)	21	69.1 ± 8.3	76.9 ± 16.7	174.2 ± 5.8	2 vessel: 7	54.5 ± 16.4	12	2.7 ± 1.9
					3 vessel: 11			
GROUP III					1 vessel: 1			
(chronic dialysis)	4	63.5 ± 9.5	79.9 ± 12.7	175.8 ± 10.8	2 vessel: 1	61.9 ± 16.2	3	6.3 ± 0.9
					3 vessel: 2			

CAD = coronary artery disease, LVEF = left ventricular ejection fraction

come of patients with and without renal impairment who received off-pump coronary artery surgery.

MATERIALS AND METHODS

Patients

From January 1997 until January 2000, 158 consecutive patients (126 male, 32 female) with coronary artery disease (1-vessel: n=57; 2-vessel: n=60; 3-vessel: n=41) underwent minimally invasive LIMA-to-LAD bypass grafting. Mean age of all patients was 63.2 ± 9.8 years and mean weight was 77.6 ± 10.4 kg (range of 59-101 kg). Left ventricular ejection fraction was 58 ± 9% (range of 35-84%). The patients were divided into three groups: group I patients (n=133) had a preoperative creatinine of <1.3 mg/dL, and group II patients (n=21) had a creatinine of ≥1.3 mg/dL (Table 1, ◎). Patients of group III (n=4) required chronic dialysis due to terminal kidney function. In 47 out of 158 patients, concomitant diseases were present (Table 2, ◎).

Anesthesia and Operative Technique

Anesthesia was maintained with a continuous intravenous infusion of propofol and sufentanil or remifentanil and a single bolus injection of pancuronium bromide. Standard monitoring of cardiac surgery was performed, including automatic ST-segment analysis and Swan-Ganz catheter monitoring in patients with a left ventricular ejection fraction of less than 45%. After an inverse L-shaped mini-sternotomy up to the left third intercostal space, the left internal mammary artery (LIMA) was harvested up to the second intercostal space under direct vision. Maximal vasodilation of the LIMA was achieved by injection of papaverine. After administration of heparin (150 IU/kg body weight), the left anterior descending artery (LAD) was snared twice in the mid-level using silicon loops with a blunt needle (see Movie, ◎). For temporary LAD occlusion and local stabilization, the midCOAST device (Aesculap, Tuttlingen, Germany) [Riess 1999] was used with the silicon loops (Figure 1, ◎) (see Movie, ◎). After five minutes of LAD occlusion followed by another five minutes of reperfusion, the LAD was occluded again, opened by incision, and anastomosis between LIMA and LAD was performed with a running 8-0 monofilic suture on the beating heart without the use of CPB (see Movie, ◎). No pharmacologically induced decrease of heart frequency was used. In the case of retrograde flow through the arteriotomy field, blood was displaced by a CO2 blower device. Preconditioning was used if severe ischemia occurred during LAD occlusion. After the five-minute test occlusion and following reperfusion of five minutes, an additional five-minute occlusion and reperfusion was performed. When anastomosis had been completed, the silicon loops were removed and the stabilizing platform opened by pressing down the button, and the pedicle was fixed with fibrin glue in order to avoid kinking of the mammary artery pedicle (see Movie, ◎). After declamping of the LIMA-to-LAD bypass, protamine chloride was administered to reverse the anticoagulatory effect of heparin and the pericardium was closed. A retrosternal drainage as well as a drainage into the left pleural cavity was inserted. The sternum was refixed with wires and the wound was occluded.

Table 2. Concomitant diseases in patients (n=47) undergoing minimally invasive LIMA-to-LAD bypass

Concomitant disease	N
Diabetes mellitus	26
Renal impairment	20
Malignancy	10
COPD	7
Neurological disease	7
Calcification of ascending aorta	7
Carotid artery stenosis	4
Bechterew's disease	2
Pancreatitis	2
Amyloidosis	1
Pulmonary embolism, protein C deficiency	1

COPD = chronic obstructive pulmonary disease

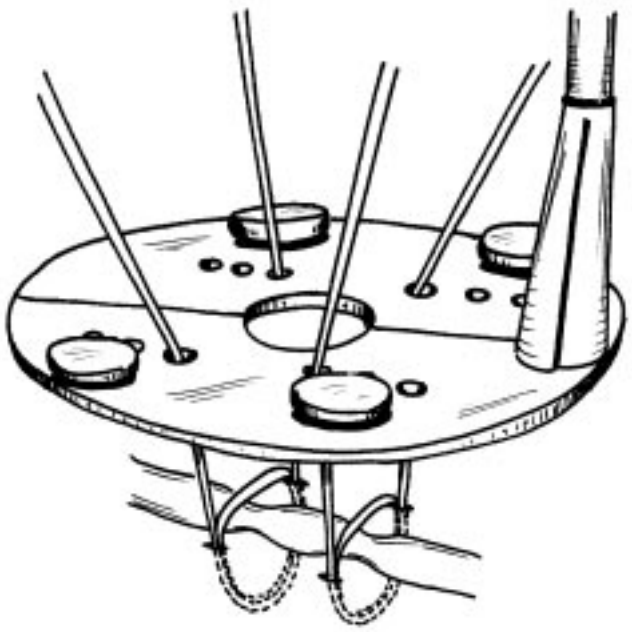

Figure 1. Principle of coronary occlusion and local stabilization with the midCOAST device.

Postoperative Management

Patients were extubated on the operating table or early postoperatively. Postoperative course of renal function was monitored by determination of creatinine values. Angiographic controls were performed early postoperatively and additionally after six months in a subgroup of 44 patients with 2-vessel (n=17) and 3-vessel (n=27) coronary disease undergoing a hybrid revascularization. Stenoses of the right coronary artery (RCA) and the circumflex artery (CX) system or the left main stem were treated by cardiological intervention techniques after the LIMA-to-LAD procedure. In these patients, coronary angiograms were performed six months after surgery to document the patency of the LIMA bypass and the quality of anastomosis, respectively, and to examine for re-stenosis in the coronary vessel, which had been treated by percutaneous transluminal coronary angioplasty (PTCA) and stenting. In addition, we looked for radiological signs of potential endothelial injuries of the LAD in the area of snaring.

RESULTS

All operations were carried out without intraoperative complications. The mean time of coronary occlusion of all patients was 18.7 ± 8.0 minutes and there was no significant difference between the three groups. LAD occlusion was well tolerated by all patients, even by patients with a severe 3-vessel coronary disease or with low left ventricular ejection fraction (LVEF ≤ 40%, n=11), who developed malignant ventricular arrhythmias. Only slight ST-segment elevations of 0.8 ± 0.7 mV (range of 0.2-2.0 mV) were present in 47 patients out of 158. In the other 111 patients, the ECGs remained completely unchanged during LAD occlusion. Preconditioning was used only in six out of 158 patients. Mild ventricular arrhythmias during LAD occlusion were observed only in six out of 158 patients. However, in three patients conversion to conventional CABG was necessary due to the above-described malignant ventricular arrhythmias during LAD occlusion. Total time of surgery was not significantly different between the three groups (Table 3, ◎). Seventy-four patients out of 158 were extubated in the operating room, and the remaining 84 patients were extubated 6.0 ± 5.5 hours (range of 1-28 hours) following surgery. Blood loss through the thoracic drainages and blood cell transfusion demand are shown in Table 3 (◎). Transfusion of red blood cells was necessary in 13 of the 158 patients during the perioperative time. The mean transfusion demand in these 13 patients is shown in Table 3 (◎). The mean hemoglobin value of all 158 patients on discharge was 12.2 ± 1.7 mg/dL (range of 8.2-15.3 mg/dL). The level of creatinine kinase (CK), measured four hours postoperatively, was 78 ± 39 IU/L (range 23 to 358 IU/L). In our protocol the myocardial band CK was only determined when the CK value exceeded 140 IU/L. This was the case in 13 patients (CK of 167 ± 21 IU/L), and the myocardial band CK values were determined 7.5 ±

Table 3. Intraoperative and postoperative data of patients with and without renal impairment undergoing minimally invasive LIMA-to-LAD bypass operations

	Patients [n]	Surgery [min]	Extubation OR [n]	Extubation ICU [hours]	Thoracic drainages [ml]	Blood cell transfusions [ml]	Max. creatinine post-op [mg/dL]	ICU stay [days]	Hospital stay [days]
Group I (creatinine < 1.3 mg/dL)	133	142 ± 27	65	4.5 ± 3.4	524 ± 462	671 ± 398 (n=6)	1.1 ± 0.4	1.3 ± 0.8	7.4 ± 2.7
Group II (creatinine ≥ 1.3 mg/dL)	21	149 ± 48	8	9.5 ± 5.7	723 ± 538	555 ± 228 (n=6)	2.9 ± 2.7	1.9 ± 1.7	9.3 ± 3.3
Group III (chronic dialysis)	4	145 ± 16	1	11.3 ± 14.5	663 ± 186	1750 (n=1)	7.6 ± 1.1	5.0 ± 2.8	13.3 ± 4.7

OR = operating room, ICU = intensive care unit

Figure 2. Postoperative angiogram of a LIMA-to LAD bypass performed six months after beating heart surgery.

2.9 IU/L. No operative or hospital (<30 days) mortality occurred. Postoperative complications included prolonged bleeding in two patients requiring a re-thoracotomy, and cardioversion due to atrial fibrillation in four patients. No respiratory insufficiency or diaphragm dysfunction occurred in any patient, and no preexistent organ dysfunction was observed to deteriorate. Mean creatinine value on admission was measured at 1.0 ± 0.1 mg/dL in group I and 2.7 ± 1.9 mg/dL in group II (Table 1, ◎). In both groups the maximal postoperative creatinine values measured were 1.1 ± 0.4 mg/dL in group I and 2.9 ± 2.7 mg/dL in group II, which were almost the same as the preoperative values (Table 3, ◎). No cerebrovascular events and no neuropsychiatric abnormalities were observed in any patients. All patients were also free of angina pectoris. Coronary angiograms performed on 113 out of 158 patients 4.8 ± 8.2 days after surgery revealed a patent LIMA-to-LAD anastomosis. Only one angiogram revealed a dissection of the LIMA graft, probably induced by preparation, that was stented successfully postoperatively. The length of ICU and hospital stay in patients of the different groups is shown in Table 3 (◎). Patients were discharged from the hospital in a good condition.

Up to the present, a six-month follow-up coronary angiogram was performed in 50 out of 158 patients, which showed a patent LIMA-to-LAD graft and a widely open anastomosis (Figure 2, ◎) except in the one patient who was stented because of LIMA dissection. A total of 61 coronary lesions treated by hybrid revascularization showed to be patent in the six-month follow-up. However, two right coronary arteries which had been recanalized during hybrid revascularization were reoccluded, and one in-stent re-stenosis in a circumflex artery (70%) was observed. Furthermore 6 out of 61 coronary artery lesions had to be treated again by PTCA/stenting because of significant re-stenosis in the area of intervention.

DISCUSSION

In patients undergoing conventional CABG with the use of CPB, preoperative impairment of renal function, which is intractable to therapy, considerably increases the risk of acute renal failure in the early postoperative period [Abel 1976, Hiberman 1979]. This may lead to an increased reliance upon diuretics or even the use of hemofiltration/dialysis, which will likely require a prolonged postoperative hospital stay and additional costs. Older age in patients and the presence of diabetes mellitus appear to be risk factors for the development of acute renal failure. A protracted CPB especially increases the risk of renal failure due to induction of a number of so-called inflammatory responses. This was clearly demonstrated by a prospective study of Kirklin [Kirklin 1983]. We investigated the outcome of patients treated by off-pump coronary artery bypass surgery with the objective of determining whether a minimally invasive LIMA-to-LAD bypass operation also has negative effects on renal function.

LIMA-to-LAD procedures were performed in a heterogeneous group of selected patients with coronary 1-3 vessel disease. Three groups of different indications can be identified: (1) patients with a severely calcified proximal LAD stenosis not suitable for coronary balloon angioplasty; (2) patients with coronary 1-3 vessel disease and severe concomitant diseases; and (3) patients with multi-vessel coronary disease, including significant stenoses in the CX and RCA systems or the left main stem treatable by balloon angioplasty but a significant proximal LAD lesion not suitable for PTCA. In all these patients, the LIMA-to-LAD procedure proved to be a safe and effective approach and the LIMA-to-LAD anastomosis could be created successfully. In three patients (2 female), however, conversion to conventional CABG was performed because of malignant ventricular arrhythmias during the period of LAD occlusion. Despite a mean LAD occlusion period of 18.7 ± 8.0 minutes, no sign of significant myocardial damage was observed, a result that was documented by the myocardial band creatinine kinase [Jansen 1996].

Patency rates of anastomoses after a minimally invasive LIMA-to-LAD procedure are reported to be about 90% [Calafiore 1996b, Subramanian 1996]. In our group, all early postoperative angiograms showed a patent LIMA-to-LAD anastomosis except the angiogram of one patient, which revealed a dissection of the LIMA graft. In this case we had performed a different approach from the other

patients by using a mini-sternotomy up to the fourth intercostal space instead of the third intercostal space. This may have increased the tension to the mammary artery during preparation, resulting in intima injury and dissection.

The most important advantage of beating heart surgery is that CPB, with its multiple side effects on every organ system, including brain, lungs, liver, and kidneys, can be avoided. The induction of inflammatory responses by the large artificial surfaces of the heart-lung machine, including tubing, cardiotomy reservoir, filters, and especially the oxygenator, appears to play an important role in organ dysfunction. Frequency of acute hemofiltration/hemodialysis after CBP is reported to be 1.1% [Chertow 1998]. Moreover especially in patients with atherosclerosis and diabetes mellitus, the risk of postoperative impairment of renal function caused by the heart lung machine is well known.

In addition to the risk of inflammatory responses, strokes occur with a considerable frequency in patients undergoing CPB [Salasidia 1995]. The avoidance of cerebrovascular strokes and neuropsychiatric abnormalities by elimination of the use of the heart-lung machine is another advantage of minimally invasive coronary bypass surgery over conventional CABG [Elefteriades 1997]. Despite the numerous risk factors, such as generalized atherosclerosis, diabetes mellitus, and previous stroke in 47 out of 158 patients (Table 2, ◎), no cerebrovascular event was observed in our study group undergoing minimally invasive LIMA-to-LAD bypass grafting.

Reduced trauma to tissue and avoidance of the high-dosages of heparin and hemodilution required by standard CPB is a further benefit of the minimally invasive LIMA-to-LAD procedure, which results in less postoperative bleeding and less demand for transfusion [Magovern 1996]. In our group, only 13 out of 158 patients received peri- or postoperative red blood cell transfusion, which is a much lower rate than for conventional CABG surgery. Interestingly, a greater percentage of patients of group II (n=6/21) received red blood cell transfusions than patients of group I (n=6/133). The reason for this was a preoperative anemia with hemoglobin values of about 10 mg/dL, probably induced by group II's greater renal impairment. Moreover, five patients of group II suffered from malignant diseases with concomitant anemia. Notably, we observed postoperatively a new episode of supraventricular arrhythmia only in six patients out of 158, which is in contrast to the experience of other authors [Jansen 1996, Elefteriades 1997]. Thus, transitory hemodynamic instability, which might be present in patients with atrial fibrillation and may have negative side effects on renal function, was rare.

Besides hemodynamic instability, respiratory insufficiency and diaphragm dysfunction may result in impaired hemodynamics and renal dysfunction. We did not observe diaphragm dysfunction resulting in respiratory dysfunction in any patient. In contrast, diaphragm dysfunction occurs in 10-80% of patients undergoing conventional CABG [Elefteriades 1996].

The minimally invasive LIMA-to-LAD procedure may also reduce the length of hospital stay and perioperative morbidity [Doty 1997] in comparison to conventional bypass technique. ICU and hospital stay is relatively long in our patient study group compared to that reported by other authors, which probably results from the fact that we had only limited experience with the postoperative recovery of patients that have undergone the minimally invasive procedure. It should also be noted that our study group contained a higher than average number of patients with severe concomitant diseases.

The ICU stay and the total hospitalization period is longer in group II than in group I (Table 3, ◎), probably due to the higher mean age of group II patients and the fact that more patients of group II suffered from concomitant diseases (Table 2, ◎).

CONCLUSION

Minimally invasive LIMA-to-LAD bypass surgery was shown to be a safe and effective procedure with low morbidity and no perioperative mortality in the first 158 patients. Preoperative renal impairment had no adverse effect on surgical outcome or residual kidney function. Thus, higher doses of diuretics and hemofiltration/dialysis were not used, resulting in a cost reduction. Therefore, this approach may be worthwhile to consider in patients with significant renal impairment who have to undergo coronary artery bypass grafting. It should be noted, however, that the investigated groups are relatively small, and randomized studies will be necessary to clarify whether beating heart surgery provides better results than the conventional approach for the patient with impaired renal function.

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