

# Midterm Results of Beating Heart Surgery in 1-Vessel Disease: Minimally Invasive Direct Coronary Artery Bypass versus Off-Pump Coronary Artery Bypass with Full Sternotomy

(#2003-31444)

Calin Vicol, Georg Nollert, Helmut Mair, Vicky Samuel, Che Lim, Michael Tiftikidis, Sandra Eifert, Bruno Reichart

Department of Cardiac Surgery of the Ludwig-Maximilian University Munich, Großhadern Medical Center, Munich, Germany

## ABSTRACT

**Background:** Off-pump cardiac surgery is becoming an established method of surgical revascularization. However, performing anastomoses on a beating heart can be challenging, especially through small incisions. We compared our midterm results in patients with 1 vessel disease using full sternotomy (OPCAB) or a left anterior minithoracotomy (MIDCAB).

**Methods:** At our institution between December 1996 and December 1998, 102 patients (OPCAB, n = 45, MIDCAB, n = 57); age,  $61 \pm 11$  years; 69% men with 1-vessel disease of the left anterior descending coronary artery (LAD) underwent off-pump myocardial revascularization through the left internal thoracic artery (LITA). In the OPCAB group 17 (37.8%) of the patients received an additional vein graft to a diagonal branch. OPCAB was generally preferred in obese or high-risk patients or patients with a long LITA-LAD distance ( $>7$  cm) on an electron beam computed tomography of the chest.

**Results:** Operative mortality was 0. Time of surgery ( $169 \pm 48$  versus  $197 \pm 45$  minutes) and coronary artery occlusion time ( $19 \pm 7$  versus  $23 \pm 6$  minutes) were significantly lower ( $P = .004$  and  $P = .009$ ) in the OPCAB group. MIDCAB surgery was related to a higher incidence of occluded (4 versus 0;  $P = .039$ ) or stenosed (7 versus 2;  $P = .06$ ) anastomoses and necessity for immediate reintervention (9 versus 0;  $P = .023$ ). During a mean follow-up period of 5.2 years, MIDCAB patients (6 MIDCAB patients versus 1 OPCAB patient) tended to need more coronary interventions and develop more recurrent angina (23 MIDCAB versus 12 OPCAB patients). Two OPCAB patients died during the follow-up period.

**Conclusions:** Our initial experience in beating heart surgery demonstrated that MIDCAB is technically more challenging than OPCAB. MIDCAB procedures should

therefore be performed by experienced surgeons on selected patients. Midterm results after OPCAB procedures tend to a lower rate of adverse cardiac events.

## INTRODUCTION

Starting in late 1994, the idea of surgical myocardial revascularization without the need for cardiopulmonary bypass evolved worldwide. In subsequent years techniques and devices were developed to facilitate beating heart surgery. Nowadays, off-pump surgery is becoming an established method of surgical revascularization. However, performing anastomoses on a beating heart, especially through small incisions, can be challenging [Ancalmo 1997, Cooley 2000, Bonchek 2002]. Off-pump coronary artery bypass with full sternotomy (OPCAB) and minimally invasive direct coronary artery bypass (MIDCAB) through a left anterior minithoracotomy are competing techniques for revascularization of the left anterior descending coronary artery (LAD). Both techniques demonstrated short-term advantages with respect to morbidity compared with outcome with conventional on-pump coronary artery bypass grafting [Arom 1999, Hernandez 2001]. However, midterm outcome data for both techniques are rare.

We reviewed our initial experience with off-pump beating heart revascularization for single-vessel disease of the LAD. We compared the 2 techniques with respect to short-term and midterm outcome.

## PATIENTS AND METHODS

At our department between December 1996 and December 1998 a total of 102 patients with 1-vessel disease underwent coronary artery bypass grafting without cardiopulmonary bypass. Indications for single-vessel revascularization were considered occlusion of the LAD, complex lesions, and restenosis after angioplasty and stenting. Patient selection for either MIDCAB or OPCAB technique was biased by coronary anatomy, topography of the chest, comorbidity, and cardiac function. If the distance between the LAD and the left internal thoracic artery (LITA) seemed too long, OPCAB was performed. Starting in 1998, all patients underwent electron beam computed tomography for measurement of this distance. OPCAB was performed on patients with an LITA to

Presented at the 9th Annual CTF Meeting 2003, Miami Beach, Florida, USA, March 19-22, 2003.

Address correspondence and reprint requests to: PD. Dr. Calin Vicol, Herzchirurgische Klinik und Poliklinik der Ludwig-Maximilians Universität München, Klinikum Großhadern, Marchioninistr. 15, 81377 München, Germany; 0049-89-7095-2358 (e-mail: cvicol@helios.med.uni-muenchen.de).

Table 1. Preoperative Data\*

	OPCAB (n = 44)	MIDCAB (n = 58)	P
Female, n	12 (27%)	20 (35%)	NS
Age, y	63.6 ± 11.4	59.0 ± 9.8	.033
Left ventricular ejection fraction, %	63 ± 13	68 ± 11	.07
Diabetes, n	11 (25%)	9 (16%)	NS
Multimorbidity, n	9 (21%)	2 (3%)	.042
CAD of Cx and RCAs (stenosis <50%), n	14 (32%)	14 (24%)	NS

\*OPCAB indicates off-pump coronary artery bypass with full sternotomy; MIDCAB, minimally invasive direct coronary artery bypass with left anterior minithoracotomy; NS, not significant; CAD, coronary artery disease; Cx, circumflex artery; RCA, right coronary artery.

LAD distance >7 cm. OPCAB also was preferred for obese or high-risk patients with serious comorbidity, including renal insufficiency, chronic obstructive pulmonary disease, peripheral vascular disease or impaired cardiac function. Necessity to revascularize a large diagonal branch also led to a decision for OPCAB. MIDCAB surgery was performed on 58 and OPCAB on 44 patients. Table 1 summarizes preoperative patient characteristics.

Surgery was performed with general anesthesia and double-lumen endotracheal tubes to allow right single-lung ventilation in MIDCAB operations and single-lumen tubes in OPCAB. Patients were placed on heating mattresses to allow homeostasis of body temperature. General anesthetic monitoring was enhanced by a Swan-Ganz catheter and transesophageal echocardiography (TEE). A dose of 100 IU/kg body weight heparin was administered prior to distal detachment of the LITA to achieve an activated clotting time exceeding 250 seconds in all patients. Protamine was given before chest closure to inactivate half of the heparin.

For MIDCAB surgery the patient was placed in a 30-degree right lateral position, and left anterior thoracotomy (5-8 cm) was performed in the fourth or fifth intercostal space. The LITA was dissected under direct vision with a retractor (ThorLift; US Surgical, Norwalk CT, USA). The LAD was immobilized with a CTS (CardioThoracic Systems, Cupertino, CA, USA) or Genzyme (Genzyme Surgical Products, Fall River, MA, USA) stabilizer. During 5 minutes of ischemic preconditioning, electrocardiography (ECG) and TEE were used for monitoring for signs of myocardial ischemia. After 5 minutes of reperfusion, the coronary artery was occluded again, cut open, and anastomosed with the LITA by means of 7-0 or 8-0 polypropylene running suture. Carbon dioxide was insufflated as necessary with a blower mister to achieve a bloodless operating field. After release, blood flow was immediately measured electromagnetically.

OPCAB procedures were performed with median sternotomy. After conventional harvest of the LITA, pericardial traction sutures were placed for exposure of the LAD. The treated vessel was immobilized with the Octopus I stabilizer (Medtronic, Minneapolis, MN, USA). The patients in this study were operated on by 12 surgeons.

All patients with postoperative signs of myocardial ischemia defined as significant (>2 mV ST-segment elevation and/or >50 IU/L increased creatine kinase-MB levels) underwent immediate control angiography and, if necessary, reintervention.

All patients were contacted 12 months and 75 ± 8 months postoperatively. Contact consisted of a telephone interview of all patients and a written questionnaire.

### Statistical Analysis

Prospective data were used within the scope of quality assurance. Univariate comparisons were carried out with the 2-tailed chi-square test with Yates correction for discrete variables and unpaired Student *t* test for continuous data (expressed as mean ± standard deviation). Whenever necessary, the Fisher exact test was used. The probability of reintervention was estimated by the Kaplan-Meier method. Differences between groups were calculated with the log-rank test. Differences were considered to be significant with a *P* value less than .05. Statistical analysis was facilitated with the help of SPSS statistical software.

## RESULTS

Operation time and time for LITA to LAD anastomosis were significantly longer in MIDCAB surgery (Table 2). One MIDCAB procedure had to be converted to cardiopulmonary bypass and 3 to full sternotomy. In 2 cases in the MIDCAB group a large diagonal branch instead of the LAD had to be revascularized. Sixteen patients in the OPCAB group received a vein graft to the diagonal branch in addition to the LITA to LAD bypass.

All patients survived the operation and were discharged. Ventilation time was approximately 3 times longer and stay in the intensive care unit (ICU) 2 times longer in the MIDCAB group, but these differences were not significant owing to the high standard deviation (Table 3). New significant ST elevations occurred more often in the MIDCAB group (21% versus 5%; *P* = .03). Immediately after occurrence of these ECG changes, the patients underwent angiography and, if necessary, reintervention. This treatment was indicated in 9 MIDCAB patients and no OPCAB patients (*P* = .023). Chest tube

Table 2. Operative Data\*

	OPCAB (n = 44)	MIDCAB (n = 58)	P
Mortality, n	0	0	
Operation time, min	169 ± 48	197 ± 45	.004
Anastomosis time, min	19 ± 7	23 ± 6	.009
Conversion to CPB, n	0	1 (2%)	NS
Conversion to OPCAB, n	—	3 (5%)	—
Bypass to diagonal branch, %	16 (36%)	2 (3%)	.001

\*OPCAB indicates off-pump coronary artery bypass with full sternotomy; MIDCAB, minimally invasive direct coronary artery bypass with left anterior minithoracotomy; CPB, cardiopulmonary bypass; NS, not significant.

Table 3. Postoperative Data\*

	OPCAB (n = 44)	MIDCAB (n = 58)	P
Perioperative mortality, %	0	0	NS
Time on ventilator, h	10 ± 6	29 ± 109	NS
Time in intensive care unit, h	32 ± 14	57 ± 129	NS
ST-segment elevation, n	4 (5%)	12 (21%)	.031
Urgent reintervention, n	0	9 (16%)	.023
Myocardial infarction, n	1 (2%)	3 (5%)	NS
Wound infection, n	0	3 (5%)	NS
Renal failure, n	0	0	NS
Neurologic complications, n	0	0	NS
Red blood cells, mL	450 ± 584	420 ± 1280	NS
Fresh frozen plasma, mL	67 ± 245	198 ± 986	NS
Reoperation for bleeding, n	1 (2.3%)	1 (1.7%)	NS
Chest tube drain, mL	1097 ± 376	675 ± 350	.044

\*OPCAB indicates off-pump coronary artery bypass with full sternotomy; MIDCAB, minimally invasive direct coronary artery bypass with left anterior minithoracotomy; NS, not significant.

drainage was increased in the OPCAB group ( $P = .044$ ), but it did not result in more reexplorations for bleeding or an increased need for blood products.

During a mean follow-up period of 5.2 years, 2 patients in the OPCAB group died (Table 4). One patient died of lung cancer 6 months postoperatively and the other of renal failure 5 years postoperatively. Results among groups were not significantly different. However, after discharge, MIDCAB patients were more susceptible than OPCAB patients to recurrent angina, myocardial infarction, and reintervention on the LAD.

## DISCUSSION

Anastomosis between the LITA and the LAD remains the gold standard of anterior wall revascularization despite the ongoing rapid development of angioplasty and stenting techniques. Short-term [Cisowski 2002, Drenth 2002] and long-term [Loop 1986, Cameron 1996] results favor surgical revascularization methods. Even the most recent results with rapamycin-eluting stents demonstrate an in-stent restenosis rate of 3% and a segmental restenosis rate of 9% after 8 months, a cumulative restenosis rate of 12% [Fromkin, 2003, Sirius trial, oral presentation at CTT 2002]. Mack et al, in a metaanalysis of 37 peer-reviewed publications, reported a more than 90% early rate of LITA to LAD patency [Mack 1998].

Revascularization of the LAD with the LITA by cardiopulmonary bypass after median sternotomy is a very invasive surgical procedure. Performing the operation through a left anterior minithoracotomy, known as MIDCAB, reduces operative trauma and offers a cosmetically favorable solution compared with median sternotomy. Renunciation of cardiopulmonary bypass leads to further advantages with respect to cost of surgery, postoperative complication rate, and length of hospital stay [Arom 1999, Hernandez 2001]. How-

ever, performance of coronary anastomoses on a beating heart, especially through small incisions, can be challenging. Under these circumstances, the quality of the anastomosis may decrease with lower patency rates of the bypasses [Ancalmo 1997]. Not all surgeons successfully pass acceptable learning curves with rapidly improving results [Bonchek 2002, Cooley 2000]. Young cardiac surgeons seem more determined and dexterous for quick implementation of these new technologies and surgical methods related to off-pump surgery [Shenib 1997].

Our investigation was a retrospective analysis of a patient cohort representing the initial experience with beating heart surgery at our clinic. A total of 102 off-pump operations was performed by 12 differently experienced surgeons and thus represent the results of 12 distinguished learning curves. Although all surgeons performed both techniques in similar numbers, the learning curve for the MIDCAB technique is obviously prolonged and has less advantageous results for patients. In this group, both operation and anastomosis time were increased. Preparation of the LITA through the small left anterior incision further prolonged surgery. Anastomosis time in OPCAB surgery compared favourably with MIDCAB techniques, and the quality of anastomoses was higher with a lower incidence of intraoperative and postoperative ischemia and myocardial infarction. Similar results have been published previously [Stanbridge 1999, Detter 2001, Gersbach 2001].

Conversion to cardiopulmonary bypass is certainly a hint of the degree of sophistication of surgical technique. We were unable to demonstrate any differences between the groups. However, conversion from MIDCAB to OPCAB in 3 patients demonstrated that the MIDCAB technique is far more challenging.

There was a trend toward longer ventilation and ICU stay after MIDCAB procedures. We hypothesize that the cause may be impaired regional postoperative ventilation due to opening of the pleural cavity and single-lung ventilation during MIDCAB. Postoperative pain caused by the thoracotomy may add to this phenomenon. The finding of Gersbach et al, in contrast to our experience, was an increased rate of immediate extubation after MIDCAB compared with OPCAB procedures [Gersbach 2001]. Epidural catheters for pain therapy in the MIDCAB group may help to explain the differences.

Table 4. Follow-up Data\*

	OPCAB (n = 44)	MIDCAB (n = 58)	P
Mortality, n	2 (4%)	0	NS
Recurrent angina, n	12 (27%)	23 (40%)	NS
New myocardial infarction, n	0	4 (7%)	NS
Reintervention on left anterior descending coronary artery, n	1 (2%)	6 (11%)	NS

\*OPCAB indicates off-pump coronary artery bypass with full sternotomy; MIDCAB, minimally invasive direct coronary artery bypass with left anterior minithoracotomy; NS, not significant.

Postoperatively we measured significantly higher blood loss through chest drains in the OPCAB group. However, the increased blood loss was not associated with transfusion need or incidence of reexploration for bleeding.

Wound infections were more common after MIDCAB surgery. This finding suggested that tension on skin and subcutaneous tissue caused by the spreader may lead to ischemia and subsequent necrosis. Similar observations concerning wound healing were reported by Ng [Ng 2000].

In summary, our initial experience with beating heart revascularization demonstrated that MIDCAB is technically more challenging than OPCAB. Consequences are increased operation time, perioperative myocardial ischemia, and a higher number of subsequent reinterventions. The small MIDCAB incision, however, is far more cosmetically satisfying than the OPCAB incision and leads to decreased blood loss. MIDCAB operations therefore should be performed on selected patients by experienced surgeons. Midterm results of the 2 off-pump methods are more gratifying after OPCAB procedures and show a trend toward a lower rate of adverse cardiac events.

## REFERENCES

- Ancalmo N, Busby JR. 1997. Minimally invasive coronary artery bypass surgery: really minimal? *Ann Thorac Surg* 64:928-9.
- Arom KV, Emery RW, Flavin TF, Petersen JP. 1999. Cost-effectiveness of minimally invasive coronary artery bypass surgery. *Ann Thorac Surg* 68:1562-6.
- Bonchek LI. 2002. Off-pump coronary bypass: is it for everyone? *J Thorac Cardiovasc Surg* 124:431-4.
- Cameron A, Davis KB, Green G, Schaff HV. 1996. Coronary bypass surgery with internal thoracic artery grafts: effects on survival over a 15-year period. *N Engl J Med* 334:216-9.
- Cisowski M, Drzewiecki J, Drzewiecka-Gerber A, et al. 2002. Primary stenting versus MIDCAB: preliminary report—comparison of two methods of revascularization in single left anterior descending coronary artery stenosis. *Ann Thorac Surg* 74:S1334-9.
- Cooley DA. 2000. Beating-heart surgery for coronary revascularization: is it the most important development since the introduction of the heart-lung machine? *Ann Thorac Surg* 70:1779-81.
- Detter C, Reichensperner H, Boehm DH, Thalhammer M, Schütz A, Reichart B. 2001. Single vessel revascularization with beating heart techniques: minithoracotomy or sternotomy? *Eur J Cardiothorac Surg* 19:464-70.
- Drenth DJ, Winter JB, Veeger NJGM, et al. 2002. Minimally invasive coronary artery bypass grafting versus percutaneous transluminal coronary angioplasty with stenting in isolated high-grade stenosis of the proximal left anterior descending coronary artery: six month angiographic and clinical follow-up of a prospective randomized study. *J Thorac Cardiovasc Surg* 124:130-5.
- Gersbach P, Imsand C, von Segesser LK, Delabays A, Vogt P, Stumpe F. 2001. Beating heart coronary artery surgery: is sternotomy a suitable alternative to minimal invasive technique? *Eur J Cardiothorac Surg* 20:760-4.
- Hernandez F, Cohn WE, Baribeau YR, et al. 2001. In-hospital outcomes of off-pump versus on-pump coronary artery bypass procedures: a multi-center experience. *Ann Thorac Surg* 72:1528-34.
- Loop FD, Lytle BW, Cosgrove DM, et al. 1986. Influence of the internal mammary artery graft on 10-year survival and other cardiac events. *N Engl J Med* 314:1-6.
- Mack MJ, Osborne JA, Shennib H. 1998. Arterial graft patency in coronary artery bypass grafting: what do we really know? *Ann Thorac Surg* 66:1055-9.
- Ng PC, Chua AN, Swanson MS, Koutlas TC, Chitwood WR, Elbeery JR. 2000. Anterior thoracotomy wound complications in minimally invasive direct coronary artery bypass. *Ann Thorac Surg* 69:1338-41.
- Shenib H, Mack MJ, Lee AGL. 1997. A survey on minimally invasive coronary artery bypass grafting. *Ann Thorac Surg* 64:110-5.
- Stanbridge RDL, Hadjiniakolaou LK. 1999. Technical adjuncts in beating heart surgery: comparison of MIDCAB to off-pump sternotomy—a meta-analysis. *Eur J Cardiothorac Surg* 16:S24-33.