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Comparison of Minimally Invasive Direct Coronary Artery Bypass and Off-Pump Coronary Artery Bypass in Single-Vessel Disease

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ABSTRACT

Background: Off-pump coronary surgery is an established method of less invasive cardiac surgery. We compared our early results in patents with 1-vessel disease who underwent surgery with full sternotomy with off-pump coronary artery bypass (OPCAB) or a left anterior minithoracotomy with minimally invasive direct coronary artery bypass grafting (MIDCAB) without cardiopulmonary bypass.

Methods: From July 2003 to June 2006, 54 patients with single-vessel disease of the left anterior descending artery who underwent surgery performed by the same surgical team were included in this prospective study. Of these patients, 27 underwent MIDCAB through an anterolateral minithoracotomy, and 27 had OPCAB through a full sternotomy. Patients were selected for the surgical groups on the basis of general condition, anatomical aspects, type of coronary lesions, comorbidities, and patient preferences. Demographic, operative, and postoperative data were collected prospectively.

Results: Demographic data, Canadian Cardiovascular Society Classification, and comorbidities were identical for both groups. There were no cases of operative mortality, early graft insufficiency, myocardial infarction, cerebrovascular accident, or conversion to cardiopulmonary bypass in either group. Durations of mechanical ventilation and total hospital stay were shorter in the MIDCAB group, 6.8 ± 3.0 hours vs 8.3 ± 1.6 hours and 4.5 ± 0.7 days vs 5.2 ± 1.4 days (P = .03 and P = .03), respectively. Atrial fibrillation was seen in 2 patients in each group; all were returned to sinus rhythm by medical therapy.

Conclusion: Although MIDCAB grafting is a challenging technique, it may be safely performed on selected patients with low postoperative mortality and morbidity.

INTRODUCTION

After the first successful surgical procedures in late 1960s, coronary artery bypass grafting (CABG) became the most commonly performed single surgical procedure [Eagle 2004]. Cardiopulmonary bypass (CPB) contributed to a new era and made cardiac surgery more easily done, with reproducible results achieved nearly all over the world.

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With the help of technical improvements, all branches of surgery evolved to become less invasive. Endoscopic or laparoscopic operations, more complex percuteneous interventions (PCIs), are now routinely performed.

In cardiac surgery, less invasive procedures first appeared as off-pump coronary artery bypass (OPCAB) procedures. A new generation of stabilizing devices increased the safety of surgery, and in recent decades OPCAB has gained popularity among surgeons and patients.

Minimally invasive direct coronary artery bypass (MIDCAB) is one of the endpoints of this evolution in cardiac surgery. We compared the results of the first MIDCAB cases performed at our institution with single-vessel OPCAB performed by the same surgical team during the same period.

MATERIALS AND METHODS

From July 2003 to June 2006, 54 patients with single-vessel disease of the left anterior descending artery (LAD) who underwent surgery performed by the same surgical team were included in this prospective study. Patients with additional cardiac and/or extracardiac pathologies (such as valve pathologies and peripheral arterial diseases) who required intervention were excluded from the study. Group I patients underwent MIDCAB surgery (n = 27; 5 women [18.5%] and 22 men [81.5%], mean ± SD age 56.07 ± 11.2 years) and group II patients underwent OPCAB surgery (n = 27; 6 women [22.2%], 21 men (77.8%), mean ± SD age 54.59 ± 8.3 years). Patient selection for surgical groups was based on general condition of the patient, anatomical aspects, and localization of coronary lesions. Comorbidities that might alter the surgical strategy (such as chronic obstructive pulmonary disease [COPD] and obesity) and patient preferences (eg, some did not want sternotomy) were also taken into account for grouping. Patients with severe COPD who could not tolerate 1-lung respiration during surgery, patients with high body mass index in whom a limited thoracotomy incision would not be enough to reach the operative field, and women with large breasts were in the OPCAB surgical group.

This study was approved by the institutional ethics and research committee, and written informed consent was obtained from all of the study patients.

Postoperative follow-up consisted of clinical evaluation, routine laboratory tests, and electrocardiogram in the first week and the end of the first month after discharge from the hospital. Conventional coronary angiography, computed tomographic angiography, or exercise stress test were performed

Table 1. Demographic Characteristics of Patients*

	MIDCAB (n = 27)	OPCAB (n = 27)	*P*
Sex, women/men	5/22 (18.5%/81.5%)	6/21 (22.2%/77.8%)	NS
Age, y	56.07 ± 11.2	54.59 ± 8.3	NS
Diabetes mellitus	4 (14.8%)	4 (14.8%)	NS
COPD	2 (7.4%)	2 (7.4%)	NS
Hypertension	13 (48.1%)	9 (33.3%)	NS
CRF	0	1 (3.7%)	NS
PAD	0	2 (7.4%)	NS
% EF	47.9 ± 4.6	45.1 ± 7.5	NS
Hyperlipidemia	10 (37%)	13 (48.1%)	NS
MI	9 (33.3%)	16 (59.3%)	NS
Obesity (BMI>30)	5 (18.5%)	8 (29.6%)	NS
CCS class I 0	0	0	
CCS class II	13 (48.1%)	15 (55.6%)	NS
CCS class III	13 (48.1%)	11 (40.7%)	NS
CCS class IV	1 (3.7)	1 (3.7)	NS

*Results are n, n (%), or mean ± SD. MIDCAB, minimally invasive direct coronary artery bypass; OPCAB, off-pump coronary artery bypass; COPD, chronic obstructive pulmonary disease; CRF, chronic renal failure; PAD, peripheral arterial disease; % EF, ejection fraction %; MI, myocardial infarction in last 3 months; BMI, body mass index; CCS, Canadian Cardiovascular Society; NS, not significant.

on some of the MIDCAB patients who gave consent for these tests. Demographic, operative, and postoperative data were collected prospectively.

SURGICAL TECHNIQUES

Group I MIDCAB

Patients were intubated with double-lumen endotracheal tubes to ensure right-lung ventilation for surgical comfort. All patients were positioned supine and tilted at 45° to elevate the left side of the thorax. Left anterior minithoracotomy incisions (approximately 8 to 10 cm) were made on the mammarian crest for better cosmetic results and wound healing. Subcutaneous relaxations were made cranially to reach the fourth intercostal space for entering the thorax. The left internal mammary artery (LIMA) was harvested with the surrounding tissue by electrocautery under direct vision. The first intercostal branch was isolated and ligated with a hemoclip. Warm, diluted papaverin solution was sprayed over the pediculated graft.

The pericardium was opened and suspended. After the LAD was identified, it was proximally occluded with 4-0 polypropylene suture. No preconditioning was performed. Intracoronary shunts were not routinely used; instead we used vacuum stabilizers in 13 patients (48%) and Octopus stabilizers (Octopus III or IV; Medtronic, Minneapolis, MN, USA) in 12 (44%). Estech stabilizers (Estech OPVAC Synergy II Stabilizer, Estech, San Ramon, CA, USA) were used for target-area stabilization. In 2 patients (7%) occlusion sutures alone provided enough stabilization. Two running 7-0 or 8-0 polypropylene sutures were used for anastomosis. The LIMA was anchored to the epicardium with 7-0 polypropylene sutures. Graft flows were not measured. After the surgery was complete a single thorax tube (36 F) was inserted and the thoracotomy was closed routinely.

Group II OPCAB

All patients underwent surgery while in a supine position, and full median sternotomy was performed in all cases. The LIMA was harvested with electrocautery thorough an asymmetrical sternal retractor. The pericardium was opened and suspended. The LAD was proximally occluded with a 4-0 polypropylene suture. Intracoronary shunts were not routinely used. Estech vacuum stabilizers (Estech OPVAC Synergy II Stabilizer; Estech, San Ramon, CA, USA) were used for stabilization. Anastomosis was done with 2 running 8-0 polypropylene sutures. The greater saphenous vein was used as a graft in 1 case, in which proximal anastomosis was performed first with a partial occluding clamp. Graft flows were not measured. Routine sternotomy closure was performed after 2 thorax tubes (36 F) were inserted, one to the thorax and the other to the mediastinum.

Statistics

Data were given as mean ± SD. Statistical differences between groups were evaluated with the Student *t*-test, Mann Whitney *U* test, χ^2, or Fischer's exact test. *P* values < .05 were considered statistically significant.

RESULTS

Age, sex, comorbidities (diabetes mellitus, COPD, hypertensive disease, renal insufficiency, hyperlipidemia, peripheral arterial disease, obesity), mean ejection fraction, myocardial infarction in the 3 months prior to surgery, and Canadian Cardiovascular Society Angina Class were similar in the 2 groups. Demographic data are detailed in Table 1.

There was no peroperative mortality in either group. Only 1 patient, in the OPCAB group, needed emergency surgery. For various reasons (injury at the distal end of the LIMA or inappropriate length) sapheneous vein grafts were anastomosed end-to-end to the LIMA in 4 (14.8%) of the patients in the MIDCAB group, and 1 (3.7%) in the OPCAB group.

There was no conversion to sternotomy in the MIDCAB group. None of the patients in the 2 groups needed CPB.

No early mortality was seen in any of the groups. Mechanical ventilation times were 6.8 ± 3.0 hours and 8.3 ± 1.6 hours for the MIDCAB and OPCAB groups, respectively (*P* = .03). Intensive care unit (ICU) times in the MIDCAB group were 21.56 ± 2.37 hours and 23.11 ± 1.62 hours for the OPCAB group (*P* = .07). Total hospital stay was significantly shorter in the MIDCAB group than the OPCAB group, 4.5 ± 0.7 days and 5.2 ± 1.4 days, respectively (*P* = .03).

Early myocardial infarction and need for intraaotic counterpulsation were not seen in either of the groups. Creatinine-

kinase–myocardial band levels on the first postoperative day were 32.9 ± 16.0 U/L for the MIDCAB group and 36.3 ± 27.6 U/L for the OPCAB group ($P > .05$). Inotropic support was required for only 1 patient, (3.7%), who was in the OPCAB group ($P > .05$).

There was no gastrointestinal bleeding, neurological events, or new-onset renal failure in either group. Postoperative atrial fibrillation was seen in 4 patients, 2 in the MIDCAB group (7.4%) and 2 in the OPCAB group (7.4%) ($P > .05$). In all cases atrial fibrillation returned to normal sinus rhythm with medical treatment.

Mean postoperative bleeding volumes were 547 ± 391 mL for the MIDCAB group and 696 ± 198 mL for the OPCAB group ($P > .05$). Transfusion requirements for patients in the MIDCAB group were 0.9 ± 1.2 U and 1.6 ± 1.1 U of fresh-frozen plasma and in the OPCAB group were 0.7 ± 0.9 U of erythrocyte suspension and 1.4 ± 0.7 U units of fresh-frozen plasma. There was no statistically significant difference in amounts transfused in the 2 groups. Hematocrit percentages on postoperative day 1 were 34.1% ± 4.3% and 31.9% ± 3.9% for the MIDCAB and OPCAB groups, respectively ($P > .05$). Three patients in the MIDCAB group and none in the OPCAB group required reoperation for bleeding ($P > .05$). Bleeding episodes were due to bleeding of the side branches of the LIMA in 2 cases and the intercostal artery in 1 case. Although this difference in bleeding episodes between groups was not statistically significant, it may have affected some other variables. After exclusion of those patients from data analysis, mean bleeding was 469 ± 264 mL in the MIDCAB group and, 696 ± 198 mL in the OPCAB group, $P = .001$, a difference that had been insignificant but became significant in favor of MIDCAB. Statistical significance of mechanical ventilation times, amount of transfusion, and ICU stay times became apparent.

Two patients in the MIDCAB group (7.4%) suffered from superficial surgical-site infection (SSSI), a problem that was resolved by a proper antibiotic regimen and frequent dressings. No SSSI were observed in the OPCAB group, but the difference between groups was not statistically significant ($P > .05$).

In both groups , no serious complications were seen in controls on the first and fourth week after discharge. Some of the patients in the MIDCAB group gave consent for control angiography (n = 5), for multidetector computed tomographic angiography (n = 2), and for exercise stress test (n = 7). None of the tests performed for postoperative evaluation showed any sign of ischemia or stenosis at the site of anastomosis.

Results are summarized in Table 2.

Table 2. Postoperative Data*

	MIDCAB (n = 27)	OPCAB (n = 27)	*P*
Mortality	0	0	
Mechanical ventilation time, h	6.8 ± 3.0	8.3 ± 1.6	.028
ICU stay, h	21.56 ± 2.37	23.11 ± 1.62	NS
Total hospital stay, d	4.5 ± 0.7	5.2 ± 1.4	.03
MI	0	0	
Postoperative day 1			
Creatinine-kinase–myocardial band, U/L	32.9 ± 16.0	36.30 ± 27.6	NS
IABP	0	0	
Inotropic agent	0	1 (%3.7)	NS
Bleeding, mL	547 ± 391	696 ± 198	NS
Reoperation	3 (11.1%)	0 (0%)	NS
Blood transfusion (U)	0.9 ± 1.2	0.74 ± 0.9	NS
FFP transfusion (U)	1.6 ± 1.1	1.4 ± 0.7	NS
Postop day 1 Hct, %	34.1 ± 4.3	31.9 ± 3.9	NS
Gastrointestinal bleeding	0	0	NS
AF	2 (7.4%)	2 (7.4%)	NS
Stroke	0	0	
SSI	2 (7.4%)	0 (0%)	NS
PO CCS class I	19	20	NS
PO CCS class II	8	7	NS
PO CCS class III	—	—	—
PO CCS class IV	—	—	—

*Results are n, n (%), or mean ± SD. MIDCAB, minimally invasive direct coronary artery bypass; OPCAB, off-pump coronary artery bypass; ICU, intensive care unit; MI, myocardial infarction; IABP, intraaortic balloon pump; FFP, Fresh-frozen plasma; HCT, hematocrit; AF, atrial fibrillation; SSI, surgical-site infection; PO, postoperative; CCS, Canadian Cardiovascular Society; NS, not significant.

DISCUSSION

Coronary artery disease is still the most frequent cause of mortality, so coronary revascularization remains an important surgical procedure. Although cardiac surgery is one of the leading single surgical procedures, it is performed in only 26% of all coronary revascularizations because of the wide availability and prevalence of PCIs, which are supported by evolutionary technological improvements such as drug-eluting stents [Dewey 2003; AHA 2008].

As with all other surgical areas, in cardiac surgery minimally invasive procedures will become increasingly important in future. The first indication of this change was OPCAB surgery, which gained popularity after the successful results in the pioneering series of Buffalo et al. and Benetti et al.[Buffalo 1990; Benetti 1991]. Despite the fact that some surgeons prefer OPCAB as the primary mode for revascularization, it is performed only in 20% to 25% of all CAB procedures in the US [Dewey 2007]. With the growing number of OPCAB cases, increasing numbers of reported studies have shown that avoiding CPB might lead to decreases in postoperative complications, total hospital stays, and eventually, costs [Arom 1999; Hernandez 2001]. As surgery improved simultaneously with technology, the quest for less invasive procedures reached one end point with the development of the MIDCAB procedure.

Our aim in this study was to determine the efficiency and safety of the first MIDCAB cases performed in our institution. We compared the early results of patients with single-vessel disease undergoing surgery with different procedures

Table 3. Results after Exclusion of Reoperation Patients

	MIDCAB (n = 24)	OPCAB (n = 27)	P
Mechanical ventilation time, h	6.3 ± 2.5	8.3 ± 1.6	.002
Bleeding, mL	469 ± 264	696 ± 198	.001
Blood transfusion, U	0.6 ± 0.8	0.7 ± 0.9	NS
ICU stay, h	21.2 ± 2.3	23.1 ± 1.6	.001

*Results are mean ± SD. MIDCAB, minimally invasive direct coronary artery bypass; OPCAB, off-pump coronary artery bypass; ICU, intensive care unit; NS, not significant.

during the same time period and performed by the same surgical team.

In this study neither conversion to sternotomy in MIDCAB nor CPB was needed in either group. These results seemed better than those for other similar studies, possibly because of the relatively small number of cases in our study. Holzhey et al reported 1.7% (n = 23) conversion to CPB, sternotomy, or both in their series of 1347 MIDCAB cases [Holzhey 2007]. Results reported by Detter et al were similar; 3.6% (n = 4) CPB, 0.9% (n = 1) sternotomy, and 2.7% (n = 3) port-access conversion in 111 MIDCAB cases, and 4.4% (n = 10) of 229 OPCAB cases needed CPB [Detter 2002].

In our study patient selection for groups was based on clinical and anatomical aspects and patient preferences; patients with comorbidities such as severe COPD or obesity were included in the OPCAB group. Differences between group characteristics were statistically insignificant but may have been biased against the OPCAB group.

Mechanical ventilation times in MIDCAB patients were significantly shorter than in OPCAB patients. Other reported data on this subject are conflicting. Gersbach et al reported a higher proportion of early extubation in MIDCAB cases, whereas Vicol et al showed that MIDCAB patients needed longer periods for ventilation and had longer ICU stays [Gersbach 2001; Vicol 2003].

We observed no statistically significant differences between groups for total amount of bleeding, erythrocyte suspension and fresh-frozen plasma transfusions, reoperations, and ICU stay times. There were 3 reoperations in group I but none in group II; although this difference was not statistically significant, reoperation rates for MIDCAB were higher than expected. There were no occurrences of bleeding from the LAD-to-LIMA anastomosis in reoperations; 2 reoperations were required because of bleeding at the side branches of the LIMA and 1 because of bleeding at the intercostal artery. Reoperations for OPCAB surgery have been performed in 1% to 2.3% of patients in several series, results that corresponded with our institution's overall statistics for off-pump surgery [Detter 2002; Vicol 2003; Fukui 2007]. The total amount of bleeding in group I patients who did not undergo reoperation seemed lower than usual, so we repeated the statistical calculations after excluding the 3 patients who required reoperation. These results are summarized in Table 3. Total bleeding and ICU stay became significant in favor of the MIDCAB group, and differences in amounts of transfusion were not significant.

Postoperative periods were mostly uneventful in both of our patient groups. Early graft failure, myocardial infarction, or significant electrocardiogram changes were not seen either group, including 4 MIDCAB and 1 OPCAB patients who had end-to-end anastomosis of LIMA to a saphenous vein graft. Two of these patients gave consent for postoperative evaluation; 1 patient underwent coronary angiography and the other an exercise stress test. No signs of stenosis or ischemia were seen. The need for a saphenous vein graft seemed to be a limitation, but increased experience in LIMA harvesting thorough a small anterior thoracotomy incision and patient selection might decrease this need. Only 1 patient, in group II, needed inotropic agents. Intraaortic balloon pump support was not used in any study patients.

Atrial fibrillation frequency after MIDCAB and OPCAB operations was equal in our study, results similar to those reported by Ascione et al, and our atrial fibrillation ratio was less than CABG averages found in many other studies [Ascione 1999; Hernandez 2001; Eagle 2004].

SSSIs involving only cutaneous and subcutaneous tissue were seen in 2 patients in group I. Both of the patients had been discharged without any sign of infection, and SSSIs were identified in the first week of follow-up and were probably due to inappropriate personal hygiene conditions. Antibiotics and frequent dressing changes for a few days were sufficient treatment. Avoidance of CPB is usually associated with lower incidence of surgical site infections and mediastinitis [Ng 2000], but there is controversy about incidence of infection in minimally invasive operations. Retractors used in MIDCAB procedures might produce tension over the cutaneous and subcutaneous tissues leading to ischemia and necrosis predisposing patients to infections [Puskas 2003; Vicol 2003]. Vicol et al reported 5% SSSI in MIDCAB and none in OPCAB patient groups [Vicol 2003]. Although our study results and those of Vicol et al were not statistically significant, this complication should be kept in mind when making decisions about the surgical procedure. Submammarian incisions might predispose patients to SSSI, but in our study the majority of patient cosmetic results after wounds healed were perfect, a concern that might be important, especially in young patients.

In our patients the length of hospital stay was significantly shorter in the MIDCAB group than OPCAB group. Previous studies reported OPCAB patients had shorter stays than CPB patients [Hernandez 2001; Puskas 2003]. Stays for MIDCAB patients were even shorter, a result with economical importance [Detter 2001].

Despite major improvements in PCI techniques (angioplasty and stenting) LAD-to-LIMA anastomosis is still the gold standard for revascularization of the anterior side of the heart [Vicol 2003]. PCI usually requires additional revascularization procedures because of a higher restenosis rate [Góngora 2007]. On the other hand, PCI surgery has better early, midterm, and late results [Fraund 2005; Guyton 2006]. Minimally invasive surgery ensures perfect long-term patency of LAD-LIMA anastomosis with less surgical trauma and faster healing.

Technical improvements in surgical equipment provide better stabilization and exposure, enhancing the feasibility

of this kind of surgery at multiple centers with reproducible good results.

MIDCAB surgery is a highly demanding and challenging technique but has good results such as shorter mechanical ventilation periods, early ambulation, and a more comfortable postoperative period. Additionally, minimally invasive techniques require less transfusion support and shorter ICU and hospital stays, all of which contribute to lower costs to the health system.

In conclusion, MIDCAB surgery may be performed safely and effectively in patients with isolated LAD stenosis who have high risk factors for PCI and are not good candidates for CPB. Our results, together with rapidly growing number of studies on minimally invasive techniques in cardiac surgery, suggest that these kinds of procedures will be more prominent and prevalent in the near future.

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