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Lower Mini-Sternotomy: a New Approach for Minimally Coronary Artery Bypass Surgery: Chances and Limitations of a New Technology

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Abstract

Background

The rate of Coronary Artery Bypass Grafting (CABG) procedures decreased generally over the past years while the relative number of off-pump coronary artery bypass grafting (OPCAB) procedures remained stable. OPCAB can be performed in different ways also using a minimally invasive direct approach (MIDCAB). This technique consists usually of the approach through the Left Anterior Small Thoracotomy (LAST) and is in principle limited for single LAD revascularization only. Lower Mini-Sternotomy (LOMS) is an optimization of the minimal-invasive approach permitting the harvest of both internal thoracic arteries (ITA) as well as excellent exposure and immobilization of the left and right coronary arteries.

Methods

Between January 2016 and June 2017 LOMS was performed in 31 patients to achieve access to the left and right internal thoracic arteries and to reach the left anterior descending coronary artery, diagonal branches, and right coronary artery for off-pump, all-arterial, aortic no-touch revascularization. Postoperative pain intensity was assessed on a daily basis for 7 days and patients were followed prospectively after operation at our outpatient clinic on a monthly basis in order to assess the incidence of complications.

Results

The mean operative time was 163 ± 49 minutes (range 119 to 260 minutes). The mean length of the skin incision was 7.4 ± 1.3 cm (range 6 to 11 cm). Neither hemodynamic changes nor transient S-T segment changes on the ECG occurred during the operation. In most patients, recovery was rapid and uneventful. No hospital death or morbidity was observed. No blood transfusion was required perioperatively. There were no perioperative neurological cognitive dysfunction events. Maximal pain levels were registered on postoperative day 2 or 3, and pain had abated in most patients on day 5. At follow-up, all patients were in New York Heart Association class I.

Conclusions

Despite more demanding surgical technique than with full-sternotomy OPCAB, our experience demonstrates that the LOMS for MIDCAB is a technically feasible procedure for myocardial revascularization. Not only the LAD and its branches but also the RCA and can be used safely with very good procedural outcomes.

Introduction

The first successful clinical coronary operation was performed by Robert Goetz as an off-pump procedure (OPCAB) on a beating heart in Boston, Massachusettes in 1960[1]. Kolessov continued to perform ITA-LAD Coronary Artery Bypass Graft (CABG) surgery without extracorporeal circulation through a minimally invasive direct coronary artery bypass (MIDCAB) approach, believing in the superiority of the off-pump technique. However, this approach fell into oblivion after establishing and standardizing the CABG procedures with use of cardiopulmonary bypass throughout the following years[2]. With the objective to provide a surgical technique with more benefits for the patient, beating heart coronary surgery was then revived and expanded during the recent twenty years despite being more demanding than conventional CABG using cardiopulmonary bypass[3,4]. Previously published reports confirmed that less tissue trauma, less myocardial damage caused by aortic cross-clamp inducted

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ischemia, better cosmetic results, and better outcomes, in particular improved neurological outcomes, were associated with an aortic no-touch technique[5]. Additional advantages in terms of cost-benefit analysis included shorter ICU and hospital stay. Coronary artery bypass grafting can be performed by full sternotomy, mini-sternotomy, thoracoscopically, or endoscopically with the use of computer-assisted telemanipulation technology, either with or without cardiopulmonary bypass [6-8]. Lower Mini-Sternotomy (LOMS) is an optimization of the minimal-invasive approach permitting the harvest of both Internal Thoracic Arteries (ITA) as well as excellent exposure and immobilization of the left and right coronary arteries. The feasibility of this approach for the MIDCAB procedure has been shown in previous reports [9-11]. Recently we described our initial experience with MIDCAB consisting of LOMS for all-arterial, aortic no-touch MIDCAB on the beating heart without cardiopulmonary bypass for multivessel disease[12]. Here we present updated results of a larger number of patients who underwent MIDCAB with the LOMS approach.

Methods

Patients with a 1 or 2 vessel coronary artery disease were selected for revascularization using MIDCAB through the LOMS approach. Contraindications for the LOMS approach included the presence of major coronary artery disease on the lateral surface of the heart and acute myocardial infarction requiring intravenous administration of nitrates or an intraaortic balloon pump. Patients were not excluded on the basis of the age, functional status, diameter of the target vessels or other preoperative risk factors, such as previous stroke or myocardial infarction.

Operative Technique

The operations were performed on the beating heart without cardiopulmonary bypass, without full sternotomy, and without touching the aorta. During the operation, the heart rate was controlled pharmacologically with betablocker Sotalex (Bristol-Myers Squibb GmbH & Co.). Transesophageal echocardiography was used in all patients to monitor changes in wall motion and heart function. The patient was placed in a supine position and prepared as for conventional cardiac surgical procedures. A skin incision was made from the fourth intercostal space to the base of the xiphoid process (7 to 8 cm). The distal third to half of the sternum was then divided up to the third rib starting from the bottom, using an oscillating saw, with making a reversed L-or T-shaped division of the sternum either on the right or left sternal side. ITA retractor (Delacroix-Chevalier, Paris-France) was used to harvest ITA by minimal-pedicle technique using electrocautery on low-level program (Maxium- KLS Martin Group, Tuttlingen, D). The ITAs were exposed and harvested to the almost usual extent obtained with full sternotomy. When the radial artery (RA) was used, it was harvested from the left forearm simultaneously with the left ITA (LITA), using scissors and clips. After all conduits were harvested, the sternum was carefully spread with the sternal retractor (Guidant-Maquet, Getinge Group, Sweden). The pericardium was opened up to the aortic root and suspended with 4 stay sutures. 1 to 1.5 mg/kg heparin was given to keep the activated clotting time around 300 seconds. The distal part of the conduit was then ligated and divided. A coronary artery stabilizer (Acrobat-i Device -Guidant-Maquet, Getinge AB, Sweden or Octopus- Medtronic, Inc, Minneapolis, USA) was set on the sternal retractor. Then the stay sutures were revised and gently pulled upward bringing up the LAD to the field. A suction-based epicardial stabilizer was routinely used. The left ITA was grafted to the LAD or a diagonal branch or used as a sequential bypass for both vessels, and the right ITA was anastomosed to the RCA. Left radial artery (LRA) was used as Y-graft constructed with either the RITA or LITA. The anastomotic site of the LAD was chosen, and a 4-0 Prolene suture (Ethicon, Johnson&Johnson Medical, Norderstedt, Germany) was passed around proximally and distally to the anastomotic site of the coronary artery using a snare with a Teflon felt pledget. A 5-minute test occlusion was undertaken routinely to confirm hemodynamic stability before proceeding with the arteriotomy and grafting, excluding cases of total occlusion of the coronary artery. When hemodynamic instability occurred, an intracoronary shunt (ClearView, Medtronic GmbH, Meerbusch-Germany) was inserted. The distal tourniquet was tightened only in cases with significant coronary backflow. The LAD was opened longitudinally and the proximal suture was snared gently to achieve hemostasis. The LITA–LAD anastomosis was carried out using single parachute technique with the 8-0 Prolene. For the anastomosis on the main RCA, a suction-type stabilizer (Expose-Guidant, Maquet, Betinge AG-Sweden) was used. The main RCA was opened longitudinally and either the right ITA (RITA)–RCA or the radial artery as a Y-graft was then carried out using the 8-0 Prolene single running suture. For the anastomosis on the right Posterior Descending Artery (PDA), the acute margin of the heart was displaced cranially by the Acrobate stabilizer to provide a good exposure of the inferior wall. The anastomotic site of the PDA was chosen and the anastomosis was performed with a running 8-0 Prolene suture. When the RA graft was used, a Y graft was constructed with either the RITA or LITA before the distal anastomosis with a running 8-0 Prolene suture. Once the anastomosis was complete, the graft flow was tested using a handheld transit-time ultrasonic flow probe (Medistim VeriQ C, Oslo-Norway) to assist in the detection of technical problems with the anastomosis. Heparin was reversed with a half dose of protamine that was given at the end of the procedure. After insertion of two drains into the pericardial cavity and the substernal space, the lower sternotomy was closed with sternal wires and soft tissue was closed in layers Figure 1, 2.

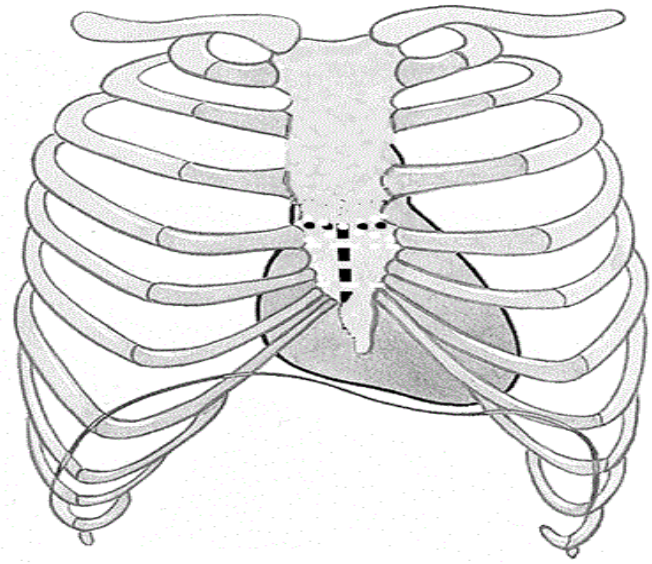

Figure 1: Reversed L-, or/and T-shaped lower mini-sternotomy (LOMS) as black broken lines and white broken lines for the closure with sternal wires

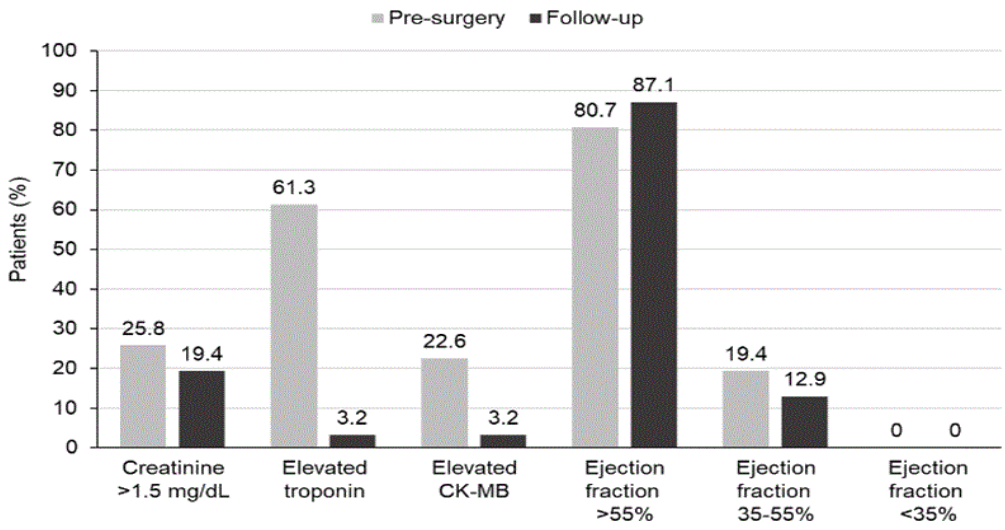

Figure 2: Laboratory parameters and ejection fraction

Patient Follow-Up

Electrocardiograms were recorded at least four times during admission, and serial myocardial fractions of creatine kinase (CK-MB) were determined at 1 hour and every 4 hours postoperatively on the first two postoperative days and then every 12 and 24 hours for the next days in all patients. Echocardiographic examinations were performed preoperatively, intraoperatively and postoperatively at discharge to evaluate changes in the regional wall motion and ejection fraction. Perioperative myocardial infarction was diagnosed in the presence of one or both of the following criteria: (a) CK-MB levels greater than 80 IU/L, or (b) the development of irreversible S-T elevation and new Q-waves. Coronary angiography was performed only in patients who fulfilled these criteria. After extubation, all patients were given oral analgesic tablets (hydromorphone 8 mg/d) two times daily for 2 days. Postoperative pain intensity was assessed on a daily basis for 7 days by direct interview using a five-step verbal rating scale (no pain, mild, moderate, severe, unbearable pain). The patients were followed prospectively after operation at our outpatient clinic on a monthly basis.

Statistical Analysis

All data are presented as mean ± Standard Deviation (SD). The 95% Confidence Interval (CI) for mortality was calculated using the exact binomial distribution. Postoperative NYHA functional class was compared with preoperative status using a paired t test. A value of $p<0.05$ was considered significant.

Results

A total of 31 patients (mean ± SD age 66.1 ± 5.9 years, 83.9% male) underwent MIDCAB using the LOMS approach over a 17-month period from January 2016 to June 2017. Baseline characteristics are summarized in Table 1, 2. Of the patients, 10 had LAD and diagonal branches disease, 12 had both LAD and RCA disease. Functionally, 12 patients were in New York Heart Association (NYHA) functional class III before operation and 10 were in class II respectively. All MIDCAB procedures were performed by the same surgeon. All patients received arterial grafts; LIMA in 22 patients, RIMA in 2, radial artery (RA) in 10. The mean number of grafts per patient was 1.59+/-0.5 (range 1-3). Neither hemodynamic changes nor transient S-T segment changes on the ECG occurred during the operation. The mean operative time was 163 ± 49 minutes (range 119 to 260 minutes) in all patients and 138 ± 19 minutes (range 124 to 175 minutes) for

Table 1: Baseline and follow-up clinical characteristics

Parameter, N=31	Baseline	Follow-up
Age, years, mean ± SD	66.1 ± 5.9	
Male, N (%)	26 (83.9%)	
Hypertension	23 (74.2)	16 (51.6)
Coronary artery disease, 2-vessel	21 (67.7)	21 (67.7)
Myocardial infarction	12 (38.7)	1 (3.2)
Congestive heart failure	11 (35.5)	0 (0.0)
NYHA class II or III	31 (100.0)	0 (0.0)
Diabetes mellitus	9 (29.0)	9 (29.0)
Renal insufficiency	8 (25.8)	8 (25.8)
Liver dysfunction	1 (3.2)	1 (3.2)
Pneumonia	6 (19.2)	1 (3.2)
Peripheral vascular disease	9 (29.0)	9 (29.0)
Carotid atherosclerotic disease	4 (12.9)	4 (12.9)
Stroke	2 (6.5)	0 (0.0)
Smoking	19 (61.3)	5 (16.1)
Chronic obstructive pulmonary disease	7 (22.6)	7 (22.6)
Percutaneous coronary intervention	8 (25.8)	0 (0.0)

Table 2: Adverse events

Parameter, N=31	N (%)
Atrial fibrillation	2 (6.5)
Myocardial infarction	1 (3.2)
Cerebrovascular adverse events	0 (0.0)
Percutaneous coronary intervention	1 (3.2)
Reoperation	0 (0.0)
Wound dehiscence or infection	0 (0.0)
Pleural effusion	5 (16.1)
Bleeding disorder > 4 units of blood	1 (3.2)
Conversion to on-pump	0 (0.0)
Ventilation >24 h	0 (0.0)
Stay in intensive care unit > 24	1 (3.2)

single graft operations. The mean length of the skin incision was 7.4 ± 1.3 cm (range 6 to 11 cm). There was no operative or follow-up mortality (CI 0% to 14.5%). In 2 patients (6.5%), transient atrial fibrillation was observed. In most patients, recovery was rapid and uneventful. All patients except two were extubated on the first day of the surgery and their intensive care unit stay was 1 day. On postoperative day 2 both drains were removed in all patients. No blood transfusion was required perioperatively in any patient. One patient had mild perioperative myocardial infarction (CKMB-82) without hemodynamic instability. In this patient the LITA-LAD anastomosis was performed on the distal hypoplastic third of LAD. Perioperative angiography was performed and showed the patent anastomosis but with retrograde flow cause of the steel phenomenon of the septal and diagonal branches. The distal site of LAD with its hypoplastic vessel structure occluded. There were no perioperative neurological cognitive dysfunction events. The most pain was reported by patients when coughing and during in-bed mobilization. Maximal pain levels were registered on postoperative day 2 or 3. Pain intensity according to the verbal rating scale at postoperative day 2 was no pain in 10 cases, mild in 15, moderate in 4 and severe in 1, which was reduced at postoperative day 5 to almost no pain (no pain in 25 cases and mild in 5). Early postoperative pain levels were relatively low as reflected by more patients expressing mild, or even no pain. After 1 week, almost all patients had no pain. At follow-up examination, NYHA functional class was significantly improved from 2.7 before operation to 1.0 ($p < 0.0001$). All patients returned to full activity within 13 days.

Discussion

The results gained from revascularization using MIDCAB through the LOMS approach over an extended period of 18 months confirmed our early experience with this novel technique[12]. The benefits of avoiding cardiopulmonary bypass during CABG have been discussed controversially in recent years. While the procedure has been associated with a decreased risk of postoperative complications such as bleeding, arrhythmia, stroke, renal failure, aortic injury, respiratory failure, and coagulation abnormalities, other data indicate increased mortality rates[13-17]. Myocardial revascularization without cardiopulmonary bypass was originally discussed by Kolessov in 1967[2]. Even 82% of his CABG procedures were performed off-pump from 1964 on, but the concept was not really popularized until the early 1980s in South America. The revival of the off-pump techniques was then described by Benetti, whose success led to enthusiasm about avoidance of extracorporeal support for CABG. Early procedures were limited to the Left Anterior Small Thoracotomy approach (LAST) through which only the LAD can be grafted[3, 4]. In patients requiring multiple vessel revascularization full sternotomy was preferred. Several techniques have been proposed to improve beating heart surgery for multiple vessel disease patients without full sternotomy[18, 19]. However, if the anterior small thoracotomy approach is used, access to both RCA and LAD requires generally two incisions, resulting in incisions with total lengths that are the same or greater than those of a full sternotomy. In contrast, minimally invasive techniques such as the Distal Ministernotomy (DIMS) and the LOMS approach provide ease of access to both vessels by means of a limited incision and allows ITA harvest under direct vision[11]. Our initial experience with DIMS for coronary artery bypass grafting has been described and evaluated for potential reduction of perioperative morbidity and accelerated postoperative recovery[20].

The results achieved with LOMS are comparable with the reported results in a series using the LAST approach, in terms of mortality, major morbidity, ICU stay, and graft patency[4]. However, similar to DIMS, the LOMS alternative approach technique shows several advantages over the LAST approach for MIDCAB, such as the use of four arterial conduits through a single incision and the feasibility of a rapid extension to a full sternotomy without additional skin incisions in emergency cases[11, 12]. Furthermore, while some studies have demonstrated that the LAST approach causes significantly more pain in the early postoperative period than with conventional full sternotomy, early postoperative pain was relatively low in our patients and abated within a week[20, 21]. The intact manubrium sterni may be responsible for the reduced pain experienced with our approach compared to full sternotomy. We did not register any cases of repeat CABG after our procedure. Potential median repeat sternotomy should not pose a problem, because the pericardium is completely closed in all patients. This extended experience with additional patients confirmed that LOMS for MIDCAB is a technically feasible approach for revascularization not only of the LAD but also the RCA system with the same small incision, leading to excellent cosmetic results. Although this procedure is more difficult to perform than conventional revascularization techniques and data on long-term outcomes are not yet available, we conclude that this minimal-invasive technique can be used safely with very good results as an alternative approach for CABG in patients with LAD and/or RCA disease.

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Declarations

Conflict of interest: none, Ethical approval: NA

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