Beating heart coronary artery surgery: is sternotomy a suitable alternative to minimal invasive technique?

Philippe Gersbach*, Christophe Imsand, Ludwig K. von Segesser, Alain Delabays, Pierre Vogt, Frank Stumpe

Departments of Cardiology and of Cardiovascular Surgery of Lausanne University Hospital and of Sion Regional Hospital, Lausanne, Switzerland

Received 5 January 2001; received in revised form 18 April 2001; accepted 30 May 2001

Abstract

Objectives: To evidence the respective advantages and drawbacks of minimal invasive-thoracotomy (MIDCAB) and off-pump sternotomy (OPCAB) coronary bypass techniques. Methods: The perioperative and mid-term (3 months) results of the first 31 MIDCABs and 39 OPCABs performed by a single experienced coronary surgeon (F.S.) were compared. Differences were assessed by two-tailed chi-square or unpaired t-test, and significance assumed for P-values ≤0.05. Results: Groups were widely comparable. There were no in-hospital deaths nor permanent neurologic events. OPCAB patients received more anastomoses (mean 1.09/patient vs. 1.89/patient, P<0.001) during a shorter coronary occlusion period (26.1±8 vs. 16.6±4.5 min, P<0.001), whilst immediate extubation prevailed in MIDCABs (22/31 vs. 17/39, P<0.05). Significant complications occurred in seven MIDCABs vs. none in OPCABs (P<0.01). Other in-hospital parameters were similar. Controls at 3 months evidenced more residual discomfort among MIDCAB patients (14/30 vs. 7/39, P<0.05). Conclusions: Differences in early complication rates may be due to a learning effect. However, OPCAB allows us to implant more grafts and is more comfortable for both patient and surgeon. These advantages may well counterbalance the cosmetic benefits of MIDCAB procedures. © 2001 Elsevier Science B.V. All rights reserved.

Keywords: Coronary bypass techniques; Minimal invasive-thoracotomy; Off-pump sternotomy; Completeness of revascularization; Early and late morbidity; Residual discomfort

1. Introduction

Coronary artery bypass surgery has been performed by relatively uniform surgical techniques over the last 25 years. The short- and long-term benefits of these standard procedures have been proven [1]. Hence, myocardial revascularization performed through a median sternotomy incision and on cardiopulmonary bypass (CPB) is still considered as the ‘golden standard’. However, the increasing recognition of the multiple clinical and subclinical deleterious effects of CPB [2,3] and, to a lesser extent, cost-containment issues as well as significant advances in transcutaneous catheter techniques have led to a resurgence of interest in off-pump coronary artery bypass (OPCAB) grafting and prompted the emergence and rapid spreading out of minimal invasive direct coronary artery bypass (MIDCAB) surgery, which adds the benefits of limited access techniques developed in general thoracic surgery to those of the off-pump technique. These two approaches share the advantages of avoiding the morbidity of CPB and aortic cross-clamping. In addition, MIDCAB, which mostly involves a small left anterior thoracotomy and a single mammary artery bypass on the left anterior descending coronary artery (LAD), aims to further reduce the surgical trauma. This potential superiority of MIDCAB over OPCAB has, however, not been proven. The present study aims to substantiate the respective advantages and drawbacks of these two approaches.

2. Patients and methods

Beating heart surgery was basically proposed:

(a) for patients in whom CPB had a presumed above-average risk of severe complications – such as coagulopathy (n=2), severely calcified ascending aorta (n=2), cancer (n=1), age over 75 years (n=5), recent major gastrointestinal bleeding (n=1), abdominal aneurysm (n=1), severe renal (n=2) or pulmonary disease (n=3);
(b) for candidates for routine coronary artery bypass grafting (CABG) technically suitable for off-pump surgery, i.e.
proximal culprit lesion of an extramyocardial and not diffusely atheromatous LAD of at least 1.5 mm, no severe lesions of major posterior branches, no electrical instability or severe cardiomegaly.

MIDCAB was only proposed for hemodynamically stable patients presenting with lesions limited to the LAD system, whilst OPCAB procedures were preferred in graftable multivessel disease, emergency procedures, and cases of thoracic deformities or severe obesity.

The clinical files of the first 70 CABG procedures performed at the beating heart under identical conditions by a single surgeon with more than 20 years of experience in coronary surgery (F.S.) were reviewed. Patients were divided into MIDCAB (n = 31) and OPCAB (n = 39) groups. General and cardiac condition 3 months postoperatively was assessed by a standardized phone interview of the patient and his home physician. To avoid a possible magnification of his condition by the patient in order to please his surgeon [4], this interview was performed by an independent cardiologist, who was not aware of the operative technique.

2.1. Operative technique

As a single major difference between groups, an epidural catheter was placed 24 h preoperatively in MIDCABs at the high thoracic level (Th 3–4) for perioperative analgesia (carbostesin/sufentanil).

Anesthetic induction was performed in both groups with short-acting hypnotics, opioids (Propofol/Sevoflurane/Remifentanil), and muscle relaxing agents (Atracrurium) in order to facilitate early extubation. The operating theater was warmed up to 26°C for preservation of temperature homeostasis. All patients received standard monitoring equipment (radial artery catheter, two surface ECG leads, pulse oximetry, end-tidal pCO₂ and, in cases of poor left ventricular function, a Swan–Ganz thermodilution pulmonary artery catheter). The ventricular function was continuously monitored by transesophageal echography (Ving Med CFM 750, Horten, Norway) in order to detect possible segmental wall motion abnormalities indicative of limited myocardial ischemia [5]. CPB facilities were systematically kept in stand-by throughout the procedures.

In OPCABs a full-length standard sternotomy was routinely performed and the left internal mammary artery (LIMA) – and occasionally the right internal mammary artery (RIMA) – was harvested with its pedicle on its whole length, simultaneously with the long saphenous vein whenever necessary. For MIDCABs, external defibrillator paddles were fixed at the external surface of the chest. A small left anterior thoracotomy was placed in the fourth intercostal space and the LIMA mobilized under direct vision as high as possible. This maneuver was facilitated by the use of a specific chest retractor (CardioThoracic Systems Inc., Cupertino, CA, USA).

MIDCAB and OPCAB operations were basically performed in a similar way: after opening of the pericardium and short inspection, low dose (150 IU/kg of body weight) heparin was administered intravenously. Short-acting β-blockers (esmolol) and/or calcium antagonists (Diltiazem) were used to control heart rate and to minimize myocardial contractility and oxygen consumption. Volume loading with infusions allowed us to optimize cardiac output during manipulations. Pericardial stay sutures [6] and laparotomy pads placed progressively behind the heart helped to expose the target vessels. Immobilization of the operative site was achieved by placing the blades of an epicardial stabilizer (CardioThoracic Systems Inc., Cupertino, CA, USA) perpendicular to the target vessel allowing, in ideal cases, full control of the native coronary blood flow. If necessary, exposure was optimized by epicardial stay sutures and occasionally by encircling 4.0 propylen sutures placed around a wide pad of surrounding tissue proximal and distal to the intended site of arteriotomy. Distal anastomoses were completed with a single 8.0 Prolen (Ethicon, Somerville, NJ, USA) running suture. In cases of multiple grafts, the most important diseased coronary artery (generally the LAD) was bypassed first. In OPCABs, additional vein grafts to the circumflex and right coronary systems were implanted on the ascending aorta using a partial occlusion clamp. In order to avoid or reduce aortic manipulations, sequential bypasses were performed as often as possible.

2.2. Statistical analysis

Continuous variables were reported as mean ± SD. Differences between groups were assessed by the two-tailed chi-square test or Student’s t-test for independent samples, and significance assumed for P-values less than 0.05.

3. Results

Groups were widely comparable for demographics, cardiac and general condition, as well as for CCS angina class and coronary risk factors, except for a prevalence of smokers in MIDCABs (Table 1).

Pertinent operative data are summarized in Table 2. Despite an almost identical number of diseased vessels, significantly more anastomoses were performed among OPCABs, mostly on the right coronary artery (n = 15) and high diagonal branches (n = 12), less often on the circumflex (n = 7) system, resulting in a more complete revascularization in this group. LAD occlusion time was significantly shorter in OPCABs, but ischemia was similarly well tolerated by both groups. No differences could be identified with regard to the duration of the whole procedure or length of ICU and in-hospital stay. A majority of MIDCAB patients were extubated in the operating room, while most of the OPCABs were extubated after a short stabilization period in the ICU. Altogether, around 75% of patients from each group were already extubated 4 h postoperatively.

There were no in-hospital deaths or clinically detectable
perioperative neurologic events in either group. Significant perioperative complications (Table 3) occurred only among MIDCABs: (a) three rather small myocardial infarctions; (b) three early rehospitalizations for chest tubing; (c) one pleural empyem followed by septic shock, transitory renal failure, and severe gastrointestinal bleeding. Immediate conversion to sternotomy and venous overbypass at the beating heart had to be performed in two of the three myocardial infarction patients. The third one underwent an early reoperation (venous overbypass on the LAD system on conventional CPB). These early procedures may have allowed us to limit the extent of the necrosis. Further conversions to sternotomy or to CPB technique were not necessary during this period. Minor perioperative complications were frequently observed, mostly: atrial fibrillation after 6 min, Dressler syndromes (n = 6), and urinary tract infections (n = 5). They were equally distributed between groups, with a statistically not significant trend towards atrial fibrillation after OPCABs and Dressler syndrome after MIDCABs.

Follow-up at 3 months was complete. The results are summarized in Table 4.

One MIDCAB patient died of unrelated cause just before control. Six MIDCAB patients required early readmission because of important pleural effusion [3], pericarditis [1], reoperation [1], or gastro-intestinal bleeding [1], vs. a single OPCAB patient with gastro-intestinal bleeding (P < 0.05). Wound problems needing ambulatory treatment occurred in 37% (11 out of 30) MIDCABs and in 13% (five out of 39) OPCABs (P < 0.05). Residual discomfort 3 months post-operatively was reported by 47% MIDCAB and by 18% OPCAB patients (P < 0.05). Their complaints are detailed in Table 4. Substantiating these subjective findings, chest X-rays were ordered by the referring physicians in 45% MIDCABs and only in 18% OPCABs (P < 0.05).

4. Discussion

CPB has long been recognized as a major cause of perioperative pulmonary, cerebral, and renal dysfunction. It also initiates a complex systemic inflammatory response that contributes to postoperative complications possibly leading to failure in any organ system [2]. Large studies have demonstrated that coronary artery surgery without CPB can be achieved with excellent early and mid-term clinical and angiographic results in selected patients with appropriate coronary lesions [7,8], Tasdemir et al. [9] have recently reported 1.9% mortality and 2.9% myocardial infarction rates in 2052 OPCABs accounting for one third of their total CABG practice. Benetti et al. [8] have achieved even lower mortality and comparable morbidity rates in 700 consecutive OPCAB patients. In their recent experience these authors completed a mean of 3.1 grafts/patient and performed 84% of their coronary procedures without CPB. Furthermore, these techniques are increasingly considered as particularly safe and useful in reoperations [10] and in high-risk patients presenting with advanced age, chronic renal failure, limited pulmonary reserve, bad left ventricular function, evolving myocardial infarction, previous cerebro-

Table 1
Demographics and preoperative variables

| Condition                  | MIDCAB (n = 31) | OPCAB (n = 39) | P-value |
|----------------------------|-----------------|----------------|---------|
| Gender (F/M)               | 5/26            | 9/30           | NS      |
| Age (mean ± SD)            | 60.8 ± 10 years | 63.3 ± 9.5 years | NS      |
| Diabetes                   | 4               | 8              | NS      |
| Hypertension               | 14              | 21             | NS      |
| Dyslipidemia               | 13              | 22             | NS      |
| Smoke                      | 18              | 11             | <0.05   |
| LVEF < 50%                 | 5               | 10             | NS      |
| Previous MI                | 11              | 15             | NS      |
| Recent (<14 days)          | 6               | 5              | NS      |
| Angina class (mean ± SD)   | 2.6 ± 1.1       | 2.9 ± 0.8      | NS      |
| Previous PTCA of LAD       | 7               | 9              | NS      |
| Previous stent in LAD      | 4               | 5              | NS      |

Table 2
Operative data

| Parameter                  | MIDCAB (n = 31) | OPCAB (n = 39) | P-value |
|----------------------------|-----------------|----------------|---------|
| Nb diseased vessels        | 1.45 ± 0.6/patient | 1.59 ± 0.6/patient | NS      |
| Nb anastomoses             | 1.09/patient (1–2) | 1.89/patient (1–3) | <0.001  |
| Less complete revascularization | 9/31          | 0/39           | <0.01   |
| Occlusion time (LAD)       | 26.1 ± 8 min    | 16.6 ± 4.5 min | <0.001  |
| Operation duration         | 124 ± 39 min    | 134 ± 27 min   | NS      |
| Immediate extubation       | 22/31           | 17/39          | <0.05   |
vascular accidents, or carotid artery disease [7,9,11]. Significantly lower transfusion needs [9], shorter ICU and in-hospital length of stay [7], as well as an earlier return to work are also expected [11], and appear particularly attractive in a period of cost-containment. Comparable results have been obtained by limited access procedures [12] thought to produce a further reduction of patient discomfort and disability by minimizing the incisional pain. It has, however, to be considered that these impressive results have been obtained in some of the world’s most experienced centers. They are, therefore, not necessarily reproducible, as evidenced by a recent report by Goldstein et al. [13] who performed systematic intraoperative angiograms in 26 MIDCABs and found technically unidentified anastomotic stenosis in 42% and arterial spasms in 35%.

The vogue of MIDCAB surgery has prompted the emergence of numerous instrumental and technical refinements that in turn improved OPCAB feasibility and safety. Despite these recent developments, beating heart surgery remains technically more demanding than conventional CABG [14]. An original recent survey on minimal invasive CABG by Shennib et al. [15] has demonstrated that 74% of the surgeons using these techniques feel somewhat uncomfortable, mostly because of difficulties in stabilizing the target vessel and concern with the quality of the anastomoses. Comparisons between MIDCAB and OPCAB techniques should, therefore, also take into account the exact influence of the learning process of each of these procedures on early patient mortality and morbidity.

In this respect, the basic conditions of this study (initial experience of a single surgeon using the same technical setup, in a single institution and during a limited period of time) allows a fair comparison between the two approaches. Among the seven substantial perioperative complications identified – exclusively – in the MIDCAB group, three myocardial infarctions in the freshly grafted LAD area may be related to inexperience: in one case of deeply embedded LAD, the anastomosis had to be performed very distally on a small vessel of poor quality; in the remaining two cases, LIMA harvesting through a small thoracotomy incision had been described as difficult. This confirms the potential of thoracoscopic techniques for LIMA preparation in MIDCABs [16], particularly when considering that such a procedure can be completed within 20 min [11].

The longer LAD occlusion time in MIDCABs must be interpreted with circumspection. Conflicting results have been reported on the risk of subclinical myocardial injury during target vessel occlusion. Bonatti et al. [17] have registered an elevation of creatine kinase MB mass concentration indicative of myocardial suffering in 56% and of cardiac troponin I level in 44% of MIDCABs. Systematic TEE observations by Jurmann et al. [5] have also evidenced hypokinetic changes in regional wall motion during LAD occlusion in 26 out of 28 MIDCAB patients. Conversely, Pentilla et al. [18] measured no significant increase of troponin T and creatine kinase-MB mass after coronary revascularization at the beating heart in 12 patients. It has finally been hypothesized that the increased perioperative mortality rate observed in hypertensive patients undergoing OPCABs may be due to lesser tolerance of hypertrophic left ventricles to short ischemic periods [9]. In the present study, no relationship could be found between the early postoperative course, the need for inotropic support, and the duration of coronary ischemia.

The different number of bypasses performed in each group mostly reflects the extent and characteristics of the underlying coronary disease, since patients necessitating a single LAD bypass can be treated as well by MIDCAB as by OPCAB procedures, whereas OPCAB is preferred in graftable multivessel disease. Nevertheless, incomplete revascularization has long been recognized as a major cause of recurrence of angina [19]. In the experience of Tasdemir et al. [9] an ungrafted circumflex artery disease emerged as the second most important determinant of in-hospital death as well as a significant predictor of perioperative myocardial infarction and low cardiac output after OPCAB procedures. Moreover, a recent observational clinical study by the group from the Cleveland Foundation [20] has shown an over 30% decrease in long-term survival among patients with non-revascularized lesions outside the LAD system. Finally, the importance of bypassing high diagonal branches that are hardly accessible through a MIDCAB approach remains controversial. Data of the CASS study [21] still indicate that the risk of myocardial infarction in any part of the LAD system over a 3-year period is 2% for mild stenosis increasing up to 7–8% for stenosis of 50–90%. Unless long-term efficiency of hybrid procedures has been proven, MIDCAB techniques should, therefore, be reserved for isolated LAD lesions.

The opinion that MIDCAB is associated with reduced postoperative pain cannot be sustained by the present study. On the contrary, even though not significant, more

Table 3
Early complications

| Grade     | MIDCAB (n = 31) | OPCAB (n = 39) | P-value |
|-----------|----------------|--------------|---------|
| Significant | 7              | 0            | < 0.01  |
| Minor     | 24             | 20           | NS      |
| None      | 9              | 22           | < 0.05  |

Table 4
Mid-term results (3 months)

| Complaints       | MIDCAB (n = 30) | OPCAB (n = 39) | P-value |
|------------------|----------------|--------------|---------|
| None             | 16             | 32           | < 0.05  |
| Thoracic pain    | 9              | 4            | NS      |
| Residual angina  | 3              | 1            | NS      |
| Rehospitalization| 6              | 1            | < 0.05  |
| Dyspnoe          | 5              | 2            | NS      |
| Pleural effusion | 3              | 1            | NS      |

* One patient of this group died just before control.
MIDCAB patients complained of persistent thoracic pain 3 months postoperatively; in two cases, the pain was considered disabling.

A slight reduction of early postoperative pain from the third postoperative day onward has actually been reported after MIDCABs [22]. However, it must be stressed that intercostal nerves can always be damaged by thoracotomy, resulting in more or less severe chronic pain. In the present study the residual pain mostly observed after MIDCABs may be related to excessive spreading of the ribs [11]. Resection of costal cartilages and systematic video assisted harvesting of the LIMA may be effective in lessening the incidence and intensity of this complication.

The two groups show no differences in ICU and hospital stay duration (8.6 ± 2.1 days in OPCABs and 8.9 ± 3.9 days for MIDCABs). Discharge was proposed at the fifth postoperative day for 34 patients without disabling complications or significant perioperative complications. Among these, 25 refused, mostly because of a feeling of insecurity and/or an inadequate social environment. It therefore appears that, in this series, hospital stay duration is influenced much more by local standards and confidence of patients, relatives, and referring physicians than by the surgical approach itself. The importance of these socio-cultural local factors has been highlighted by a recent study showing that in another environment even patients of patients, relatives, and referring physicians than by the surgical approach itself. The importance of these socio-cultural local factors has been highlighted by a recent study showing that in another environment even patients with conventional CPB procedures can be safely discharged on the first and second postoperative day [23].

In summary, MIDCAB procedures are technically more demanding than OPCABs. For this reason, sternotomy seems to be the best approach when beginning with off-pump techniques. Furthermore, OPCAB allows a more extensive coronary revascularization and is more comfortable for both the patient and the surgeon. In case of hemodynamic instability, OPCAB also allows immediate conversion to CPB technique. These advantages may well counterbalance the cosmetic benefits of MIDCAB procedures.

References
[1] Fitzgibbon GM, Kafka HP, Leach AJ, Keon WJ, Hooper GD, Burton JR. Coronary bypass graft fate and patient outcome: angiographic follow-up of 5,065 grafts related to survival and reoperation in 1,388 patients during 25 years. J Am Coll Cardiol 1996;28:616–626.
[2] Dunning JJ. Systemic effects of cardiopulmonary bypass. In: Pillai R, Wright J, editors. Surgery for ischaemic heart disease, Oxford: Oxford University Press, 1999. pp. 43–55.
[3] Anderson RE, Hansson LO, Vaage J. Release of S100B during coronary artery bypass grafting is reduced by off-pump surgery. Ann Thorac Surg 1999;67:1721–1725.
[4] Caine N, Harrison SCW, Sharples LD, Wallwork J. Prospective study of quality of life before and after coronary artery bypass grafting. Br Med J 1991;302:511–517.
[5] Jurmann MJ, Menon AK, Haerel LB, Salehi-Gilani S, Ziemer G. Left ventricular geometry and cardiac function during minimally invasive coronary artery bypass grafting. Ann Thorac Surg 1998;66:1082–1086.
[6] Cartier R, Blain R. Off-pump revascularization of the circumflex artery: technical aspect and short-term results. Ann Thorac Surg 1999;68:94–99.
[7] Buffolo E, Gerola LR. Coronary artery bypass grafting without cardiopulmonary bypass through sternotomy and minimally invasive procedure. Int J Cardiol 1997;62(Suppl 1):S89–S93.
[8] Benetti J, Hangler H, Hörmann C, Mair J, Falkensammer J, Mair P. Myocardial damage after minimally invasive coronary artery bypass grafting on the beating heart. Ann Thorac Surg 1998;66:1093–1096.
[9] Tasdemir O, Vural KM, Karagöz H, Bayazıt K. Coronary artery bypass grafting on the beating heart without the use of extracorporeal circulation: review of 2052 cases. J Thorac Cardiovasc Surg 1998;116:68–73.
[10] Boonstra PW, Grandjean JG, Mariani MA. Reoperative coronary bypass grafting without cardiopulmonary bypass through a small thoracotomy. Ann Thorac Surg 1997;63:405–407.
[11] Izzat MB, Yim APC. Minimally invasive LAD revascularisation in high-risk patients with three-vessel coronary artery disease. Int J Cardiol 1997;62(Suppl 1):S101–S104.
[12] Calafiore AM, Teodor G, Di Giammarco G, Vitolla G, Iaco’ A, Iovino T, Cirimen S, Brisco G, Scipioni G, Gallina S. Minimally invasive coronary artery bypass grafting on a beating heart. Ann Thorac Surg 1997;63:S72–S75.
[13] Goldstein JA, Safian RD, Aliabadi D, O’Neill WW, Shannon FL, Bassetti J, Sakwa M. Intraoperative angiography to assess graft patency after minimally invasive coronary bypass. Ann Thorac Surg 1998;66:1978–1982.
[14] Tsui SSL, Dunning JJ. Alternative approaches for coronary artery bypass grafting. In: Pillai R, Wright J, editors. Surgery for ischaemic heart disease, Oxford: Oxford University Press, 1999. pp. 217–229.
[15] Shennib H, Mack MJ, Lee AG. A survey on minimally invasive coronary artery bypass grafting. Ann Thorac Surg 1997;64:110–115.
[16] Massetti M, Babatasi G, Nataf P, Bhoyroo S, Le Page O, Khayat A. Minimally invasive internal thoracic artery harvest: the hybrid approach. Ann Thorac Surg 1999;67:632–634.
[17] Bonatti J, Hangler H, Hörmann C, Mair J, Falkensammer J, Mair P. Myocardial damage after minimally invasive coronary artery bypass grafting on the beating heart. Ann Thorac Surg 1998;66:1087–1092.
[18] Pentillii HJ, Lepojärvi MVK, Kaukoranta PK, Kiviluoma KT, Yitalo KV, Peukurinen KJ. Myocardial metabolism and hemodynamics during coronary artery surgery without cardiopulmonary bypass. Ann Thorac Surg 1999;67:683–688.
[19] Buda A, MacDonald I, Anderson M, Strauss H, David T, Berman N. Long-term results following coronary bypass operation: importance of preoperative factors and complete revascularization. J Thorac Cardiovasc Surg 1981;82:383–389.
[20] Scott R, Blackstone ER, McCarth PM, Lytle BW, Loop FD, White JA, Cosgrove DM. Isolated bypass grafting of the left internal thoracic artery to the left descending coronary artery. Late consequences of incomplete revascularization. J Thorac Cardiovasc Surg 2000;120:173–184.
[21] Ellis S, Alderman E, Cain K, Fisher L, Sanders W, Bourassa M. Prediction of risk of anterior myocardial infarction by lesion severity and measurement of stenoses on the left anterior descending coronary artery distribution: a CASS registry study. J Am Coll Cardiol 1982;11:908–916.
[22] Wallerth T, Falk W, Metz S. Pain and quality of life after minimally invasive versus conventional cardiac surgery. Ann Thorac Surg 1999;67:1643–1647.
[23] Walji S, Peterson RJ, Neis P, DuBroff R, Gray WA, Benge W. Ultra-fast track hospital discharge using conventional cardiac surgical techniques. Ann Thorac Surg 1999;67:363–370.