

Improved Recovery after the Endoscopic Atraumatic Coronary Artery Bypass Procedure Compared with Sternotomy for Off-Pump Bypass of the Left Internal Thoracic Artery to the Left Anterior Descending Coronary Artery: A Case-Matched Study

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ABSTRACT

Objective: The endoscopic atraumatic coronary artery bypass (endo-ACAB) procedure allows single-vessel coronary artery bypass grafting (CABG), avoiding sternotomy or thoracotomy. We set out to define the effect of this surgical approach on postoperative recovery, blood loss, and return to work.

Methods: We performed a case-control comparison of our first 29 endo-ACAB procedures for left anterior descending coronary artery (LAD) disease against 29 control patients, who underwent off-pump beating heart CABG via sternotomy for isolated LAD disease in the same institution. Control pairs were matched for age, sex, and ventricular function.

Results: In a matched population, endo-ACAB is associated with shorter postoperative ventilation times (6.2 hours versus 9.0 hours, $P = .034$) and hospital stays (5.3 nights versus 6.4 nights, $P = .04$), less blood loss (363.9 mL versus 570.3 mL, $P = .017$), and lower transfusion requirements. Endo-ACAB patients were more likely to return to employment and did so at a mean of 6.6 weeks earlier than sternotomy patients ($P = .019$).

Conclusions: Endo-ACAB for grafting of the left internal mammary artery to the LAD is associated with reduced blood loss and faster postoperative recovery. Avoiding sternotomy appears to be a significant factor in recovery after beating heart single-vessel CABG surgery.

INTRODUCTION

Minimally invasive techniques have been developed and incorporated into most surgical specialties. In cardiac surgery, endoscopically-assisted left internal thoracic artery (LITA) harvest and anterior minithoracotomy is a less invasive approach to off-pump coronary artery bypass (CAB) on the anterior and lateral heart surfaces and has evolved into the endoscopic atraumatic CAB (endo-ACAB) procedure [Vassiliades 2001]. Thoracoscopic dissection of the LITA removes

the need for a large thoracotomy and painful rib retraction, which are required for open LITA harvest and identification of the left anterior descending coronary artery (LAD) in the minimally invasive direct CAB (MIDCAB) approach.

Surgery for isolated LAD stenosis remains popular for several reasons. First, recent randomized trials have demonstrated reduced reintervention rates following both multiple-vessel [Serruys 2001, SoS Investigators 2002] and isolated LITA-to-LAD grafting [Cisowski 2002, Diegeler 2002], compared with percutaneous stenting. In addition, some coronary lesions, particularly occluded or tortuous lesions, are difficult to treat percutaneously.

A debate remains among surgeons as to the optimal surgical approach for single-vessel LITA-to-LAD off-pump CAB (OPCAB). The long-term patency of sternotomy LITA-to-LAD grafting is excellent [Lytle 1985, Fitzgibbon 1986], and equivalent early angiographic patency rates of 98% have been reported with the MIDCAB approach [Diegeler 1999]. The sternotomy approach is known to all cardiac surgeons but is associated with uncommon yet serious complications, including dehiscence and mediastinitis [Demmy 1990, Bellchambers 1999]. Endoscopic assistance has been shown to be less painful in the early postoperative period than sternotomy or MIDCAB approaches [Bucerius 2002]. However, little direct comparison of patient recovery following these alternative approaches has been reported.

Since 1999, 1 surgeon at our hospital (A.D.S.) has used the endo-ACAB approach as the procedure of choice for patients referred for LITA-to-LAD grafting as part of a robotic CAB grafting development program within our hospital. We set out to determine the effect of surgical incision on postoperative recovery after beating heart surgery by performing a case-control analysis of the first 29 endo-ACAB procedures performed in our institution for single-vessel LAD disease. We used case controls drawn from our OPCAB LITA-to-LAD sternotomy patients during the same period.

METHODS

This study was a single-center case-controlled clinical trial.

Patient Groups

Endo-ACAB Patients. All endo-ACAB patients who underwent operations for single-vessel LAD disease in our hospi-

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tal were included. This group of operations covered the period from 1999 to 2003. No emergency or redo patients were offered endo-ACAB during this period. Endo-ACAB procedures were performed by a single surgeon (A.D.S.).

Selection of Sternotomy Case-Control Pairs. The hospital computer database was used to identify single-vessel CAB grafting procedures performed between January 1999 and January 2003, corresponding to the period in which the endo-ACAB operations had been performed. One hundred seventy-five patients were identified, of which 29 were the ITA-to-LAD endo-ACAB cases reported. Endo-ACAB procedures for non-LAD grafting or performed as part of a hybrid surgery-and-stent revascularization approach were excluded from the analysis. Patients intraoperatively converted to sternotomy from endo-ACAB were excluded from the control group. From the sternotomy population we excluded emergency and salvage procedures, redo operations, non-LAD grafting, and the use of cardiopulmonary bypass, all of which were excluded in the endo-ACAB population. These exclusions left 60 potential control cases.

Control pairs were initially linked on the basis of sex, ventricular function, and age, as recorded on the hospital's computerized patient analysis and tracking system (PATS) database. Once potential control pairs had been identified, their case notes were screened. Patients who underwent concomitant major surgery or for whom more than 1 bypass was planned but not carried out because of operative findings were excluded (to avoid including incompletely revascularized patients in the sternotomy group). All control patients included in the analysis underwent planned conventional nonemergency beating heart LITA-to-LAD grafting. No data collection was performed until case matching was complete.

Operative Details

The endo-ACAB procedure has been previously described [Vassiliades 2001]. In brief, it involves endoscopic dissection of the LITA via 3 ports in the left chest, followed by a muscle-splitting anterior microthoracotomy, through which a hand-sewn ITA-to-LAD anastomosis is performed. We used a soft-tissue retractor (endo-ACAB kit; Computer Motion, Santa Barbara, CA, USA) to provide exposure, but forceful rib retraction was avoided. We used single-lung ventilation with double-lumen endotracheal ventilation, carbon dioxide insufflation at 4 to 8 mm Hg, the Aesop 3000 endoscope controller (Computer Motion), and an endoscopic epicardial stabilizer (Computer Motion). The LITA was dissected with a Harmonic Scalpel (Ethicon Endo-Surgery, Cincinnati, OH, USA) without diathermy or clips. In 8 patients, the Zeus robotic system (Computer Motion) was used to perform the ITA harvest.

Postoperatively, patients were managed in the same intensive care or surgical recovery unit. Operational policy specified transfusion if the hemoglobin concentration fell below 8 g/dL. Patients were discharged home once they were independently mobile.

Data Collection

In-Hospital Variables. All in-hospital outcome variables were documented prospectively. Preoperative and predis-

charge hemoglobin levels and transfusion requirements were recorded as part of the routine data set in our institution.

Mediastinal blood loss in the first 12 hours, the time from induction of anesthesia to transfer from the operating theater, and the time from leaving the theater to endotracheal extubation were recorded with the CareVue computerized data-storage system (Philips Medical Systems, Surrey, UK). The total anesthetic and theater time was used to allow an overall comparison of theater use for the 2 procedures, including the double-lumen endotracheal intubation and equipment positioning, which are required in endo-ACAB procedures. Postoperative stay was documented by the PATS computerized hospital information system and cross-referenced with case note records.

Postdischarge Variables. In early 2003, all patients were followed up by telephone. Patients who could not be contacted were sent written questionnaires, and primary-care physicians were contacted for follow-up details. Patients who had returned to employment following surgery were asked how many weeks from the day of surgery they had remained off work. A decline in employment status was defined as a move from full-time to part-time work or from employment to unemployment, retirement, or permanent sick leave. Remaining in full-time employment in another job was not counted as a decline in function.

Statistical Methods

Continuous variables were analyzed by the Student unpaired *t* test. When the SDs of the 2 groups differed by more than a factor of 2, the unequal variance modification was employed. Categorical variables were analyzed by the chi-square test with the Yates correction.

RESULTS

Preoperative patient variables are summarized in Table 1, and postoperative outcome variables are summarized in Table 2.

In-Hospital Complications

One patient of the 29 in each group underwent reexploration for postoperative bleeding, with the endo-ACAB patient undergoing reexploration via thoracoscopy. In both cases, chest wall bleeding was thought to be responsible. One patient in the endo-ACAB group required drainage of a pleural effusion, 1 endo-ACAB and 2 sternotomy patients were treated with antibiotics for lower respiratory-tract infections, 1 endo-ACAB and 3 sternotomy patients developed postoperative atrial fibrillation, 1 sternotomy patient experienced an in-hospital pulmonary embolus, and 1 patient in each group was treated for pericarditis. One patient in the sternotomy group with chronic renal failure developed acute-on-chronic renal failure and was admitted to the hospital for renal artery stenting.

None of these complications showed a statistically significant difference between the groups when they were analyzed individually.

Postdischarge Follow-up

Eighty-three percent of sternotomy and 93% of endo-ACAB patients were successfully contacted, and all agreed to

Table 1. Preoperative Patient Characteristics*

	Endo-ACAB	Sternotomy OPCAB	P
Mean age, y	60.4 (9.03)	59.7 (8.48)	.75
Male sex, n/total	25/29 (86%)	25/29 (86%)	1.00
LV ejection fraction >45%, n/total	26/29 (90%)	27/29 (93%)	.46
Previous LAD PTCA or attempted PTCA, n/total	5/29 (17%)	7/29 (24%)	.38
Mean Parsonnet score	4.69 (6.22)	4.83 (6.30)	.93
Patients of working age (<65 y), n/total†	19/27 (70%)	17/24 (71%)	.69
Patients employed, n/total†	13/27 (48%)	15/24 (62%)	.17
Mean body mass index, kg/m ²	26.9	27.4	.69

*For continuous variables, figures in parentheses represent 1 SD from the mean. Endo-ACAB indicates endoscopic atraumatic coronary artery bypass; OPCAB, off-pump coronary artery bypass; LV, left ventricular; LAD, left anterior descending coronary artery; PTCA, percutaneous transluminal coronary angioplasty.

†Only those patients followed up are included.

provide further information. The minimum time to telephone follow-up was 4 months (mean, 30.2 months for sternotomy and 13.4 months for endo-ACAB surgery). At follow-up, none of the patients who were still out of work had plans to return to work. The results of the follow-up are summarized in Table 2. In addition, 1 endo-ACAB patient of the 14 previously not working took up work following surgery, compared with 0 of 9 nonworking sternotomy patients.

The mean time to follow-up was longer in the sternotomy group, reflecting a gradual transition to increased endo-ACAB surgery during the study period.

Patients Converted from Endo-ACAB to Sternotomy

During the study period, 7 patients (19.4% of the 36 procedures attempted) were converted from endo-ACAB to a sternotomy approach following induction of anesthesia. In all cases, surgery was performed without cardiopulmonary bypass. Reasons identified for conversion were an inability to insert a double-lumen endotracheal tube in 1 patient, an inability to perform endoscopic ITA harvest in 3 patients, difficulties with the endoscopic endocardial stabilizer in 1 patient, and pericardial adhesions in 1 patient. These patients were not included in the endo-ACAB or sternotomy group analysis.

DISCUSSION

This study suggests that avoiding sternotomy in single-vessel LITA-to-LAD OPCAB shortens postoperative recovery and reduces postoperative blood loss. Mediastinal drainage, fall in serum hemoglobin level, and blood transfusion requirements were all decreased by the endo-ACAB approach. Endo-ACAB patients were ventilated for a shorter period after surgery, spent less time in the hospital, and were more likely to return to work afterwards. The mean time taken off work was 46% less in the endo-ACAB patients who returned to employment.

Avoiding sternotomy by using the MIDCAB approach improves vital capacity and the forced expiratory volume in 1 second [Lichtenburg 2000], and improved respiratory mechanics may have contributed to some of the improved recovery we have seen with endo-ACAB. Our data for postoperative ventilation times closely mirror those of a previous series of sternotomy and MIDCAB cases [Diegeler 1998]. This series reported 9 hours and 6.5 hours ventilation, respectively, for the 2 groups, although with only 13 patients in the sternotomy group, this difference did not achieve statistical significance. An article on a series of 300 endo-ACAB

Table 2. Blood Loss, Transfusion, and Postoperative Recovery*

	Endo-ACAB	Sternotomy OPCAB	P
Mean mediastinal blood loss (first 12 h), mL	363.9 (231.5)	570.3 (379.1)	.017
Patients receiving blood products, n/total	2/29 (7%)	5/29 (17%)	.05
Mean change in hemoglobin concentration preoperative to postoperative, g/dL	-1.71 (1.07)	-2.72 (1.45)	.0026
Mean total theater time (entering anesthetic room to leaving theater), h	5.9 (1.4)	2.6 (0.6)	<.0001
Time ventilated after leaving theater, h	6.2 (5.1)	9.0 (6.0)	.034
Postoperative hospital stay, nights	5.3 (1.8)	6.4 (2.4)	.04
Employed patients returning to preoperative employment level, n/total†	13/13 (100%)	9/15 (60%)	.005
Mean time taken to return to work, wk‡	8.5 (3.9)‡	15.1 (7.2)‡	.019

*For continuous variables, figures in parentheses represent 1 SD from the mean. Endo-ACAB indicates endoscopic atraumatic coronary artery bypass; OPCAB, off-pump coronary artery bypass.

†Total includes only those patients successfully contacted postoperatively (83% of sternotomy cases and 93% of endo-ACAB cases) who were working prior to surgery.

‡Endo-ACAB, n = 13; sternotomy OPCAB, n = 9.

procedures reported that most of the last 50 cases were extubated immediately after surgery, raising the possibility of a more aggressive extubation policy for future endo-ACAB procedures [Vassiliades 2002]. Our extubation policy during the study period did not differentiate between endo-ACAB and sternotomy cases. Extubation was performed when patients were normothermic and self-ventilating and when arterial blood gas levels were acceptable.

Endo-ACAB procedures involve less soft-tissue cutting and avoid bony disruption altogether. These factors probably explain the decreased postoperative blood losses and transfusion requirements we observed. The increased fall in hemoglobin concentrations following sternotomy suggests that asymmetric clinical decisions about transfusion are not responsible for the decreased transfusion rate seen following endo-ACAB.

Perhaps most surprising was the larger number of patients who returned to work following endo-ACAB procedures. Given that age and employment status were equivalent for the 2 groups prior to surgery, a return-to-work rate of 100% against 60% is a considerable improvement. Similarly, of those patients who did return to work, endo-ACAB patients took 44% less time off work than the sternotomy patients. A previous case series of 38 employed endo-ACAB patients in the United States showed a mean time to return to work of 2 weeks [Vassiliades 2001]. No control sternotomy group was reported in this series, and the longer time to return to work seen in both arms of our study may represent differences in employment practices between our countries. It was our practice during the trial period to review all patients at 5 to 6 weeks postoperatively; it is possible that earlier outpatient review encouraged a faster return to work. The rate of return to work in the sternotomy arm of this study mirrors that of a previous multiple-vessel sternotomy CAB grafting trial in our institution (the Optimal Surgical Care for Arterial Revascularisation Trial [OSCAR]). In this study, 45% of patients were employed preoperatively, and 45% of these patients had returned to work by 12 weeks postoperatively (J. Booth, J. R. Pepper, personal communication).

Endo-ACAB surgery uses more theater time than open OPCAB. The mean total time for the last 10 endo-ACAB cases reported was 4.9 hours against 6.6 hours for the first 10 cases ($P = .007$), suggesting that theater times may decline as theater staff gain experience with the new technique. A previous large series of endoscopic LITA harvest has shown that theater times continue to decline even after 200 cases have been performed in an institution [Vassiliades 2002]. Therefore, the difference in theater times seen between the 2 approaches may decrease further in the future. Nevertheless, the requirement for double-lumen intubation and thoracoscope setup in endo-ACAB means it is unlikely to reach time parity with open surgery. Longer theater times must be balanced against shorter ventilation and hospitalization times in the postoperative period.

Case control has been used rather than comparison of our entire endo-ACAB and sternotomy population. During our early experience, which we report here, our endo-ACAB patients were selectively chosen with a preference

for the nonobese, nonurgent patient with preserved ventricular function, whereas many high-risk patients were included in the general sternotomy population. Case controlling for age, sex, and ventricular function was used to eliminate this intrinsic bias. Preoperative variables were closely matched between the groups selected, suggesting that they are comparable. Without case control, greater preoperative morbidity among the sternotomy patients would have made comparison invalid.

Data on postdischarge recovery were collected retrospectively, and therefore only return-to-work timing—which patients were able to give accurate dates for—has been used, rather than data on return to other activities.

Seven patients were converted to sternotomy from a planned endo-ACAB. This series represented our first experience with the endo-ACAB approach, and our conversion rate may fall with further experience. It is reassuring that attempted endo-ACAB followed by sternotomy was not associated with any obvious detriment to patients in this series.

CONCLUSION

The endo-ACAB approach is associated with a significantly shorter inpatient stay, decreased blood loss, and both increased and faster return to employment for those patients who were working preoperatively. Endo-ACAB is a practical alternative to sternotomy for off-pump LITA-to-LAD grafting for patients who can tolerate 1-lung ventilation. More information on long-term rates of major adverse cardiac events following endo-ACAB and sternotomy OPCAB is needed, ideally from a randomized trial of the 2 approaches. In our study population, sternotomy was an important factor in recovery after off-pump CAB surgery.

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REVIEW AND COMMENTARY

Editorial Board Member MB134 writes:

Patients with sternotomy are often told not to perform manual labor for 6 to 8 weeks after surgery in order to prevent sternal dehiscence. Was this recommendation given to the sternotomy patients in your institution? If so, does this account for the differences in return-to-work time between the 2 groups?

Author's Response by Dr. Douglas West:

This article covers our early experience of the endo-ACAB procedure. During this time, we reviewed all cases at 5 to 6 weeks following surgery (both endo-ACAB and sternotomy) and suggested that patients avoid driving or heavy lifting during this time. As such, our advice to both groups was the same. While this protocol was in place, we noted that many endo-ACAB patients returned to employment or exercise prior to their clinic review, and our policy (started after the cases reported here) has since been revised to review endo-ACABs at 2 to 3 weeks.

This experience is not randomized, and it is possible that those patients who were highly motivated to return to work preferentially opted for minimal-access surgery. This possibility is a potential source of bias; however, the similarity of preoperative patient demographics suggests that the groups were broadly comparable.