The Heart Surgery Forum #2001-6108
4 (4):331–334, 2001 Online address: www.hsforum.com/vol4/issue4/2001-6108.html

Atraumatic Coronary Artery Bypass (ACAB): Techniques and Outcome

(#2001-6108)

Thomas A. Vassiliades, Jr., MD

Pensacola Heart Institute, Pensacola, FL

Dr. Vassiliades

INTRODUCTION

Minimally invasive coronary artery bypass grafting continues to progress through multiple levels of development. We propose several modifications to single-vessel coronary artery bypass grafting (CABG) that we believe significantly decrease the physical trauma to the patient without appreciably increasing the technical difficulty of the operation.

PATIENTS AND METHODS

Patients

Between November 1996 and May 2001, we performed 300 minimally invasive coronary artery bypass (MICAB) procedures using endoscopic internal mammary artery harvesting. The 300 patients (191 male/109 female) ranged in age from 28 to 85 years, with a mean age of 69.8. Clinical presentation of New York Heart Association (NYHA) classification consisted of class I (47.3%), class II (40.8%), class III (7.4%), and class IV (4.5%). All patients presented for operation in one of five categories as outlined in Table 1 ( ). Of all patients, 74 (24.6%) had experienced a documented myocardial infarction within one week of surgery and 122 (40.7%) had a previous catheter-based intervention to the left anterior descending artery (LAD). Eleven patients (3.67%) had previously undergone CABG with all vein grafts.

Methods

The atraumatic coronary artery bypass (ACAB) technique consists of endoscopic internal mammary harvesting followed by an atraumatic chest incision through which a direct-vision anastomosis is performed using conventional instruments.

For left internal mammary artery (LIMA) harvesting, the patient's left side is rotated about 20 degrees off the table. Ports for the endoscope are usually placed at the fifth intercostal space in the anterior axillary line (5 mm scope), at the seventh intercostal space slightly more anterior for a grasper, and in the anterior axillary line that utilizes the third and fourth intercostal spaces for cautery and smoke evacuator. Single-lung ventilation and carbon dioxide insufflation is safe and absolutely necessary in providing the space needed to harvest the entire length of the LIMA. Carbon dioxide at levels of 8 to 10 mmHg, when introduced gradually, pushes the heart and mediastinal fat pad away from the chest wall, greatly facilitating dissection. The LIMA is then harvested from its subclavian artery origin to the sixth rib as a pedicled graft using the electrocautery device on a low setting. Details of the technique of endoscopic dissection have been provided previously [Vassiliades 2000]. Control of the thoracoscope is best accomplished using a voice-activated robotic arm (AESOP, Computer Motion, Inc., Goleta, CA). A human assistant cannot hold and maneuver the scope with the precision that is necessary to perform a time-efficient harvest. Additionally, the ability to save positions in three-dimensional space allows rapid movement up and down the length of the LIMA. The lateral endoscopic view allows a harvest that is more accurate and complete than even the direct-vision sternotomy approach. With practice, harvest times can be reduced to 20-30 minutes.

After completion of the harvesting phase, the pericardium is opened and the target vessel or vessels identified clearly. The purpose of this step is to prevent misidentification of the target arteries that can occur as a result of small incisions. With the endoscope, the surgeon can view the entire anterolateral wall of the heart and confirm course patterns of the coronaries to corroborate with the catheterization films. It is extremely helpful to have the catheterization films on hand to view during this phase of the operation. Additionally, viewing with the endoscope allows the surgeon to discover the presence of intramyocardial portions of the coronaries before any incision is made. Trans-illumination of the chest wall with the scope can identify the rib locations on the surface so that the incision may be placed in the middle of the interspace. A long spinal needle is then passed through the chest wall and the endoscopic view identifies the ideal incision location. The incision is centered directly over the target vessel at the precise location of the anticipated anastomosis.

A 4 to 5 cm incision is usually sufficient. In our experience, the fourth intercostal space just medial to the nipple is the most

Presented at the Minimally Invasive Cardiac Surgery (MICS) Symposium, Key West, Florida, May 27, 2001.

Address correspondence and reprint requests to: Thomas A. Vassiliades, MD, Cardiothoracic Surgical Associates of Northwest Florida, 5151 North Ninth Avenue, Suite 200, Pensacola, FL 32504, Phone: (850) 857-1734, Fax: (850) 857-1747, Email: vassiliades@pol.net

Table 1. Clinical Presentation

Clinical Presentation	#	%
Proximal LAD +/- Diag Stenosis with LVEF> 50%	249	83
Proximal LAD +/- Diag Stenosis with LVEF< 50%	29	9.67
Multi-vessel Disease with LVEF> 50%	5	1.67
Multi-vessel Disease with LVEF< 50%	9	3
Proximal RCA Stenosis with LVEF> 50%	8	2.67
Total	300	

LVEF: Left Ventricular Ejection Fraction

Table 2. Operations

Operation	# (%)
LIMA to LAD	259 (86.33)
RIMA to RCA	8 (2.66)
Sequential LIMA to LAD and Diagonal	9 (3.00)
"LIMA to LAD, vein ""T"" graft to Diagonal"	14 (4.66)
"LIMA to LAD, radial artery ""T"" graft to Diagonal"	6 (2.00)
LIMA to LAD and RIMA to RCA via lower hemi-sternotomy	4 (1.33)
Total	300

common place for grafting the LAD. The next step is to perform an atraumatic chest wall incision. This consists of dividing the intercostal muscle but not necessarily the pectoralis major. The latter muscle can be separated in the direction of the fibers as in any "muscle-sparing" incision. A standard metal or plastic rib-spreading retractor is not placed. Rather, a cloth soft-tissue retractor (Computer Motion, Inc., Goleta, CA), which provides adequate space in all but the smallest of patients, is used. If the target spot on the vessel has been centered within the incision, then it is not necessary to spread the ribs. The incision needs only to be large enough to accept the surgeon's forceps and needle driver. The array of accompanying equipment is brought in through the three ports previously used for the graft harvest. The highest port (cautery port) is used to introduce a long 3 mm clamp (Computer Motion, Inc., Goleta, CA) to open and close the LIMA flow. The 6 mm stabilizer arm (Computer Motion, Inc., Goleta, CA) is brought in through the scope port incision and is attached to the bed rail using a universal clamping device (Computer Motion, Inc., Goleta, CA). The stabilizer arm has a side tube running parallel to it that will accept a carbon dioxide mister. The low profile stabilizer plate (Computer Motion, Inc., Goleta, CA) is introduced through the skin incision and attached to the end of the arm. The coronary artery is occluded by means of soft silastic tapes (Quest Medical, Allen, TX) that are attached to the stabilizer foot (Computer Motion, Inc., Goleta, CA). No equipment is passed through the incision, which would obstruct the surgeon's view.

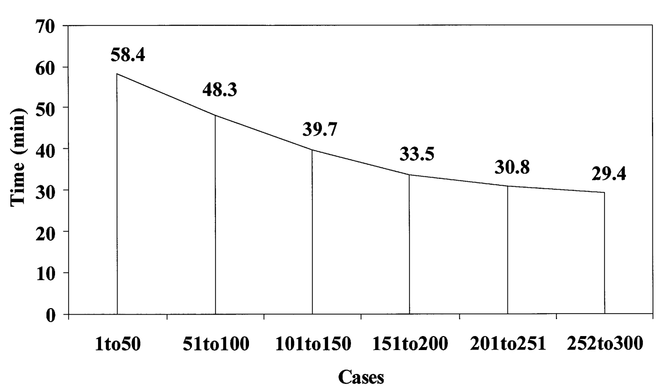

Figure 1. Endoscopic IMA Harvest Times

The anastomosis is facilitated by means of an IMA holder (Computer Motion, Inc., Goleta, CA) that attaches to the stabilizer plate and places the LIMA in very close proximity to the LAD arterotomy. The anastomosis is constructed by hand using conventional instruments according to the surgeon's routine. The ability to clamp and unclamp the LIMA allows bleeding and flow to be checked easily throughout the procedure.

After removal of all instrumentation, a 20fr chest tube is inserted in the most inferior port site and two-lung ventilation is re-established. Intercostal nerve blocks are administered and the patient is extubated in the operating room.

Postoperative care consists of observation for four hours in an intensive care setting followed by routine ward care with telemetry. Discharge is planned for 48 hours.

RESULTS

Thirty-Day Outcome

The mean time required for LIMA harvest (from origin to sixth rib) for the last 50 cases was 29.4 minutes (range 17 to 61 min.) and the mean operating time for the entire procedure was 96.4 minutes (range 54 to 154 min.). See Figure 1 (◎).

With respect to the entire group of 300 patients, there were two iatrogenic injuries to the distal LIMA, neither one requiring conversion to sternotomy. The grafts and incisions performed are listed in Table 2 (◎). Eleven procedures were redo-CABG operations.

The mean coronary occlusion time was 10.3 minutes (range 6 to 21 min.). Forty-two of the last 50 patients (92%) were extubated in the operating room. Table 3 (◎) lists the in-hospital clinical outcomes in six chronological groups of 50 patients. Of the total group of 300 patients, only one patient required re-operation for graft failure.

Of the last 50 patients, 38 (mean age 54.8 years) were employed prior to operation. For this group, the mean time for return to work was 14.6 days (range 9-32 days).

DISCUSSION

One of the primary goals of a minimally invasive operation should be the achievement of the same long-term results as its corresponding "conventional" procedure but with less trauma to the patient. In the case of minimally invasive CABG, this translates into uncompromised long-term graft patency rates regardless of the approach. Therefore, the future of performing operations with minimal

Table 3. In-Hospital Clinical Outcome

	Outcomes: Six Chronological Groups of 50 Patients						
Data Point	1-50	51-100	101-150	151-200	201-250	251-300	Total
Mean LOS in ICU (hrs)	21.4	18.4	11.5	8.9	5.6	5.4	11.9
Mean LOS in Hospital (days)	2.8	2.7	2.2	2.3	2.2	2.3	2.4
Blood Transfusion Rate (%)	11.2	10.7	10.6	10.1	9.9	9.6	10.5
Atrial Fibrillation (%)	22.3	22	21.2	24.5	19.3	20.1	21.6
30 day Mortality (%)	0	0	0	0	1	0	0.33
Postop Myocardial Infarction (%)	0	0	0	1	1	0	0.66
Neurological Events (%)	0	0	1	0	0	1	0.66
Wound Complications (%)	0	1	1	1	0	1	1.33
Pulmonary Complications (%)	7	6	9	9	7	5	14.3
Six month graft patency (%)*	NA	98.3*	NA	NA	NA	NA	NA

LOS = length of stay; ICU = intensive care unit; *[Vassiliades 2000]

physical trauma depends upon our ability to get the job done without relying on the inherently traumatic sternotomy or thoracotomy.

The transition from open, conventional CABG to minimally invasive procedures must take an incremental approach. One cannot expect to leap directly from exclusively performing on-pump CABG with sternotomy to routinely performing totally endoscopic, beating-heart operations. The original MIDCAB procedure [Calafiore 1996], while conceptually sound, underestimated the trauma that would be inflicted to the patient's chest wall during a direct-vision IMA harvest through an anterior thoracotomy. Additionally, many surgeons in the United States learned off-pump techniques in conjunction with a minithoracotomy, thereby learning two challenging techniques simultaneously. As a result, for many surgeons and cardiologists, the MIDCAB procedure failed to demonstrate significant advantages over the conventional method [Ancalmo 1997, Bonchek 1998]. Nevertheless, for many surgeons, off-pump CABG with the latest techniques and devices is not only possible but preferable to conventional CABG.

The second problem to confront in the minimally invasive procedure is the incision itself. Several assertions can be made based on our experience thus far: (1) disruption of the bony chest wall and its accompanying nerves by either an incision or a port results in significant postoperative discomfort, (2) disruption of the bony chest wall or intercostal nerves is more likely to result in long-term negative sequelae than a sternotomy, (3) spreading and elevating the ribs is a maneuver to avoid if a thoracotomy is to be atraumatic, (4) the size of the skin incision has little to do with postoperative pain and is often not a patient concern. Given these facts, one may ask whether the term "atraumatic thoracotomy" is an oxymoron.

The cardiac surgeon who embarks on the ambitious task of making CABG an atraumatic operation must undertake an individualized education process. This process might include the following steps: (1) mastery of off-pump techniques in the setting of a full sternotomy, (2) mastery of the general principles and techniques of thoracoscopy in pulmonary operations, (3) learning endoscopic internal mammary harvesting, (4) performing single-vessel CABG procedures with endoscopic IMA harvesting and a minithoracotomy with a direct-vision anastomosis, (5) performing a minithoracotomy with little or no rib spreading combined with a direct-vision anastomosis, and transitioning the operation from using the thoracotomy to using the existing ports, (6) performing the anastomosis endoscopically with a small, working thoracotomy to provide assistance as well as the capability of alternating between direct-vision and endoscopic suturing, and (7) performing a totally endoscopic, ports-only, single-vessel CABG.

A new minimally invasive procedure should possess enough inherent reproducibility to allow the majority of surgeons to master it. The atraumatic coronary artery bypass technique (steps 5 and 6 above) consists of an endoscopic IMA harvesting followed by an atraumatic chest incision through which a direct-vision anastomosis is performed using conventional instruments. The key elements for making this procedure atraumatic are (1) avoiding the use of cardiopulmonary bypass and (2) creating a window through an interspace that avoids disruption of the bony chest wall. Avoidance of rib spreading should result in the same limited

Table 4. Comparison of the off-pump minimally invasive procedures for LAD grafting

Features	MIDCAB	ACAB	TECAB
IMA Harvest	direct vision	endoscopic	endoscopic
Incision size	7-8cm and no ports	4-5cm and 3 ports	4-6 ports only
Rib spreading	significant	minimal to none	none
Chest wall elevation	significant	none	minimal to none
Muscle sparing	no	yes	yes
anastomosis	direct vision	direct vision	endoscopic
Technical complexity	lowest	middle	highest
Operating room costs	lowest	middle	highest

MIDCAB: Minimally Invasive Direct Coronary Artery Bypass
ACAB: Atraumatic Coronary Artery Bypass
TECAB: Totally Endoscopic Coronary Artery Bypass (off-pump)

trauma as a "ports-only" approach. When all of the instruments are placed through ports (stabilizer arm with footplate and IMA holder, carbon dioxide mister, IMA bulldog), the incision is left uncluttered and the natural interspace width is adequate to allow a direct-vision anastomosis using conventional instruments.

The ACAB technique is valuable not only as a step toward the totally endoscopic approach but contains inherent advantages of its own. By combining endoscopy for the less technically demanding tasks (e.g., IMA harvest, pericardiotomy, vessel identification, incision planning) and conventional direct methods for the more demanding segments (e.g., vessel dissection, preparation, and anastomosis), ACAB offers a shorter learning curve (see Table 4,). Perhaps more importantly, because the technique limits stress on the thoracic skeleton, it is comparatively atraumatic. The atraumatic coronary artery bypass technique should be considered a realistic procedural goal for the innovative cardiac surgeon.

REFERENCES

1. Ancalmo N, Busby JR. Minimally invasive coronary bypass: really minimal? Ann Thorac Surg 64:928-9, 1997.
2. Bonchek LI, Ullyot DJ. Minimally invasive coronary bypass: a dissenting opinion. Circulation 98:495-7, 1998.
3. Calafiore, AM, Di Giammarco G, Teodori G, et al. Left anterior descending coronary artery grafting via left anterior small thoracotomy without cardiopulmonary bypass. Ann Thorac Surg 61:1658-65, 1996.
4. Vassiliades, TA, Rogers, EW, Nielsen, JL, et al. Minimally invasive direct coronary artery bypass grafting: intermediate-term results. Ann Thorac Surg 70:1063-5, 2000.