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Repeat Surgery for Coronary Artery Bypass Grafting: The Role of the Left Thoracotomy Approach

David G. Harris, MMed, FCS, Andre R. Coetzee, MMed, FCA, PhD, Johan T. Augustyn, MMed, Andre Saaiman, MD, MMed

Departments of Cardiac Surgery and Cardiology, Kuils River Private Hospital, Cape Town, South Africa

ABSTRACT

Objective: Repeat coronary artery bypass surgery has increased risks compared with the first operation, including low cardiac output and injury to patent grafts. The left thoracotomy approach has been advocated specifically in patients with intact grafts of the left internal mammary artery (LIMA) to the left anterior descending coronary artery (LAD) needing lateral wall grafting. We have evaluated this technique in conjunction with an off-pump procedure in all patients.

Methods: There were 55 patients over an 8-year period, and 6 (10.9%) were female. The mean age was 63.2 years (range, 41-82 years), and the age at the time of the previous operation was 51.7 years (range, 31-69 years). Four patients (7.2%) underwent a third operation. Comorbidities were diabetes mellitus (25 patients, 45.5%), renal impairment (8 patients, 14.5%), calcified ascending aorta (9 patients, 16.4%), carotid disease (4 patients, 7.2%), and peripheral vascular disease (11 patients, 20.0%). Fifteen patients (27.2%) had previous coronary stents. Nine patients (16.4%) had a preoperative intra-aortic balloon pump. Predicted mortality (logistic EuroSCORE) was 14.2%.

Results: Forty-three patients (78.1%) had intact LIMA-to-LAD grafts. Twenty-two patients (40.0%) required a major posterolateral thoracotomy, and 33 patients (60.0%) had a minor thoracotomy. Thirteen patients (23.6%) had stents placed as a hybrid procedure during the same admission. Thirteen patients (23.6%) additionally underwent anterior wall grafting (LAD to the first marginal area). The LIMA was used in 7 patients where it had not been used before. There were 91 distal grafts (including 4 sequentials). We performed 54 venous grafts and 26 radial artery grafts. Twenty-one patients (38.1%) had 1 distal graft, 32 patients (58.1%) had 2 grafts, and 2 patients (3.6%) had 3 distal grafts performed (mean, 1.6 grafts/patient). The proximal graft site was the proximal descending aorta in 20.0% of the patients, the distal aorta in 67.5%, and the subclavian artery in 12.5%. In 10 patients (18.2%), the distal branches of the right coronary (posterior descendens or right posterolateral) were grafted. No patient required conversion to cardiopulmonary bypass or sternotomy. No patient needed an intra-aortic balloon pump postoperatively. The mean blood loss (24 hours) was 380 mL (range, 125-1100 mL), the mean ventilation time was 4.8 hours (range, 0-12 hours), the mean intensive care unit stay was 2.7 days (range, 2-8 days), and the mean hospital stay was 6.3 days (range, 5-20 days). There was 1 postoperative death (1.8% mortality). One late death occurred on follow-up. Four patients underwent cardiac catheterization for chest pain, and the grafts were shown to be open.

Conclusion: The procedure is safe, especially in patients with intact LIMA-to-LAD grafts needing lateral and inferior wall revascularization. Multislice computed tomography scanning allows better preoperative planning, especially regarding the site of implantation of the proximal graft, allowing a less invasive incision. The off-pump technique preserves cardiac and pulmonary function. The in-hospital death rate (1.8%) compares very well with the EuroSCORE-predicted mortality (14.2%).

OBJECTIVE

Repeat coronary bypass procedures have increased risks, and the technical difficulties that may be encountered include adherence of an intact left internal mammary graft (LIMA) to the sternum, decreased space on the ascending aorta for implantation of the proximal graft, cardiac-protection problems, and more difficult exposure of the lateral wall. This increased risk is especially relevant for patients needing only lateral-wall grafting. A direct approach to the lateral wall with on-pump [Ungerleider 1985; Burlingame 1988; Gandjbakhch 1989; Grosner 1990; Randolph Bolton 1997] and off-pump [Fanning 1993; Baumgartner 1999; D'Ancona 2000; Azoury 2001; Kuniyoshi 2003; De Oliveira 2004] techniques has already been described. We describe our techniques and results with this procedure, which we used with an off-pump technique in all patients.

PATIENTS AND METHODS

Over an 8-year period (2000-2008), 55 patients underwent operation by a single surgeon (D.G.H.). Table 1 summarizes the preoperative data. The mean age was 63.2 years (range, 41-82 years), and the mean age at the time of the previous operation was 51.7 years (range, 31-69 years). There were 6 female patients (10.9%). Forty-three patients (78.2%) had

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Correspondence: D.G. Harris, MMed, Kuils River Private Hospital, Cape Town, South Africa (e-mail: drdharris@yahoo.co.uk).

Table 1. Patient Profile*

Patients, n	55
Male	49 (89.1%)
Female	6 (10.9%)
Mean age (range), y	63.2 (41-82)
Congestive heart failure, n	7 (12.7%)
COPD (severe), n	16 (29.0%)
Diabetes, n	25 (45.5%)
Hypertension, n	36 (65.4%)
Ejection fraction, n	
30%-50%	21 (38.2%)
<30%	4 (7.3%)
Preoperative IABP, n	9 (16.4%)
Preoperative inotrope use, n	5 (9.0%)
Previous stents, n	15 (27.3%)
Severe PVD, n	11 (20.0%)
Carotid disease, n	4 (7.3%)
Previous Q-wave infarct, n	17 (30.9%)
Calcified aorta, n	9 (16.4%)
Renal impairment, n	8 (14.5%)
Unstable angina, n	25 (45.5%)
Cholesterol >5.0 mmol/L, n	30 (54.5%)
Recent infarct, n	3 (4.5%)
Parsonnet score	23 (10-29.5)
EuroSCORE	7 (3-19)
Mean age at previous operation (range), y	51.7 (31-69)
Mean time since previous operation (range), y	12.1 (1-31)
First redo operation, n	51 (92.7%)
Second redo operation, n	4 (7.3%)

*COPD indicates chronic obstructive pulmonary disease; IABP, intra-aortic balloon pump; PVD, pulmonary vascular disease.

patent LIMA grafts to the left anterior descending coronary artery (LAD). Comorbidities included diabetes mellitus (25 patients, 45.5%), renal impairment (8 patients, 14.5%), calcified ascending aorta (9 patients, 16.4%), peripheral vascular disease (11 patients, 20.0%), and carotid disease (4 patients, 7.2%). Four patients underwent their third operation. Fifteen patients (27.3%) had stents placed during previous admissions. Nine patients (16.4%) had a preoperative balloon pump inserted. The predicted mortality (logistic EuroSCORE) was 14.2%.

The patients initially selected for the procedure were those needing isolated circumflex vessels grafted. Later, as our experience with the procedure grew, we selected all patients requiring left-sided grafts for the procedure, and we included patients requiring grafts to the distal branches of the right coronary artery (posterior descendens and right posterolateral). Fourteen patients (25.5%) had target vessels in the anterior zone, 34 (61.8%) had target vessels in the mid or posterior zones, and 7 patients (12.7%) needed vessels grafted in both zones. When a hybrid procedure was performed, stents were placed a few days before the surgery in most cases. Patients have recently been loaded with 300 mg clopidogrel at the time of stent placement, and patients are continued on the usual dosage of 75 mg/day.

All patients were anesthetized with a double-lumen endotracheal tube for single-lung ventilation and were placed in the right lateral position. Routine hemodynamic monitoring included a left radial line and a central venous line; occasionally, a pulmonary artery catheter was placed when the anesthesiologist felt one to be indicated. Transesophageal echocardiography was not used. In this position, the right radial artery could be harvested simultaneously along with the vein from the right leg. When the right saphenous vein had previously been harvested, we first placed the patient in a supine position for harvesting from the left leg and then turned the patient. A lateral thoracotomy was made in the fifth space when grafts were required in the mid zone (second marginal area) and was made in the sixth space for grafts to the mid and posterior zones (second and third marginals, and posterior descending coronary artery [PDA]) if computed tomography (CT) scanning confirmed that the aorta was not too thick in this area. An anterior thoracotomy was made in the fourth space for grafts to the anterior zone (LAD, diagonals, intermedius) and when the subclavian artery was anticipated to be used for inflow. We mobilized the lower lobe of the lung and incised the inferior pulmonary ligament. We opened the pericardium anterior to the phrenic nerve for anterior-zone grafting, posterior to the nerve for mid- and posterior-zone grafting, and often both anteriorly and posteriorly for better exposure.

The off-pump method was used in all patients. Traction sutures in the pericardium and diaphragm aided exposure. Heparin (2 mg/kg) was administered and topped up to maintain an activated clotting time of >300 seconds. We immobilized vessels with the Octopus suction stabilizer (Medtronic, Minneapolis, MN, USA); more recently, we have used the Guidant Acrobat system (Boston Scientific, Santa Clara, CA, USA) as well. We usually snared the vessels gently with a 4/0 polypropylene suture while opening them and usually used intracoronary shunts (Medtronic ClearView). The proximal grafts were usually performed first, usually on the descending aorta at the level of the inferior pulmonary vein or much higher up if the aorta was diseased in this area. The intrathoracic left subclavian artery was used if the aorta was too calcified and in cases in which the anterior zone required grafting. Proximal anastomoses were made with the aid of a side clamp on the aorta. The subclavian artery was clamped with a side clamp or sometimes with 2 straight clamps, with the distal clamp placed via a small separate stab incision in the axilla to allow more space. The distal branches of the right coronary artery (PDA and posterior descendens) were exposed after making a wide pericardiotomy anterior to the phrenic nerve that extended medially over the apex and diaphragmatic surface of the right ventricle. The right ventricle, apex, and inferior wall (down to the inferior vena cava) were then dis-

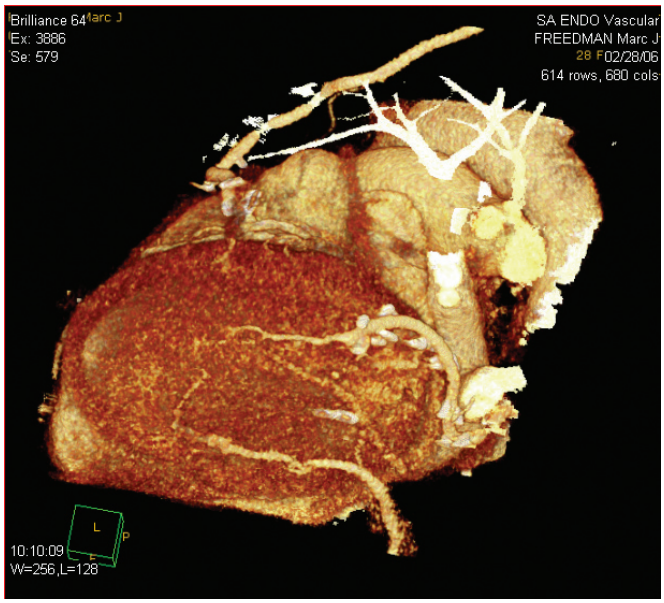

Figure 1. Computed tomography angiogram showing intact graft of the left internal mammary artery to the left anterior descending coronary artery. Also shown are grafts from the descending aorta: the radial artery to second marginal and the saphenous vein to the right posterolateral branch.

sected free, stay sutures were placed in the diaphragm, and the inferior vessels were then exposed by verticalizing the heart.

The heparin was partially reversed before the chest was closed. Patients were occasionally extubated in the operating room, but most patients were ventilated for a few hours.

Postoperative pain relief was managed by immediate infiltration of the intercostal spaces and paravertebral area with 10 mL of 7.5% ropivacaine. An epidural catheter was placed into the opened intercostal space beneath the pleura and advanced as far medially as possible. The intercostal space was then closed with sutures at the insertion site to prevent leakage of the local anesthesia. The thoracotomy was closed with #5 Ethibond sutures (Ethicon/Johnson & Johnson, Somerville, NJ, USA) placed through the upper rib space and through the drill holes placed in the lower rib spaces to prevent postoperative pain from strangulated intercostal nerves. Postoperative boluses of 10 mL ropivacaine were given every 2 to 4 hours.

All of the data collected for this study were obtained from detailed review of hospital records; over the past 3 years, the data have been recorded prospectively.

Table 2. Distal Coronary Vessels Grafted

Distal Vessel	No. of Grafts
Obtuse marginal (third)	13
Posterior descending artery	10
Obtuse marginal (second)	41
Obtuse marginal (first)/ramus	14
Left anterior descending artery	10
Obtuse marginal (third) in groove	2
Diagonal artery	1
Total	91

Table 3. Postoperative Data*

Blood loss in 24 hours, mL	380 (125-1100)
Ventilation time, h	4.8 (0-12)
ICU stay, d	2.7 (2-8)
Hospital stay, d	6.5 (5-20)
Early deaths, n	1 (1.8%)
Late deaths, n	1 (1.8%)
Repeat angiography, n	4 (7.3%)

*Data are presented as the mean (range) where indicated. ICU indicates intensive care unit.

RESULTS

Thirteen patients (23.6%) had stents placed as a hybrid procedure. The vessels stented were the right coronary in 6 patients, the LAD in 3 patients, the large septal perforator in 2 patients, the circumflex in 1 patient, and the mainstem in 1 patient. Grafting was required in the anterior zone in 14 patients (25.5%), in the mid to posterior zone in 34 patients (618 %), and in both zones in 7 patients (12.7%). A major thoracotomy was performed in 22 patients (40 %), and a minor thoracotomy was performed in 33 patients (60%). Seven patients had a fourth-space thoracotomy, 42 patients had a thoracotomy in the fifth space, and six patients had a thoracotomy in the sixth space. Ninety-one distal grafts were performed, including 4 sequentials (mean, 1.6 grafts/patient; Table 2). There were 54 venous grafts and 26 radial artery grafts. The LIMA was used in 7 patients where it had not been used before. Twenty-one patients had 1 distal graft (38.2%), 32 patients had 2 distal grafts (58.2 %), and 2 patients had 3 distals (3.6%). The site of the proximal graft was the proximal descending aorta (at the ligamentum) in 16 patients (20%), the distal descending aorta in 54 patients (67.5%), and the subclavian artery in 10 patients (12.5%). Grafts to the anterior zone were routed anterior to the hilum, those to the mid and posterior zones were routed behind the hilum, and the grafts were routed through the hilum (between the bronchus and the inferior pulmonary vein) in 5 patients to prevent kinking. Seven patients underwent LAD grafting only as a minimally invasive direct coronary artery bypass (MIDCAB) procedure. In 3 patients, the descending aorta was too calcified to use, and the subclavian was used instead. In 1 patient in whom the PDA was a target, we were unable to adequately expose the vessel, so it was not grafted.

Table 3 summarizes the postoperative data. No patient required conversion to cardiopulmonary bypass or sternotomy, and postoperative placement of an intra-aortic balloon pump was not necessary for any patient. No patient required reexploration for bleeding. There was one in-hospital

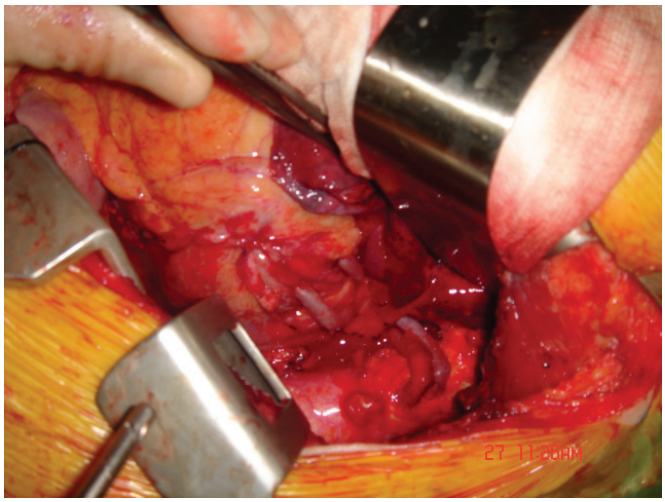

Figure 2. Two vein grafts from the descending aorta are routed through the hilus above the inferior pulmonary vein to prevent kinking. Note vein patch repair of the aorta lower down where the aorta was opened but found to be too thick to use.

mortality from a suspected graft occlusion. One elderly patient had a prolonged hospital stay (20 days) due to a hematoma and infection at the site of vein harvest. Five patients (9.1%) developed postoperative atrial fibrillation. Four patients underwent repeat angiography evaluation after 6 months, and all grafts were shown to be patent. One patient underwent a CT angiographic evaluation of the coronaries, which confirmed 2 patent grafts to the lateral wall (Figure 1).

DISCUSSION

A redo procedure to the lateral wall may be a risky procedure, especially when the LIMA-to-LAD graft is intact. If the patent LIMA graft is injured, the mortality may be as high as 50% [Dobell 1984]. A direct approach to the lateral wall is much simpler and has been considered the method of choice for these patients when the circumflex is the only target [Ungerleider 1985; Baumgartner 1999; Azoury 2001].

When an isolated circumflex graft is required, the technique is highly advantageous in the following situations:

- Patent LIMA grafts
- Prior mitral valve replacement to prevent lifting of the heart
- Prior mediastinitis/sternal wound infection
- Calcified ascending aorta
- Prior mediastinal irradiation or radical mastectomy [Burlingame 1988].

The procedure is not new, having been mentioned as early as 1982 [Faro 1982]. Credit should be given to Dr. Benetti for his pioneering work on the MIDCAB procedure [Benetti 1981], because some of the earlier off-pump redo procedures were performed as a MIDCAB by those experienced with this technique [Calafiore 1996; Boonstra 1997].

Initial experience was gained in the 1980s in the context of cardiopulmonary bypass with fibrillatory arrest [Ungerleider 1985; Burlingame 1988; Gandjbakhch 1989; Grosner 1990; Randolph Bolton 1997]. The main issue was to avoid sternotomy. Femoro-femoral bypass was usually used [Burlingame 1988; Gandjbakhch 1989; Grosner 1990; Randolph Bolton 1997]. Cannulation of the descending aorta and pulmonary artery has also been described [Ungerleider 1985]. Some groups have used on-pump and off-pump techniques [Allen 1997; Byrne 2001]. Byrne et al [2001] described results for operations on 50 patients, 13 of which were performed off pump. The Heartport endoaortic balloon occluder (Heartport/Johnson & Johnson, Redwood City, CA, USA) was used in 4 patients of the on-pump group; fibrillatory arrest was used in the rest. No deaths occurred in the off-pump group, and there were 3 deaths in the on-pump group [Byrne 2001]. The off-pump procedure appears to be safe, with no mortality in the limited smaller series that have been published [Baumgartner 1999; Azoury 2001; Kuniyoshi 2003; De Oliveira 2004]. The largest study published so far mentioned 67 patients, with a mean of 1.3 grafts and a mortality of 4.5% [Azoury 2001]. It should be borne in mind that these patients are in a higher risk category, and in our group, the predicted mortality with the EuroSCORE was 14.2%.

In our series, we did not concentrate solely on the circumflex. We also grafted other vessels, including the distal branches of the right coronary artery. One option that has been mentioned when the PDA also needs grafting is sequential subxiphoid and thoracotomy incisions [Shennib 2005]. The PDA is grafted first via the subxiphoid approach, and the graft is left in the pericardium. After proceeding with the thoracotomy, the graft is located and grafted to the aorta along with another graft, which is to be used on the circumflex. We did not find this option necessary, however, and after extensive mobilization of the adhesions, we could locate the vessel via the thoracotomy. An incision in the sixth space worked best for this purpose, but we also used the fifth space.

A smaller thoracotomy incision could be used when the vessels were located within one region, eg, the PDA and a third marginal, both of which are located in the posterior zone. Both are easily exposed via the sixth space. An additional target vessel in the anterior zone would require a larger incision in the fifth space. Likewise, the site of the proximal grafts also dictates the incision. If one is unsure of the quality of the lower descending aorta, an incision in fifth space is wiser, because all areas for proximal graft sites (subclavian artery, proximal descending aorta, distal ascending aorta) are accessible. For grafting in the anterior zone only, a small anterior incision in the fourth space would suffice, because both the subclavian artery and the proximal aorta are accessible. We are considering using this approach for all our patients because it simplifies and standardizes the routing of the grafts (always anterior to the hilus). The posteroinferior zone is easily exposed via a small incision in the sixth space, but this approach is a potential problem if the aorta is too thick or calcified here. One option would be to use the infraclavicular subclavian/axillary artery as the inflow site, and this approach has been used successfully [Bonatti 2000]. Another report mentioned the use of the splenic artery [Baumgartner 1999]. We have found that a preoperative CT angiogram of

the aorta is useful to confirm the state of the distal descending aorta, which is the most often used and the most convenient site for the proximal anastomosis for this zone.

In some cases, the vessels on the heart may be lying more anteriorly, with the danger that the grafts will kink around the hilus of the lung. This problem can be solved by using the subclavian artery or, alternatively, the proximal part of the descending aorta, and routing the grafts anterior to the hilus. After accumulated experience, the latter has become our preferred site of proximal graft anastomosis. If the lower part of the aorta is the only part that can be used (because of technical factors such as calcium), then the grafts can be routed through the hilus of the lung, between the inferior pulmonary vein and main bronchus (Figure 2). In 4 patients, the subclavian artery was used for inflow in the presence of an intact LIMA-to-LAD graft. We did not perform preconditioning but maintained a good blood pressure, and we had no electrocardiographic changes and no hemodynamic instability. When an intra-aortic balloon pump was present, it was simply switched off, and the descending aorta was side-clamped; there were no incidents of balloon perforation or signs that it had been included in the clamped area.

Although this procedure is feasible in most patients, exposure of the LAD and distal branches of the right coronary artery may be difficult. Patients requiring more than 2 grafts in all 3 zones may have less benefit, a prolonged operation, and a larger thoracotomy incision. The ideal patient remains one who requires 1 or 2 grafts to the circumflex system, because this procedure is simplified and relatively easy. The goal should always be complete revascularization; in many of our cases, this goal can be achieved by a hybrid procedure.

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