Left Mini-Thoracotomy for Beating Heart Bypass Grafting
A Safe Alternative to High-Risk Intervention for Selected Grafting of the Circumflex Artery Distribution

Todd M. Dewey, MD; Mitchell Magee, MD; James Edgerton, MD; Rhonda Vela; Syma L. Prince, RN; Tea Acuff, MD; Michael J. Mack, MD

Background—Progression of disease and bypass graft attrition results in a population of patients who require repeated coronary interventions. Frequently, these patients have patent internal mammary artery grafts and require isolated intervention to the circumflex distribution. As an alternative to high-risk repeated sternotomy and conventional bypass surgery or catheter-based intervention, the circumflex marginal vessels may be approached by thoracotomy. We reviewed our experience in revascularizing the circumflex distribution with off-pump techniques via left mini-thoracotomy.

Methods and Results—Thirty-two patients underwent off-pump bypass grafting of the circumflex vessels via thoracotomy from December 1995 to April 2000. Twenty-seven patients presented with circumflex disease after having previous bypass grafting. Five patients, who presented with circumflex disease and either nondiseased or ungraftable disease in their other arteries, were revascularized as a primary procedure. There was no observed mortality. Seven patients (22%) required inotropes on leaving the operating room, and 3 patients (9.4%) received transfusion of packed red blood cells. There was 1 reoperation for bleeding and 1 patient with a postoperative neurological deficit. There were no perioperative myocardial infarctions. The average length of stay was 4.8 days from time of surgery to discharge.

Conclusions—Off-pump grafting via thoracotomy provides a safe and effective alternative approach for patients requiring limited revascularization. Potential cardiac injury and danger to viable grafts from repeated sternotomy is minimized, and manipulation of the diseased ascending aorta is avoided. Morbidity, hospital length of stay, and cost are less than for conventional repeated coronary bypass surgery. (Circulation. 2001;104[suppl I]:I-99-I-101.)

Key Words: cardiovascular disease ■ revascularization ■ surgery

Median sternotomy remains the standard approach for most operations performed on the heart. Access to the heart via thoracotomy has been used for valvular procedures, repair of atrial septal defects, aortic arch and descending aortic aneurysm repair, aortic valve replacement, and minimally invasive and reoperative CABG.1–7 Coronary reoperations continue to increase as patients experience progression of native vessel disease or attrition of previous bypass grafts. Reoperative CABG patients have an increased operative mortality and morbidity compared with patients undergoing primary revascularization.8–10 Various strategies have evolved to minimize the risks of reoperative revascularization. These include avoiding repeat sternotomy in which the potential exists to injure patent grafts, reducing the manipulation of the aorta or previous grafts to decrease the potential for embolization, and changes in approach to myocardial protection.

CABG without the aid of cardiopulmonary bypass (CPB) continues to gain popularity as an alternative to standard techniques of revascularization, especially in reoperative or high-risk patients. Revascularization by mini-thoracotomy remains an alternative to standard grafting in a population at increased risk for morbidity and mortality. We reviewed our experience in a select population undergoing off-pump revascularization of the circumflex distribution via left mini-thoracotomy.

Methods

Thirty-two patients underwent off-pump bypass grafting of the circumflex vessels via thoracotomy from December 1995 to April 2000. Twenty-seven patients (84%) presented with circumflex disease after having previous bypass grafting. Patients were selected in a nonrandomized manner for the off-pump group on the basis of coronary anatomy or risks inherent in more traditional approaches in those with patent anterior grafts. Five patients presented with circumflex disease and either nondiseased or ungraftable disease in their other arteries and medical comorbidities that were felt to increase the risk of CPB. These patients were revascularized as a primary procedure.

Patient demographics are listed in Table 1. This population comprised 26 men (81%) and 6 women (19%), with a mean age of 64.3 years. Thirteen patients (41%) had previous myocardial infarctions, and 9 (28%) were known to have left main stem stenosis >50%. The average ejection fraction was 51%. Patient risk factors are listed in Table 2. Most patients were hypertensive and current smokers. There...
TABLE 1. **Patient Demographics**

<table>
<thead>
<tr>
<th>Risk Factor</th>
<th>Patients (n=32)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total patients, n</td>
<td>32</td>
</tr>
<tr>
<td>Average age, y</td>
<td>64.3</td>
</tr>
<tr>
<td>Male, n (%)</td>
<td>26 (81.3)</td>
</tr>
<tr>
<td>Female, n (%)</td>
<td>6 (18.8)</td>
</tr>
<tr>
<td>Previous CAGB, n (%)</td>
<td>27 (84.38)</td>
</tr>
<tr>
<td>Prior myocardial infarction, n (%)</td>
<td>13 (40.6)</td>
</tr>
<tr>
<td>Arrhythmia, n (%)</td>
<td>4 (12.5)</td>
</tr>
<tr>
<td>Left main stenosis &gt;50%, n (%)</td>
<td>9 (28.1)</td>
</tr>
<tr>
<td>Average LVEF, %</td>
<td>50.7</td>
</tr>
</tbody>
</table>

_LVEF indicates left ventricular ejection fraction._

was also a large number of diabetics (34%) and patients with hypercholesterolemia (44%).

Patients were taken to the operating room and after induction of general anesthesia and insertion of a double-lumen endotracheal tube, were placed in the right lateral decubitus position after harvesting of bypass conduit (radial artery or saphenous vein). A posterolateral thoracotomy incision was then performed in the fifth or sixth intercostal space, depending on the target vessel selected for revascularization. The left lung was then collapsed, and the inferior pulmonary ligament was divided. This allowed mobilization of the lung superiorly to the level of the inferior pulmonary vein. Patients with previous left internal mammary artery grafts generally had adhesions between the lung and the mammary bed that had to be taken down to fully mobilize the lung and expose the pericardium. The pericardium was then opened longitudinally posterior to the phrenic nerve. Lysis of existing adhesions and target vessel identification were then performed. Patients were anticoagulated with 1.5 mg/kg heparin to achieve an activated clotting time of >300 seconds. A silaratic suture was placed proximally around the target vessel to achieve vascular control. A CTS (CardioThoracic Systems Inc) stabilizer was positioned to straddle the anastomotic area. A moistened CO2 blower was used to keep the anastomotic site clear of blood and the edges of the artery separated. The anastomosis was performed in a continuous fashion with a 7-0 prolene suture. The graft was then positioned inferiorly to the hilum of the lung in a gentle curve.

Preoperative, perioperative, and postoperative data were collected with a customized version of the Society of Thoracic Surgeons (STS) database and compared with the 1999 STS national database.

### Results

The perioperative results of the 2 groups are shown in Table 3. The mortality expected on the basis of STS database criteria was 4.9%. There was no observed mortality, defined as 30-day postoperative survival in this patient group. There were no conversions to CPB to complete the procedure, and no patients required an intra-aortic balloon pump in the postoperative period. Thirty-five bypasses were performed, with 3 patients receiving 2 grafts and 29 patients receiving single bypasses. Radial artery was used as conduit for 6 grafts (17%), and saphenous vein was used for 29 grafts (83%).

Three patients required transfusion of blood or blood products, and 1 patient returned to the operating room for bleeding. There were no perioperative myocardial infarctions as defined by new ischemic changes on a surface 12-lead ECG accompanied by a serial rise in cardiac isoenzymes. One patient suffered a permanent neurological deficit postoperatively. There was a single episode of atrial fibrillation in this group (3.1%), which was significantly lower than the STS national average of 19.6%.

The average intensive care unit length of stay was 1.3 days, with an overall length of stay of 4.8 days from time of surgery to discharge. The length of stay was significantly less than the 1999 STS national average of 7.8 days for first time reoperations ($P<0.001$).

### Discussion

Since the introduction of CABG in the 1960s, an increasing number of patients return for evaluation of reoperative surgery. Early reports document an incidence of reoperative CABG of 3% at 5 years, 11% at 10 years, and 17% at 12 years. Other studies report an incidence of reoperation of 3% to 9% overall. This is particularly relevant in that...
reoperative revascularization carries a higher mortality than primary CABG.8–10 Although the Cleveland Clinic reported an operative mortality for reoperative CABG of 3.4%,15 most other centers report a higher mortality of up to 12.5%,12 with a median of 6% to 8%.8–10

A number of techniques are used to reduce the morbidity associated with reoperative bypass grafting. These include reduced manipulation of previous grafts and the aorta to avoid embolization of debris, avoidance of repeated sternotomy when patent grafts may be jeopardized, and single aortic cross clamping. Other strategies involve the use of both antegrade and retrograde cardioplegia to reduce operative mortality. Although these techniques may reduce the risks associated with reoperative surgery, the complications associated with CPB remain. CPB causes massive fluid retention, intercompartmental fluid shifts, and singular bleeding complications.16,17 The contact of blood with the artificial surface of the bypass circuit produces a diffuse systemic inflammatory response that affects multiple organ systems.18 This inflammatory cascade can result in impaired pulmonary function through the degradation of surfactant and activation of complement and neutrophils, leading to increased capillary permeability, interstitial edema, and decreased pulmonary compliance.19,20 In addition, increased time on bypass has been identified as a significant independent predictor of mortality after reoperative CABG.21

We believe that a mini-thoracotomy with off-pump grafting provides a viable alternative to traditional approaches for selected revascularization of the obtuse marginal vessels. This technique avoids potential injury to patent anterior grafts, reduces manipulation of diseased grafts, and eliminates the need for CPB. Our review demonstrates significantly reduced rates of atrial fibrillation and lengths of stay compared with the 1999 STS national database. While noting that the average number of grafts performed in this highly selected group was only 1.1 per patient, we observed no mortality in this population, which compares favorably to published rates for reoperative bypass grafting. The first 10 patients in the series underwent PET and cardiac catheterization to assess residual ischemia and graft patency. There was no residual ischemia, and all grafts were patent. Given these results, subsequent patients were followed clinically in regard to new ECG changes or return of symptoms to avoid repeated catheter intervention. We believe that this confirms the adequacy of revascularization when taken in conjunction with no observed mortality or perioperative myocardial infarction. Long-term patency can be demonstrated only by ongoing follow-up with regards to return of symptoms or need for reintervention.

Technical challenges include performing the coronary anastomosis deep inside the patient’s chest at an unusual orientation for the surgeon. In addition, the more barrel chested the patient is, the more the surgeon tends to operate at the limits of the surgical instruments. Calcification of the descending thoracic aorta may require alternative proximal sites, such as the aortic arch or the subclavian artery.

In summary, our results indicate that off-pump grafting via left mini-thoracotomy provides a safe and effective alternative to traditional approaches for patients requiring limited revascularization. Extensive dissection with possible embolization of debris from old grafts can be avoided, and adequate revascularization of culprit coronary lesions can be achieved with reduced morbidity and mortality.

References

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