Reoperative MIDCAB grafting: 3-year clinical experience

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Abstract

Objective: Minimally invasive direct coronary artery bypass (MIDCAB) is performed under direct vision without sternotomy or cardiopulmonary bypass. The technique is used in reoperative patients through various incisions to revascularize one or two areas of the heart. The internal mammary artery, gastroepiploic artery, radial artery, or saphenous vein are used as graft conduits.

Methods: Anterior coronary targets are grafted with the internal mammary artery via a small anterior thoracotomy. Inferior coronary targets are grafted with radial artery or saphenous vein via a posterior thoracotomy. Inferior coronary targets are grafted with the gastroepiploic artery via a small midline epigastric incision. Lateral coronary targets are grafted with radial artery or saphenous vein via a posterior thoracotomy. After partial heparinization, the anastomosis is facilitated by local coronary occlusion and stabilization. Graft follow-up consists of outpatient Doppler examination and selective recatheterization.

Results: Between January 1994 and August 1997, 81 patients underwent reoperative MIDCAB grafting. Twenty-one patients (25.9%) had internal mammary grafting, 39 (48.2%) had gastroepiploic grafting, and 21 (25.9%) had lateral grafting with radial artery or saphenous vein. There were nine early deaths (four cardiac, five non-cardiac), five late deaths (three cardiac, two non-cardiac), and nine myocardial infarctions in remaining patients. Sixteen patients underwent recatheterization; there were one graft occlusion, two graft stenoses, and eight anastomotic stenoses. Mean postoperative length of stay was 3.8 days. Ninety percent (55/61) of patients are free of symptoms at a mean follow-up of 7.8 months (range 0–39).

Conclusions: Reoperative MIDCAB grafting avoids the risks of resternotomy, aortic manipulation, and cardiopulmonary bypass. The techniques yield an early patency rate of 94%, which includes eight patients who had postoperative catheter-based interventions. Reoperative MIDCAB grafting had lower rates of supraventricular arrhythmia and transfusion when compared with conventional coronary artery bypass grafting, but did not offer an advantage for mortality, stroke or myocardial infarction. This 3-year experience suggests that while reoperative MIDCAB grafting can effectively revascularize focal areas of the heart, patients should be carefully selected to minimize operative risk. © 1998 Elsevier Science B.V. All rights reserved

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1. Introduction

Minimally invasive direct coronary artery bypass (MIDCAB) grafting is being applied to a wider range of patients as operative techniques and instrumentation continue to evolve. These techniques now allow for grafting of all coronary distributions in the primary setting and there are several series with early follow-up [1–4]. This early success has led to the application of MIDCAB techniques in small groups of reoperative patients [5,6].

The features which make MIDCAB grafting particularly appealing for reoperative coronary surgery are its small incisions, the absence of cardiopulmonary bypass, and the avoidance of great vessel or existing graft manipulation. Resternotomy has inherent risks, including injury to patent grafts, the heart and great vessels, embolization of atherosclerotic debris from the aorta or diseased grafts, and wound breakdown after surgery [7,8]. Conventional reoperative
coronary artery bypass (CAB) is associated with both prolonged cardiopulmonary bypass and overall operative times due to more extensive dissection. Manipulation of diseased vein grafts can result in embolization or acute occlusion.

This experience with reoperative MIDCAB grafting demonstrates that the techniques can result in satisfactory early graft patency while reducing some of the morbidity associated with reoperative surgery, such as supraventricular arrhythmias and blood transfusion. Although these approaches do not eliminate the increased risks of reoperative surgery, patients can be expected to recover more rapidly and leave the hospital sooner than with conventional CAB. All surfaces of the heart can be addressed by these techniques and most patients have excellent relief of symptoms.

2. Materials and methods

2.1. Patient selection

Patients were selected for revascularization using MIDCAB techniques who had significant coronary artery disease or previous graft stenosis (>50% narrowing by angiography) limited to one coronary distribution. All patients had symptoms refractive to medical therapy, including catheter-based interventions. Exclusion criteria for the MIDCAB approach included the presence of significant coronary disease in two or more coronary distributions and active myocardial ischemia requiring intravenous nitrates or mechanical support. Patients were not excluded on the basis of age, functional status, presence of functional grafts to other areas of the heart, or other preoperative risk factors such as previous stroke or myocardial infarction. Preoperative demographic data are summarized in Table 1.

2.2. Operative technique

The patient is prepared for MIDCAB surgery as for conventional cardiac surgery, including central venous access, arterial pressure monitoring, and a urinary drainage catheter. A pulmonary artery catheter which monitors continuous cardiac output and mixed venous oxygen saturation is used, (Baxter Vigilance Monitor, Edwards Critical Care, Irvine, CA) and external adhesive defibrillation pads are placed on all patients (R2 Medical Systems, Niles, IL).

2.2.1. Anterior approach

The anterior approach was used in 21 (25.9%) patients for internal mammary artery (IMA) grafting to the left anterior descending (LAD) artery or diagonal branch (LADD), the proximal right coronary artery (RCA), and to stenotic saphenous vein grafts (SVGs) supplying these vessels. This approach was also used to harvest the right IMA for free grafting elsewhere on the heart. The anterior chest is prepped and draped as for conventional cardiac surgery, with wide draping on the intended side of the anterolateral MIDCAB incision.

An 8-cm transverse skin incision is made at the level of the fourth costal cartilage, just lateral to the sternal border. The fourth cartilage is released just lateral to the IMA and reflected inferiorly. The IMA is dissected off the third costal cartilage and skeletonized from the chest wall from the undersurfaces of the first through fifth costal cartilages. Exposure is optimized by using an integrated retraction system (Rultract, Cleveland, OH) to simultaneously elevate the third cartilage and the sternal table. Existing aorto-coronary vein grafts are avoided by the lateral course of the dissection.

Mobilization to the level of the first rib facilitates a tension-free anastomosis for LAD, LADD, and proximal RCA targets. After completion of the anastomosis (see below), a soft Hemovac® drain is placed across the pericardium into the pleural space. The fourth costal cartilage is secured with a single wire, a lateral intercostal block is performed with bupivacaine, and the soft tissue is closed in layers.

2.2.2. Inferior approach

This approach was used in 39 (48.2%) patients for gastroepiploic artery (GEA) grafting to the distal RCA, posterior descending artery (PDA), and distal LAD. The anterior chest is prepped and draped as for conventional cardiac surgery, with extended inferior draping to allow for the upper midline laparotomy. A vertical skin incision is made from the xiphoid process halfway to the umbilicus. The xiphisternum is excised and the sternum retracted vertically and superiorly. Adhesions along the undersurface of the heart must be released with care, as existing grafts may course over the acute margin of the heart. Adhesions

<table>
<thead>
<tr>
<th>Table 1</th>
<th>Patient demographics (n = 81)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Risk factors</td>
<td>Mean age (years) (range)</td>
</tr>
<tr>
<td>Indication for operation</td>
<td>Angina (92.6%)</td>
</tr>
<tr>
<td>Preoperative catheter-based interventions</td>
<td>PTCA (45.7%)</td>
</tr>
<tr>
<td>Any intervention</td>
<td>58 (71.6%)</td>
</tr>
</tbody>
</table>
between the posterior surface of the sternum and the heart should be left undisturbed, as these aid in retraction and elevation of the heart. The diaphragm is retracted inferiorly, and relaxing incisions are performed subcostally to enhance exposure.

The right GEA is dissected proximally to obtain optimal caliber and gently palpated for evidence of plaque. Side branches are carefully ligated, and adequate length is ensured prior to grafting. Intraluminal injection of papaverine and verapamil is routinely used for this conduit, as the vessel is prone to spasm from operative manipulation. The GEA pedicle is brought anterior to the stomach and left lobe of the liver. For distal RCA and LAD targets, the pedicle is directed over the diaphragm; for PDA targets, the pedicle is routed through a small incision in the right hemidiaphragm.

Following completion of the anastomosis (see below), the GEA pedicle is secured to the epicardium to ensure proper orientation. A soft Hemovac® drain is directed across the peritoneum and pericardium, and into the pleural cavity if indicated. The diaphragm is repositioned, and the soft tissue is closed in layers.

2.2.3. Lateral approach

This approach was used in 21 (25.9%) patients for grafting the circumflex marginal artery (CXM), obtuse marginal branches (OMB), and stenotic SVGs supplying these vessels. Conduits used in this approach include free radial artery (RAD), saphenous vein, and free right IMA. The patient is positioned as for standard left posterolateral thoracotomy, and saphenous vein is harvested from the medial right thigh. A radial artery conduit is harvested from the non-dominant forearm prior to patient positioning. Double-lumen endotracheal intubation is performed to allow selective lung ventilation. A limited incision is made from the midaxillary line posteriorly towards the spine, exposing but not dividing 3–4 cm of the paraspinal muscle and ligaments. The latisimus dorsi muscle is divided and the chest entered through the sixth intercostal space. Two 1-cm segments of the posterior aspect of the ribs above and below the incision are removed just behind the paraspinal ligaments to permit maximal intercostal opening.

The inferior pulmonary ligament of the left lung is released and the left lung packed into the apex. Following completion of the distal anastomosis (see below), the conduit is anastomosed end-to-side to the descending aorta, facilitated by a side-biting clamp. The graft should conform to a gentle ‘S’ curve to prevent kinking when the lung is re-expanded. A chest tube is placed in the pleural cavity, a posterior intercostal block is performed with bupivacaine, and the soft tissue is closed in layers.

2.2.4. Anastomotic technique

The pericardium is opened over the intended target vessel and 10 000 units of intravenous heparin administered. Silastic tapes are passed proximally and distally to the site of grafting for native coronary targets; these tapes are then passed through the pericardium, which improves vessel occlusion and enhances exposure. Heavily diseased targets are not occluded distally to prevent luminal plaque fracturing. One to three 5-min cycles of ischemic preconditioning are performed as tolerated by patient hemodynamics.

An arteriotomy is fashioned in the target vessel, and the conduit is trimmed to conform. Probing of the distal target vessel is avoided, as this may result in vessel wall disruption or occlusion of plaque when performed on the non-arrested heart. The site is stabilized using a hand-held right-angle clamp with rubber bolsters and the conduit anastomosed end-to-side in an antegrade fashion using a 7-0 prolene single parachute technique. Intraoperative graft flow is measured using a transit-time ultrasound flow probe (Transonic Systems, Ithaca, NY) to assist in detection of technical problems with the anastomosis prior to closure.

2.3. Patient follow-up

Serial cardiac enzyme analysis was performed at 1, 8, and 16 h postoperatively, and additional analysis was performed as indicated. Patients were followed prospectively after surgery with clinic visits at 2 weeks, 3 months, and then annually. Transcutaneous Doppler evaluation was performed on the first postoperative day to assess graft patency in patients with IMA or GEA conduits. Follow-up Doppler examination was performed on an outpatient basis at 2 weeks, 3 months, and 1 year. Non-invasive graft study was not performed in patients undergoing lateral reoperative surgery, as these conduits are not adequately assessed by Doppler evaluation. Exercise stress thallium testing was performed at 3 months to evaluate improvement in myocardial perfusion in the grafted distribution. Coronary angiography was performed selectively for persistent or recurrent anginal symptoms, failure to visualize the graft on Doppler evaluation, and for a persistent ischemic deficit on stress thallium.

2.4. Statistical analysis

Patients were assigned to an operative risk category based on the presence of preoperative risk factors, which included hypertension, diabetes mellitus, previous myocardial infarction, previous stroke, audible carotid bruit, ejection fraction less than 35%, and prior catheter-based interventions. Patients with two or more risk factors were considered to be high-risk candidates, while patients with one or no risk factors were considered to be usual-risk candidates. These risk groups were then compared using Fisher’s exact test for the incidence of death, postoperative stroke, and perioperative myocardial infarction.

3. Results

Eighty-one patients underwent reoperative MIDCAB
grafting over a 43-month period from January 1994 to August 1997. Seven patients have been lost to follow-up at varying intervals; only one patient had no follow-up after surgery. Mean length of follow-up was 7.8 months (range 0–39). Operative procedure data for target vessel selection and graft conduit utilization are summarized in Table 2.

3.1. Mortality

Fourteen (17.3%) deaths have occurred in the series to date and are summarized in Table 3. Nine (11.1%) of these deaths occurred within 30 days of operation; only four (4.9%) of these were from cardiac causes. Five (6.2%) patients suffered late deaths at periods ranging from 1 to 29 months after operation. Four (4.9%) of these patients died from cardiac causes. Overall, cardiac causes of death included arrhythmia in two (2.5%) patients, failure in four (4.9%), and unknown but presumed cardiac cause in one (1.2%).

3.2. Morbidity

Nine (11.1%) patients suffered myocardial infarction, defined as a CPK-MB value greater than 50 I/U on any two postoperative measurements. Four patients had undergone GEA grafting, three IMA grafting, one SVG grafting, and one RAD grafting. Six (7.4%) patients had a CPK-MB value greater than 100 I/U. One patient died on postoperative day 9 from failure and one patient died 4 months after operation from arrhythmia. In the surviving patients, three underwent recatherization and had successful percutaneous dilation of graft or anastomotic stenoses.

Eight (9.9%) patients developed atrial fibrillation or supraventricular tachycardia during the postoperative period. All occurred and were treated prior to discharge; no patient developed supraventricular arrhythmia after discharge from the hospital. The highest incidence of supraventricular arrhythmia occurred in patients who underwent lateral MIDCAB grafting (23.8%, 5/21). Two of 21 (9.5%) patients with IMA grafting and one of 39 (2.6%) patients with GEA grafting developed supraventricular arrhythmias.

Three (3.7%) patients suffered stroke or other significant neurological impairment. One patient died 2 weeks after surgery after developing a stroke during hospitalization for pneumonia at another institution. This patient had undergone left IMA grafting to the LAD and had been discharged on the second postoperative day. The second patient had undergone GEA grafting to the PDA and developed visual symptoms consistent with cerebral ischemia ten days after operation. The third patient died from a stroke 21 months after operation; this patient had been doing well without complaints of angina or other cardiac symptoms.

Eight (9.9%) patients developed infections of the primary operative site. Two (2.5%) patients required operative débridement and revision of the incision, one patient with an anterior incision and one with an inferior incision. The remaining six patients had minor infections treated with incision and drainage, packing, and antibiotics. One (1.2%) patient developed infection of the saphenous vein harvest site. Four (4.9%) patients required thoracentesis for pleural effusion prior to discharge. No patient required thoracentesis after discharge from the hospital. Two patients had lateral grafting, one had GEA grafting, and one had IMA grafting.

Two (2.5%) patients required re-exploration for bleeding. One patient had undergone lateral grafting with SVG and developed increased chest tube output after vigorous coughing. No discrete site of bleeding was noted at reoperation. One patient underwent full sternotomy without cardiopulmonary bypass for left IMA grafting to the LAD and SVG grafting to the OMB. The patient was re-explored twice on the day of surgery; no discrete site of bleeding was found. Seventeen (21.0%) patients required administration of blood products during their hospital course. Seven (8.6%) patients were transfused for postoperative bleeding, eight (9.9%) for low preoperative hematocrit, one (1.2%) for gastrointestinal bleeding, and one (1.2%) for coagulopathy. Mean number of red cell units transfused for the entire series was 0.61 ± 1.31 units. The mean number of units for patients receiving red cell transfusion was 2.90 ± 1.30 units. Eight (9.9%) patients received 2 units of red cells or less; only two (2.5%) patients received more than 5 units. Only one (1.2%) patient required transfusion of fresh-frozen plasma; no patient required transfusion of platelets.

3.3. Conversion to conventional bypass grafting

One (1.2%) patient required partial conversion to conventional bypass grafting techniques. This patient developed bleeding during early dissection and required femoral cardiopulmonary bypass. Grafting was not performed due to excessive bleeding and the patient’s symptoms resolved.

Table 2

<table>
<thead>
<tr>
<th>Conduit and target vessel grafting</th>
<th>n</th>
<th>Target vessel</th>
<th>n</th>
</tr>
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<tbody>
<tr>
<td>IMA</td>
<td>21</td>
<td>LAD</td>
<td>13</td>
</tr>
<tr>
<td>Left IMA</td>
<td>19</td>
<td>LAD</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>LADD</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Existing SVG</td>
<td>5</td>
</tr>
<tr>
<td>Right IMA</td>
<td>2</td>
<td>RCA</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>GEA (free graft)</td>
<td>1</td>
</tr>
<tr>
<td>GEA</td>
<td>39</td>
<td>PDA</td>
<td>20</td>
</tr>
<tr>
<td></td>
<td></td>
<td>RCA</td>
<td>12</td>
</tr>
<tr>
<td></td>
<td></td>
<td>LAD</td>
<td>7</td>
</tr>
<tr>
<td>SVG</td>
<td>12</td>
<td>OMB</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Existing SVG</td>
<td>5</td>
</tr>
<tr>
<td>RAD</td>
<td>9</td>
<td>OMB</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td></td>
<td>RCA/PDA</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>OMB/ramus branch</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>GEA</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>PLD</td>
<td>2</td>
</tr>
</tbody>
</table>
without further intervention. Two (2.5%) patients underwent full sternotomy without cardiopulmonary bypass. One patient is described above. The second patient had left IMA grafting to the LAD; an upper lobe squamous cell tumor was identified at the time of surgery and the patient died on postoperative day 15 from respiratory failure.

3.4. Length of Stay

Mean overall postoperative length of stay for all patients was 3.8 days (range 0–23). Mean overall length of stay excluding in-hospital deaths was 3.3 days (range 1–15). Mean length of stay was lowest in patients who had GEA grafting (2.7 days), followed by patients receiving left IMA grafts (3.5 days) and patients who underwent lateral grafting (5.9 days).

3.5. Reinterventions

Sixteen (19.8%) patients underwent recatheterization for symptoms, inadequate graft flow on Doppler evaluation, persistent defect on stress thallium testing, or during a planned procedure on another vessel (Table 4). Three patients had normal grafts and four had native coronary vessel stenosis. One (1.2%) patient had occlusion of a RAD graft to the PDA; two attempts at percutaneous dilation at 1 and 5 weeks postoperatively were unsuccessful.

Two (2.5%) patients developed graft stenoses during the study period. One graft stenosis occurred in a patient who had a SVG conduit to the OMB. Three percutaneous dilation attempts were performed at 32, 33, and 35 months after operation. This patient subsequently underwent a second MIDCAB operation and a free right IMA graft was placed to the CXM. The second graft stenosis occurred in a patient who had a left IMA graft to the LAD. This patient underwent a percutaneous dilation attempt at 3 months postoperatively; the graft remained stenotic on repeat catheterization.

Six (7.4%) patients developed anastomotic stenoses; one within the perioperative period, two within 3 months of operation, and three greater than 3 months after operation. All but one patient had successful percutaneous dilation of the stenosis. Fifty-eight of the 67 surviving patients had patent grafts, for an early graft patency rate of 86.6%. Five of these stenoses were successfully dilated, for an early graft patency rate of 94.0% (63/67) after catheter-based interventions.

3.6. Follow-up

Transcutaneous Doppler analysis of the graft was performed on all patients with GEA and IMA grafts on postoperative day 1, and all grafts were patent. Doppler analysis was performed on 38 patients at 2 weeks, 30 patients at 3 months, and 18 patients at 1 year; all grafts evaluated were patent. One patient has had Doppler evaluation annually for 3 years and the graft remains patent.

Stress thallium testing was performed on 32 (39.5%) patients at three months. Nine patients had a persistent ischemic defect; all grafts evaluated by Doppler study demonstrated flow. Two patients underwent recatheterization; one patient had native coronary vessel stenosis which

<table>
<thead>
<tr>
<th>Patient</th>
<th>Age</th>
<th>Interval</th>
<th>Cause</th>
<th>Risk factors</th>
</tr>
</thead>
<tbody>
<tr>
<td>I.J.</td>
<td>69</td>
<td>Intraoperative</td>
<td>Cardiac (failure)</td>
<td>Hypertension, prior PTCA × 3</td>
</tr>
<tr>
<td>M.M.</td>
<td>70</td>
<td>1 h</td>
<td>Cardiac (arrhythmia)</td>
<td>Prior MI, CHF, low EFa</td>
</tr>
<tr>
<td>L.Y.</td>
<td>67</td>
<td>9 days</td>
<td>Cardiac (arrhythmia)</td>
<td>Prior MI, prior PTCA × 3, arrhythmias, low EFa</td>
</tr>
<tr>
<td>J.B.</td>
<td>81</td>
<td>9 days</td>
<td>Cardiac (failure)</td>
<td>Prior MI, hypertension, DM, prior atherectomy low EFa</td>
</tr>
<tr>
<td>M.D.</td>
<td>84</td>
<td>2 days</td>
<td>Respiratory arrest</td>
<td>Hypertension</td>
</tr>
<tr>
<td>W.B.</td>
<td>69</td>
<td>3 days</td>
<td>Respiratory arrest</td>
<td>DM, prior PTCA</td>
</tr>
<tr>
<td>J.H.</td>
<td>77</td>
<td>2 weeks</td>
<td>Respiratory failure</td>
<td>COPD, low EFa</td>
</tr>
<tr>
<td>W.N.</td>
<td>68</td>
<td>2 weeks</td>
<td>CVA</td>
<td>Hypertension, low EFa</td>
</tr>
<tr>
<td>D.H.</td>
<td>74</td>
<td>3 weeks</td>
<td>Pneumonia</td>
<td>Prior MI, DM, prior stent, CHF, low EFa</td>
</tr>
</tbody>
</table>

Late (30 days or more after operation)

<table>
<thead>
<tr>
<th>Patient</th>
<th>Age</th>
<th>Interval</th>
<th>Cause</th>
<th>Risk factors</th>
</tr>
</thead>
<tbody>
<tr>
<td>S.R.</td>
<td>65</td>
<td>3 months</td>
<td>Cardiac (failure)</td>
<td>Hypertension</td>
</tr>
<tr>
<td>J.B.</td>
<td>67</td>
<td>7 months</td>
<td>Cardiac (sudden death)</td>
<td>Hypertension, prior PTCA</td>
</tr>
<tr>
<td>R.R.</td>
<td>61</td>
<td>22 months</td>
<td>Unknown (presumed cardiac)</td>
<td>Hypertension, DM, low EFa</td>
</tr>
<tr>
<td>E.D.</td>
<td>70</td>
<td>29 months</td>
<td>Cardiac (failure)</td>
<td>Prior MI, hypertension, prior PTCA × 2, atrial fib.</td>
</tr>
<tr>
<td>N.S.</td>
<td>64</td>
<td>21 months</td>
<td>CVA</td>
<td>Hypertension, DM, prior PTCA, prior CVA</td>
</tr>
</tbody>
</table>

aLess than 35%.
was successfully treated with percutaneous dilation. The second patient had graft stenosis and underwent three late attempts at percutaneous dilation, as described above.

Sixty-one (91.0%) of 67 surviving patients were evaluated for symptoms during clinic visits at 2 weeks, 3 months, and then annually. Of these, three (4.9%) had persistent symptoms and three (4.9%) had recurrent symptoms. Resolution of anginal symptoms was documented in 90.2% (55/61) of patients seen in clinic, with or without additional medical therapy.

### 4. Discussion

MIDCAB grafting continues to evolve with the advent of new techniques and instrumentation. The techniques are being used for a wider range of patients and in increasingly more difficult operative settings. This early experience with reoperative patients illustrates several points which may help refine the use of MIDCAB grafting for coronary revascularization in this population.

In this early experience, reoperative MIDCAB grafting did not offer an advantage over traditional techniques in the incidence of perioperative myocardial infarction. Nine (11.1%) patients in this series suffered a myocardial infarction, which is higher than the rates of 5.5–8.9% reported after conventional CAB [9–12]. Eight of these patients were in the high-risk group and one patient was in the usual-risk group. This difference was statistically significant ($P = 0.008$).

No patient underwent full conversion to sternotomy and cardiopulmonary bypass. The option to conversion may be limited in the reoperative setting due to inordinate risk and the surgeon should be prepared to enlist other techniques, such as full sternotomy without cardiopulmonary bypass, femoro-femoral bypass or conventional thoracotomy [13–16]. Full sternotomy without cardiopulmonary bypass was used in two patients in this series, one patient requiring grafting to the anterior and lateral surfaces of the heart, and one patient requiring concomitant resection of an upper lobe lung tumor.

The reoperative patient may present with several preoperative risk factors, greatly increasing the incidence of untoward events, including death, myocardial infarction, and stroke [17,18]. The in-hospital mortality in this series of patients was 11.1%, which is greater than expected. This rate, however, is not different from the rates of 3.4–15.0% reported for conventional reoperative CAB [9,11,12, 15,17,18]. Moreover, only 4.9% of reoperative MIDCAB patients died from cardiac causes within 30 days of operation. The cumulative mortality from all causes in this series is 17.3%, which compares to mortality rates ranging from 11 to 17% over the first few years after conventional CAB [12,15].
Eleven of the patients who died in the series were classified in the high-risk category, compared with three patients in the usual-risk category (Table 3). Seven of these high-risk patients had three or more risk factors, and only one had an ejection fraction over 35%. Of the remaining three patients classified as usual risk operative candidates, two died from cardiac causes, one patient 3 months after operation and one patient 7 months after operation. The difference between the high-risk group and the usual-risk group for the incidence of death was statistically significant ($P = 0.037$). Importantly, 50% of patients in this series have died from causes unrelated to their underlying coronary artery disease, which illustrates the severity of comorbidities found in this population.

One of the primary advantages of MIDCAB surgery is the avoidance of cardiopulmonary bypass and great vessel manipulation involved in conventional CAB. The manipulation of diseased great vessels at reoperative surgery may dislodge atheromatous debris, increasing the risk of stroke [19,20]. Furthermore, cardiopulmonary bypass has an inherent risk of stroke and carries the additional problems of coagulopathy and systemic inflammatory response.

Use of MIDCAB techniques obviates the need for cardiopulmonary bypass, avoiding coagulopathic changes, platelet dysfunction, and the systemic stress from inflammation. Use of the IMA and GEA for MIDCAB revascularization avoids aortic manipulation, preventing potential embolization [5,6]. Lateral reoperative MIDCAB grafting does require some manipulation of the aorta, as the saphenous vein or radial artery graft must be anastomosed to the descending aorta, but does not require cardiopulmonary bypass or hypothermic fibrillatory arrest [21–23]. Only two (2.5%) patients developed symptoms consistent with stroke within 30 days of operation, a rate which is comparable with rates reported after conventional CAB [9,11,12,19,20]. No patient had lateral MIDCAB grafting and all events occurred after the patient had been discharged from the hospital. There was no statistically significant difference between the high-risk and usual-risk patient groups for the incidence of postoperative stroke.

Transfusion for bleeding after MIDCAB surgery was substantially lower than the incidence associated with conventional CAB, which ranges between 50 and 77% [11,15,24]. Seventeen (21.0%) patients required transfusion for any cause; only seven (8.6%) required transfusion for bleeding and only one (1.2%) patient required transfusion for coagulopathy. Multiple transfusions were also infrequent, with only four (4.9%) patients requiring 4 or more units of blood products. Mean red cell units transfused per patient in this series was 0.61 ± 1.31 units as compared with a mean of 3.8 ± 0.5 units in one conventional series [24].

The hazards of resternotomy for reoperative conventional CAB are well known, including the increased risk of postoperative sternal wound infection. MIDCAB techniques avoid sternotomy, placing small incisions directly over the intended target vessels. Patent anterior grafts are left undissected with the anterior and inferior approaches to the LAD and proximal RCA. In this series, eight (9.9%) patients developed wound infections of the primary operative site. This rate is higher than that of conventional CAB, where 0.7–1.5% of patients develop sternal infections [25,26]. However, the majority of MIDCAB wound infections were minor, with only two (2.5%) of these infections requiring additional operative intervention. Importantly, no patient in this series died as a result of wound infection, compared with the mortality rate of 13–30% from sternal infections after conventional CAB [25,26].

In this series of patients, MIDCAB surgery has a lower incidence of postoperative supraventricular arrhythmias when compared with conventional CAB [27,28]. Eight (9.9%) patients in this series developed new postoperative atrial fibrillation or supraventricular tachycardia, as opposed to rates ranging from 17 to 38% after conventional CAB. All events occurred during the immediate postoperative period and resolved with medical therapy prior to discharge from the hospital.

Reoperative MIDCAB grafting in this series demonstrated a reduction in postoperative length of stay when compared with conventional CAB, with the overall mean length of stay of 3.8 days [12]. In addition, the mean length of stay of 3.5 days for the IMA patients in this series compares favorably with one other small series of reoperative MIDCAB patients [5]. Patients undergoing anterior or inferior MIDCAB grafting left the hospital sooner than patients requiring lateral grafting due to the slightly longer postoperative recovery required with the thoracotomy incision. Although there were no patients who developed supraventricular arrhythmias or required thoracentesis after discharge from the hospital in this series, patients should still be closely followed in the outpatient clinic after reoperative MIDCAB grafting in order to diagnose these potential problems in the early postoperative period.

Early recatheterization data after reoperative MIDCAB grafting has been encouraging (Table 4). There has been only one (1.2%) total occlusion of a free radial artery graft which could not be successfully treated with percutaneous dilation. A second patient had restenosis of a free radial artery graft after two attempts at percutaneous dilation, and eventually required conventional reoperative coronary bypass surgery. All remaining graft or anastomotic stenoses were successfully dilated.

Coronary angiography was performed selectively in this series, reserving recatheterization for persistent or recurrent anginal symptoms, failure to visualize the graft on Doppler evaluation, and for a persistent ischemic defect on stress thallium. Of the 67 surviving patients, nine were demonstrated to have either graft occlusion, graft stenosis or anastomotic stenosis, resulting in an early patency rate of 86.6%. However, successful dilation of stenoses was achieved in five of these patients, resulting in an early patency rate of 94.0% after catheter-based interventions. Of the 61 survivors seen in clinic, over 90% ($n = 55$) had
resolution of their symptoms, with or without additional medical therapy.

In conclusion, reoperative MIDCAB grafting in this series of patients had lower rates of supraventricular arrhythmia and transfusion when compared with conventional reoperative CAB. Postoperative length of stay is markedly reduced, and there was no mortality from either major or minor wound infections. Perioperative myocardial infarction and postoperative stroke rates were comparable with those after conventional reoperative CAB. Reoperative MIDCAB grafting mortality rates were similar to conventional reoperative CAB mortality rates, and there was a trend towards higher mortality in patients with a greater number of preoperative risk factors. Reoperative MIDCAB grafting demonstrated good results for resolution of symptoms, and early patency rates after catheter-based interventions were satisfactory. Patients being considered for reoperative MIDCAB grafting should undergo careful selection based on the presence of known preoperative risk factors and options for conventional coronary artery bypass grafting in order to achieve the optimal result.

References

very strong message that we need to do angiograms. In our unit, we advocate intraoperative angiography. We are now doing this routinely on all our MIDCAB patients. It only adds 20–30 min to your operating room time but you can leave the room with the peace of mind that you have not done any harm to your patients.

**Dr Doty:** I apologize, the slide may have been misleading. Seven of the patients had normal grafts and there were a total of 16 grafts presented there. Your comment about intraoperative angiography is well taken. We assess all grafts with transit-time ultrasound for patency prior to wound closure but we have not elected to use intraoperative angiography.

**Dr F.W. Mohr (Leipzig, Germany):** I have a little concern in terms of the high grade of anastomotic stenosis, and I reflect your data in terms of time also. You go back about 3 years. If I look back into the development, you were using rather crude tools to stabilize your anastomotic sites. We also have an experience of about 25 patients with re-ops and the patency rate is 97%. And I think it is only because of the fact that we have better tools now. If you look back into your data and in a timewise analysis, could you differentiate if your results are better now than 3 years ago? Could you comment on that, please?

**Dr Doty:** We have evaluated our early experience versus our late experience and really have not noticed any difference in increased anastomotic stenoses during our early experience. We have used the same operative technique and stabilization throughout the series, so we feel that it is reproducible.

**Professor Yim:** I want to pick up what you just said about transcutaneous Doppler. It has been shown that this is not a reliable way to confirm that you have a technically acceptable graft. Diastolic flow does not mean a good anastomosis. To believe that it does only gives you a false sense of security. Angiography should remain the gold standard.

**Dr Doty:** We did not use transcutaneous Doppler, as you mentioned; we used intraoperative, on the graft, ultrasound flow analysis. We use outpatient transcutaneous Doppler clinic evaluation to follow the grafts.

**Dr J. Craver (Atlanta, Georgia):** I feel that these results are unacceptable. To have this high a death rate in basically single-vessel operations, if it were the only vessel remaining, perhaps it might be tolerable; to have 12% risk for single-vessel disease revascularization is unacceptable. A 12% risk in conventional bypass surgery would quickly put us out of business. And since that comes in association with your high anastomotic stenosis rate with requirement for secondary intervention, I would ask are you still doing it this way? And if not, are you changing to some other way?

**Dr Doty:** An article published of over 600 patients in the Journal of Thoracic and Cardiovascular Surgery in 1995 demonstrated reoperative mortality of 11% in patients within 30 days of operation. It is a high mortality rate and we acknowledge that. We have certainly changed our indications for using this technique in the reoperative patient. Single-vessel bypass, as you suggest, should have a better outcome for the reoperative patient. However, it may be mitigated by the patients that are often referred for MIDCAB reoperative grafting, as they may be considered too ill for conventional reoperative surgery, which is why we urge cautious and careful selection of these patients, especially given the histories of multiple risk factors and comorbidities.