Early and mid-term results of off-pump endarterectomy of the left anterior descending artery

Mitsuko Takahashi, Sunir Gohil, Bonnie Tong, Patrick Lento, Farzan Filsoufi and Ramachandra C. Reddy

Abstract

OBJECTIVES: Many patients referred for coronary artery bypass surgery (CABG) today have diffusely diseased coronary vessels, and some of them may require coronary endarterectomy to provide adequate revascularization. Most reports of coronary endarterectomy describe an on-pump procedure. As off-pump coronary artery bypass graft has become safer and more routine, there is renewed interest in off-pump coronary endarterectomy. We report on our series of patients who underwent off-pump coronary endarterectomy of the left anterior descending (LAD) artery using an open endarterectomy technique.

METHODS: All patients undergoing open heart surgery at The Mount Sinai Medical Center are entered into a state-mandated, audited database. A retrospective review of this database revealed 12 patients between January 2008 and June 2012 who underwent off-pump endarterectomy of the LAD as part of their coronary revascularization. Additional data were collected from a review of the patients’ charts.

RESULTS: There were a total of 12 patients, with a mean age of 72 ± 4 years. Nine (75%) were male and 3 (25%) were female. Comorbidities included hypertension in 11 (92%) patients, dyslipidaemia in 10 (83%), diabetes in 8 (67%), renal failure in 6 (50%) and stroke in 1 (8%). The mean number of diseased coronary territories was 3 ± 0.4 (range 2–3), and the mean number of coronary bypass grafts performed was 4 ± 0.8 (range 2–5). Eight patients required transfusion with packed red blood cells (67%). One (8%) patient was converted from off-pump to on-pump. The mean intensive care unit stay was 3 ± 2.8 (range 1–8 days), and the mean hospital length of stay was 15 ± 13 (range 4–54 days). Postoperative follow-up (mean 24 ± 19 months, range 1–53) is complete, and no ischaemic events have occurred in the early and mid-term follow-up period.

CONCLUSIONS: We conclude that off-pump endarterectomy of the LAD is a viable option for patients with diffuse LAD disease.

Keywords: Off-pump • Coronary • Endarterectomy

INTRODUCTION

The spectrum of surgically treated coronary artery disease continues to evolve. Patients referred for surgery today are more likely to have had multiple coronary interventions and often present with diffuse disease [1, 2]. Diffuse coronary artery disease can be surgically treated either with bypass to a relatively normal location on the native artery or with endarterectomy. Endarterectomy may also be required when unexpected disease is found at the site of arteriotomy, preventing the safe placement of sutures.

Coronary endarterectomy was first introduced in the 1950s for the relief of angina [3]. Despite its success in angina relief, it fell out of favour due to its substantial morbidity and mortality [3]. Since that time, several reports of large series of patients undergoing on-pump endarterectomy have been published [4–6]. Off-pump coronary endarterectomy has also been reported, but the literature is limited. The advent of safe off-pump coronary bypass (OPCAB) with better stabilization of the target vessels has renewed our interest in this procedure in selected patients [7]. Here, we report our series of patients who underwent coronary endarterectomy of the left anterior descending (LAD) artery and describe our approach of open endarterectomy in conjunction with OPCAB.

MATERIALS AND METHODS

All patients undergoing open heart surgery at The Mount Sinai Hospital are entered into a prospective database that is audited and mandated by the New York State Department of Health. A retrospective review of all patients who underwent coronary...
artery bypass surgery was performed. This database revealed 12 patients who underwent off-pump endarterectomy of the LAD as part of their coronary revascularization between January 2008 and June 2012. All endarterectomies were done by a single surgeon as part of a consecutive series of 232 off-pump cases over the same period. We followed a 100% intention to treat off-pump strategy with all coronary cases performed by this surgeon being planned for an off-pump technique. The overall conversion rate was 2.2%. Additional data were obtained from hospital records and office charts. All data were handled in accordance with the instructions of the Institutional Review Board and every attempt was made to exclude the use of individually identifiable personal health information.

**Technique**

All patients in this series had multivessel coronary artery disease and underwent OPCAB through a full midline sternotomy. Our technique of OPCAB has been previously described [8]. Patients with diffuse disease on the preoperative catheterization were given 300 mg of clopidogrel on the morning of surgery. The left internal mammary artery (LIMA) was harvested using a skeletonized technique. Full heparinization was performed to achieve an activated clotting time goal of >300 s. The entire length of the LAD was easily exposed by placement of a moist sponge behind the heart with traction of the sutures placed on the left edge of the pericardium. Care was taken not to place any traction on the right side of the pericardium.

A mechanical stabilization device (Maquet™, Maquet Cardiovascular LLC, Wayne, NJ, USA) was used to stabilize the appropriate portion of the LAD. Silastic loops were placed proximally and distally to temporarily disrupt blood flow. A CO2 blower was used to clear blood from the field and to allow for good visualization. The final decision to perform a coronary endarterectomy was made intraoperatively once the LAD had been exposed. If the initial arteriotomy revealed a severely diseased and occluded lumen unsuitable for grafting, the arteriotomy was extended proximally and distally until the plaque tapered or a reasonable lumen was reached (Fig. 1). The stabilizer was moved sequentially to allow the entire length of the LAD to be worked on. A microendarterectomy blade was used to carefully dissect and lift the plaque off the vessel wall (Fig. 2a). Care was taken to ensure that the entire core, along with its branches, was excised. The proximal and distal ends of the tapering plaque were divided sharply with scissors. The proximal and distal intimal edges were stabilized and laterally tacked down to the vessel wall using interrupted 7-0 polypropylene sutures (Fig. 2b). The LIMA was then opened to the appropriate length and an on-lay patch angioplasty type of anastomosis was performed with the LIMA being anastomosed to the LAD in an end-to-side fashion using 7-0 polypropylene (Fig. 3). The silastic loops were removed and the blood flow through the LIMA restored, to allow for revascularization of the LAD territory. The flow was checked using a transit time flow probe (Medistim™, Medistim, Inc., Plymouth, MN, USA).

The remaining vessels were revascularized using standard off-pump techniques. Heparin was reversed and the mediastinum explored to ensure adequate haemostasis. Chest tubes were placed and the chest closed in the standard fashion. Postoperatively, all patients were maintained on dual antiplatelet therapy with clopidogrel and aspirin. The first postoperative doses were administered 6 h after surgery if bleeding was controlled. Early postoperative beta blockade along with statins was also routine.

**RESULTS**

A total of 12 patients underwent off-pump endarterectomy during the study period. The average age of the patients was 72 ± 4 (range 63–79 years). There were 9 male (75%) and 3 female (25%) patients. Eleven (92%) patients had hypertension (HTN), 10 (83%) had dyslipidaemia, 8 (67%) had type 2 diabetes, 6 (50%) had renal failure, 1 (8%) had a history of a previous cerebral vascular accident and 1 (8%) had peripheral vascular disease. The mean number of diseased coronary territories identified on preoperative cardiac catheterization was 3 ± 0.4 (range 2–3), and the average preoperative ejection fraction was 51 ± 15 (range 20–72%). The syntax score was available in 6 of the patients and was 33 ± 4. Patient characteristics are summarized in Table 1.

All patients underwent multivessel OPCAB with the mean number of bypass grafts being 4 (range 2–5). One patient was converted to on-pump surgery due to inadequate stabilization, giving us a conversion rate of 8%. Preoperative haemoglobin levels were 11.5 ± 1.5 (range 8.4–13.4), and postoperative haemoglobin levels were 9.8 ± 1.4 (range 7.8–12.9). Transfusion of either cell saver or packed red blood cells (PRBC) was required in all patients. Eleven (92%) patients were transfused with cell saver with a mean volume of 809 ± 368 ml. Eight (67%) patients required PRBC transfusion; 5 of them (42%) required 1
unit, 2 (17%) patients required 2 units and one (8%) required 4 units (Table 2). The average length of the endarterectomy was $4.7 \pm 2.8$ (range 2–10.2 cm).

There were no hospital deaths. There were no postoperative myocardial infarctions or strokes in the series. Postoperative troponin levels were not routinely checked, but 4 of our patients (33%) had a level drawn. One (8%) patient had a postoperative troponin of 10 without evidence of new wall motion abnormalities. Two patients had a level of 0 and the other a troponin of 3.7 also with no evidence of new wall motion abnormalities. Two (17%) patients required re-exploration for bleeding and both had no identifiable source of bleeding. Two (17%) patients developed transient postoperative atrial fibrillation. The mean intensive care unit (ICU) stay was $3 \pm 2.8$ (range 1–8 days), and the overall length of stay (LOS) was $15 \pm 13$ (range 4–54 days). One patient developed respiratory failure requiring a tracheostomy and had an LOS of 54 days. The overall LOS of the remaining 11 patients was $11 \pm 4.13$ (range 4–18 days).

Given the very diffuse disease in these patients and the prolonged operative times, the ICU LOS was longer than usual. These patients were monitored for additional periods of time because of concerns that postoperative ischaemia would be more common. This, however, was not our experience in these patients, with no perioperative ischaemic events in this group.

Postoperative follow-up (mean 24 ± 19 months; range 1–53) is complete. One of the patients had a computed tomography (CT) angiogram (Fig. 4) and 1 had a coronary angiogram done for vague symptoms. Both studies showed patency of the LIMA to LAD grafts.

**DISCUSSION**

Coronary endarterectomy was introduced in the mid-1950s [3], and predated coronary bypass surgery. It remains a useful approach for patients with diffuse disease, particularly of the LAD [9, 10]. Multiple vessel endarterectomy has been described, but the results are suboptimal compared with single-vessel LAD endarterectomy [6]. The LAD is easier to visualize along the majority of its length, easier to stabilize, and requires less displacement of the heart in off-pump procedures. On-lay patch grafting with the mammary artery is also largely limited to the LAD. We have therefore chosen to limit elective endarterectomy to this vessel.

OPCAB has emerged as an alternative to the traditional on-pump approach [11, 12]. The description of coronary endarterectomy in off-pump cases is limited [13, 14]. Off-pump endarterectomy of the LAD is feasible because the severe underlying ischaemia conditions the myocardium to flow interruption for prolonged periods during the endarterectomy. Secondly, the ischaemic myocardium is often easier to stabilize. As opposed to the early attempts at off-pump endarterectomy in the 1950s, the availability of specialized retractors and stabilizers and the prevailing degree of comfort with OPCAB techniques have allowed the use of careful open endarterectomy in selected patients in our center. The best approach to off-pump...
Endarterectomy is to sequentially stabilize short segments of the blood vessel. As opposed to a non-beating heart, endarterectomy in this situation requires very deliberate movements in order to avoid inadvertent tearing of tissue.

Coronary endarterectomy is performed using either a closed or an open technique. In the closed technique, a small arteriotomy is created and gentle steady traction is placed on the atheromatous plaque until it comes apart from the native artery proximally and distally. With this technique, it is not possible to prevent intimal flaps and possible residual obstruction [15]. With the open technique, the native artery is opened longitudinally beyond the limits of the endarterectomy to allow for the plaque to be carefully lifted off under direct vision and the edges to be fixed. It requires a patch closure of the LAD and bypass grafting [16]. With this technique, there is greater assurance of complete relief of obstruction and prevention of flaps.

There is no standard anticoagulation protocol for endarterectomy patients [16]. Several authors have described the use of heparin infusions followed by warfarin for several months. It has been our practice to give patients with diffuse coronary disease a preoperative or intraoperative dose of clopidogrel in addition to postoperative aspirin and clopidogrel. We have not used warfarin in these patients.

Two of our patients had postoperative coronary imaging, which revealed patent grafts and endarterectomized segments. Ischaemic events have not occurred in the early and mid-term follow-up period. We conclude that off-pump endarterectomy of the LAD is a viable option for patients with diffuse LAD disease, particularly in centers with considerable OPCAB experience.

**Table 1:** Patient demographics

<table>
<thead>
<tr>
<th>Total number of patients</th>
<th>12</th>
</tr>
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<tbody>
<tr>
<td>Age (years)</td>
<td>72 ± 4</td>
</tr>
<tr>
<td>Range</td>
<td>63–79</td>
</tr>
<tr>
<td>Gender</td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>9 (75%)</td>
</tr>
<tr>
<td>Female</td>
<td>3 (25%)</td>
</tr>
<tr>
<td>Comorbidities</td>
<td></td>
</tr>
<tr>
<td>Hypertension</td>
<td>11 (92%)</td>
</tr>
<tr>
<td>Dyslipidaemia</td>
<td>10 (83%)</td>
</tr>
<tr>
<td>Diabetes</td>
<td>8 (67%)</td>
</tr>
<tr>
<td>Renal failure</td>
<td>6 (50%)</td>
</tr>
<tr>
<td>Cerebrovascular accident</td>
<td>1 (8%)</td>
</tr>
<tr>
<td>Chronic obstructive pulmonary disease</td>
<td>0 (0%)</td>
</tr>
<tr>
<td>Peripheral vascular disease</td>
<td>1 (8%)</td>
</tr>
<tr>
<td>Preop evaluation</td>
<td></td>
</tr>
<tr>
<td>No. of vessels</td>
<td>3 ± 0.4</td>
</tr>
<tr>
<td>Ejection fraction (%)</td>
<td>51 ± 15</td>
</tr>
</tbody>
</table>

**Table 2:** Operative and postoperative characteristics

<table>
<thead>
<tr>
<th>Operative</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>No. of bypass grafts</td>
<td>4 ± 0.8</td>
</tr>
<tr>
<td>Conversion</td>
<td>1 (8%)</td>
</tr>
<tr>
<td>Transfusion</td>
<td></td>
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<tr>
<td>Cell saver volume (ml)</td>
<td>809 ± 368</td>
</tr>
<tr>
<td>No. patients packed red blood cells</td>
<td>8 (67%)</td>
</tr>
<tr>
<td>Postoperative</td>
<td></td>
</tr>
<tr>
<td>A-fib</td>
<td>2 (17%)</td>
</tr>
<tr>
<td>Cerebrovascular accident</td>
<td>0 (0%)</td>
</tr>
<tr>
<td>Re-exploration</td>
<td>2 (17%)</td>
</tr>
<tr>
<td>Intensive care unit stay (days)</td>
<td>3 ± 2.8</td>
</tr>
<tr>
<td>Hospital length of stay (days)</td>
<td>15 ± 13</td>
</tr>
<tr>
<td>Follow-up (months)</td>
<td>24 ± 19</td>
</tr>
</tbody>
</table>

**Figure 3:** Left internal mammary artery (LIMA) to left anterior descending (LAD) artery on-lay patch angioplasty type repair.

**Figure 4:** Postoperative CT angiogram of left internal mammary artery (LIMA) to left anterior descending (LAD) artery on-lay patch angioplasty repair.
Several limitations of our study need to be recognized. This is a retrospective study of a small non-randomized cohort of patients. A control group of patients with similar disease undergoing conventional surgery would be ideal, but may not be feasible. The absence of clinical ischaemic events, while encouraging, does not prove the patency of the endarterectomy sites. The observational nature of the study prevents us from drawing conclusions other than the feasibility and safety of the technique.

Conflict of interest: none declared.

REFERENCES


eComment. Coronary endarterectomy with or without inflow conduit?

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doi:10.1093/icvts/ivs558
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We read with great interest the work by Takahashi et al. [1], investigating early- and mid-term outcomes of off-pump endarterectomy of the left anterior descending (LAD) artery. The study spanned a 5-year period (2008–2012) and included 12 patients. The results of the present study indicate that coronary endarterectomy can be carried out with a low operative risk in suitable patients, for whom a vascular territory would otherwise not have been revascularized. Of note, there were no ischaemic events in the early- and mid-term follow-up period.

Surgeons are faced with an increasing number of patients with diffuse and advanced coronary artery disease. Therefore, many patients with diffuse LAD are currently considered inoperable by conventional coronary artery bypass grafting (CABG). Coronary endarterectomy of the LAD and the on-lay patch with a left internal thoracic artery are considered by many as a valuable option when applied in a highly selective manner to only that small percentage of target vessels otherwise not graftable [2, 3]. Indications for endarterectomy of the LAD artery include the absence of a vessel lumen, failure to pass a 1-mm probe or in-stent restenosis [4]. Coronary endarterectomy is technically challenging and care must be taken in dissecting the core from the adventitia and during the on-lay anastomosis because side diagonal artery branches could inadvertently be occluded. The surgeon must ensure that the entire plaque is removed with proper distal tapering. If distal tapering is not observed, then the arteriotomy should be extended.

The left internal thoracic artery to LAD graft has long been established as the cornerstone of improved early and late surgical outcomes for CABG. If the atherosclerotic core is removed, then competitive flow from the native coronary bed may cause occlusion of the inflow conduit, raising concerns about long-term durability of the left internal thoracic artery in this patient population. Although the internal thoracic artery is the best-equipped arterial conduit to withstand the competition between graft flow and native coronary flow, the risk of graft attrition is not insignificant [5]. Therefore, coronary patch reconstruction after endarterectomy without an inflow conduit can be performed in the absence of proximal LAD stenosis in order to avoid graft failure.

The merits of endarterectomy and arterial patch reconstruction have been reiterated by the present study. In some patients, coronary endarterectomy may be considered as the last option, but there are still many unanswered questions regarding the indications and long-term results of this treatment.

Conflict of interest: none declared.

References


eComment. Does off-pump coronary endarterectomy improve long-term outcomes?

Authors: Ahmet Baris Durukan, Hasan Alper Gurbuz, Murat Tavasoglu and Cem Yorgancioglu
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doi:10.1093/icvts/ivs558
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The publication by Takahashi et al. highlights an area with limited data [1]. They successfully performed off-pump coronary endarterectomy to the left anterior descending (LAD) artery in 12 patients. We congratulate the authors for their effort and successful results.

In this report, there are a few topics we would like to discuss. The study population belonged to a consecutive series of 232 off-pump cases performed by a single surgeon. We believe that the surgeon’s preference and experience played major role on the outcomes of coronary artery bypass grafting (CABG), particularly on...