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Extra-Anatomic Redo of MIDCAB and OPCAB: An Early Experience

Dr. Sinclair

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Michael C. Sinclair, MD,[1] Martin LeBoutillier III, MD,[1]
William Gee, MD,[2] Theodore Phillips, MD,[1] Raymond L. Singer, MD[1]

Lehigh Valley Hospital, Allentown, Pennsylvania
[1]Division of Cardiothoracic Surgery, Department of Surgery
[2]Vascular Laboratory, Department of Surgery

ABSTRACT

Background: Eighteen patients with unstable angina underwent repeat myocardial revascularization without cardiopulmonary bypass using saphenous vein grafts from either the left (13) or right (2) axillary arteries or the descending thoracic aorta (3). Patients' ages ranged from 53 to 85 years. Left ventricular ejection fractions ranged from 15% to 60%.

Methods: In 14 patients, the heart was exposed through an anterior thoracotomy, a minimally invasive direct coronary artery bypass (MIDCAB) technique. In 3 patients a left posterolateral thoractomy (lateral MIDCAB) was performed. One patient underwent repeat sternotomy (off-pump coronary artery bypass: OPCAB). In MIDCAB and lateral MIDCAB patients, the "target" vessel was a coronary artery in 8 patients and a previously placed vein graft in the remaining 9 patients. One patient underwent repeat sternotomy, and 3 coronary arteries were bypassed with a complex vein graft attached to the left axillary artery. Two patients died of mesenteric ischemia on the 2nd and 7th postoperative day. The remainder of patients were discharged from the hospital free of angina. Early graft patency was demonstrated by noninvasive vascular laboratory testing and/or angiography in the 13 survivors in whom the axillary artery had been the site of the proximal anastomosis.

Results: Follow-up ranged from 1 to 25 months. No other patients have died, and none have undergone additional surgical or catheter-based procedures. Three patients have developed recurrent angina, and in 4 patients the extra-anatomic bypass grafts have apparently become occluded.

Conclusion: Extra-anatomic, off-pump bypass from the axillary artery or descending thoracic aorta to one or more coronary arteries can be performed safely in seriously ill patients requiring a repeat bypass procedure. The early results, regarding relief of angina, are encouraging.

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Address correspondence and reprint requests to: Michael C. Sinclair, MD, Lehigh Valley Hospital, Cedar Crest & I-78, P.O. Box 689, Allentown, PA 18105-1556, Phone: (610) 402-1296, Fax: (610) 402-1667, Email: sally.lutz@lvh.com

INTRODUCTION

Bypass of the left internal mammary artery (LIMA) to the left anterior descending artery through a small left anterior thoracotomy without cardiopulmonary bypass (CPB), a minimally invasive direct coronary artery bypass (MIDCAB) technique, has become an accepted operative procedure [Subramanian 1995, Calafiore 1996a, Borst 1997, Shennib 1997, Nguyen 1998, Matheny 1999]. In addition to MIDCAB, there has been considerable interest in other novel approaches to myocardial revascularization such as xiphoid MIDCAB, ministernotomy MIDCAB, lateral MIDCAB, sternotomy with off-pump coronary artery bypass (OPCAB), and port-access revascularization [Benetti 1991, Robinson 1995, Buffolo 1996, Stevens 1996a, Stevens 1996b, Fonger 1997, Dullum 1999, Hart 1999].

Though the long-term results of these procedures compared with standard coronary bypass grafts with sternotomy and CPB are yet to be determined [Calafiore 1996b, Bonchek and Ullyot 1998, Mathey 1999], it is clear that coronary arteries can be bypassed in the beating heart with relative safety. The avoidance of CPB is particularly attractive for patients in whom the bypass itself is felt to be hazardous—namely the elderly, patients with arch vessel disease, and patients with poor left ventricular function and/or renal insufficiency. In addition, there is some advantage to avoiding a repeat sternotomy in patients requiring re-operation. The absence of a usable LIMA need not be a contraindication to MIDCAB or OPCAB [Calafiore 1996b, Knight 1997, Bhimji 1998]. Provided

Table 1. Patients Who Underwent Repeat Extra-anatomic Myocardial Revascularization Without Cardiopulmonary Bypass

									Vascular Laboratory**			Clinical***	
Patient	Age	Sex	LVEF (%)	Date Prior Op	Op	Date Op	Proximal Anastomosis	Distal Anastomosis	Angiogram*	Initial	Last Check Up *(mos. postop)*	Results	Months Postop	Angina
1	82	F	40	1984	MIDCAB	01/30/97	LAA	SVG/LAD	nd	nd	****			
2	77	M	60	1981 1992	MIDCAB	07/07/97	LAA	SVG/LAD	nd	+	9	+	25	+
3	71	F	40	1997	MIDCAB	10/20/97	LAA	SVG/LAD	+	+	nd		22	++
4	71	M	25	1989	MIDCAB	12/28/97	LAA	DIAG	nd	+	1	+	15	-
5	60	F	60	1974 1982 1991	MIDCAB	03/24/98	RAA	SVG/RCA	nd	+	14	+	14	-
6	85	F	50	1983	MIDCAB	05/26/98	LAA	SVG/LAD	nd	+	13	-	13	-
7	77	M	55	1986	MIDCAB	11/06/98	LAA	LAD	nd	+	7	-	7	-
8	84	F	50	1983	MIDCAB	11/11/98	LAA	LAD	nd	+	6	-	9	-
9	53	M	45	1985	MIDCAB	12/11/98	RAA	SVG/PDA	nd	+	7	+	7	+
10	70	M	55	1990	MIDCAB	03/02/99	LAA	LAD	nd	+	4	-	4	-
11	75	F	50	1997	MIDCAB	03/22/99	LAA	LAD	nd	+	nd		4	-
12	73	F	25	1991	MIDCAB	03/25/99	LAA	LAD	nd	+	3	+	4	-
13	60	M	55	1993	LATMIDCAB	04/01/99	Desc. Aorta	SVG/PL	nd	nd	nd		5	-
14	80	M	45	1981	OPCAB	05/18/99	LAA	LAD,DIAG,OM	+	?	nd		2	-
15	64	M	20	1996	MIDCAB	10/01/99	LAA	SVG/LAD	nd	+	nd		2	-
16	75	M	15	1990	LATMIDCAB	01/20/00	Desc. Aorta	OM,CIRC	nd	nd	****			
17	74	M	45	1994	LATMIDCAB	02/21/00	Desc. Aorta	OM	nd	nd	nd		2	-
18	77	M	45	1981,1998	MIDCAB	02/29/00	LAA	LAD	nd	+	nd		2	-

LVEF= left ventricular ejection fraction; MIDCAB = minimally invasive direct coronary artery bypass; LAT = lateral; OPCAB = off-pump coronary artery bypass; LAA = left axillary artery; RAA = right axillary artery; SVG/LAD = old vein graft to left anterior descending artery; DIAG = diagonal artery; SVG/RCA = old vein graft to right coronary artery; LAD = left anterior descending artery; SVG/PDA = old vein graft to posterior descending artery; SVG/PL = old vein graft to posterolateral artery; OM = obtuse marginal artery; CIRC = circumflex artery.
* nd = not done, + = patent, - = occluded
** nd = not done, + = patent, - = occluded, ? = not visualized
*** - = no angina, + = occasional angina, ++ = frequent angina
**** died postoperatively

Figure 1. (1) Infraclavicular incision for exposure of the axillary artery. (2) Second interspace incision for tunneling through the chest wall. (3) Inframammary incision for exposure of the heart.

there is no significant subclavian stenosis, the axillary artery can be used as a site for a proximal anastomosis. In addition, a graft can be anastomosed directly to the descending aorta through a lateral or posterolateral thoracotomy to revascularize the posterior surface of the heart. If the proximal portion of the graft is superficial, it can be interrogated in the vascular laboratory to determine graft patency.

PATIENTS

Between January 1997 and February 2000, 19 patients, who were felt to be candidates for off-pump procedures, were referred for repeat myocardial revascularization. In 1 patient, the LIMA was grafted to the left anterior descending artery; that patient was excluded from this report. The remaining 18 patients had at least 1 hospitalization for unstable angina which could not be managed medically. Some had multiple admissions. Patients were considered for extra-anatomic, off-pump bypass if a single "culprit" lesion was present which was accessible via 1 of these approaches. It is uncommon to recommend conventional repeat sternotomy with CPB for single-vessel disease. Two or more previous sternotomies or a history of a sternal wound infection are reasons to consider alternatives to repeat sternotomy. Left ventricular impairment, renal insufficiency, and advanced age were considered relative contraindications to CPB. The presence of a culprit lesion in the posterior surface of the heart is a reason to consider a lateral MIDCAB approach. Patient no. 16, for example, had 3 catheter-based procedures for a recurring circumflex lesion. There was a reluctance to

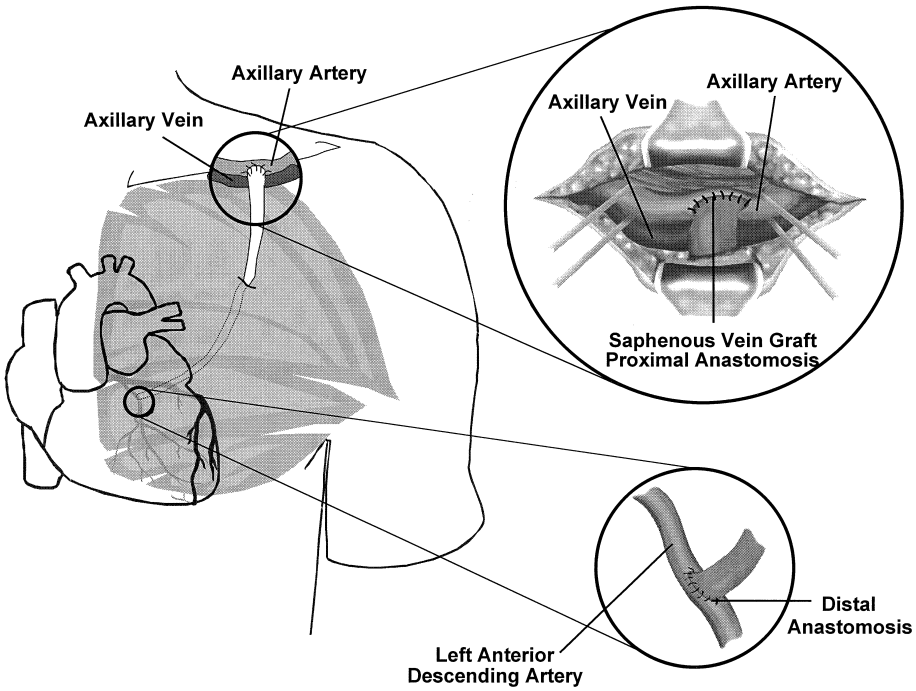

Figure 2. Anatomical diagram showing axillary vein and artery and a saphenous vein graft proximal anastomosis.

consider reoperation because of his age (75 years), chronic hemodialysis, severe left ventricular impairment, and the fact that he had a patent LIMA graft adjacent to the sternum. He was again admitted with angina requiring intravenous heparin and nitroglycerin and an operation was offered despite the fact that it was considered to be high risk. The clinical characteristics, operative information, and limited follow-up data are illustrated in Table 1 (◉). There were 11 men and 7 women in this series whose ages ranged from 53 to 85 years. The patients' left ventricular ejection fractions ranged from 15% to 60%. In 14 patients, the heart was exposed through an anterior thoracotomy. The "target" vessels were coronary arteries in 7 patients and previously placed vein grafts in the remaining 7 patients. One patient underwent repeat sternotomy, where 3 coronary arteries were bypassed with a complex vein graft attached to the left axillary artery. This patient was considered for conventional repeat myocardial revascularization. At cardiac catheterization and CAT scan, it was noted that his ascending aorta was heavily calcified ("egg shell aorta") making it unsuitable for either cannulation or attachment of proximal anastomoses. Because of concern about the safety of using the innominate artery in this instance, the left axillary artery was selected as the site for the proximal anastomosis. In 3 patients, vein grafts were placed from the descending aorta to circumflex coronary artery and/or its branches through a posterolateral thoractomy. Though most patients had their previous operations many years earlier, 1 patient had undergone emergency saphenous vein bypass grafting to the left anterior descending and obtuse marginal arteries only 7 months prior to re-operation.

OPERATIVE TECHNIQUE

The standard MIDCAB patients are placed in the supine position with the operative side slightly elevated on a small pillow. General anesthesia is administered through either a single- or, preferably, a double-lumen endotracheal tube. Standard arterial, pulmonary artery, electrocardiographic, and usually transesophageal echocardiographic monitoring is used. External defibrillation pads are placed so as not to interfere with the surgical incisions. An assistant harvests a segment of saphenous vein. The vein is turned antegrade, and the valves are ablated with a valvulotome. The axillary artery is exposed through an infraclavicular incision (Figures 1 and 2, ◉). The pectoralis major fibers are split, and the pectoralis minor is detached from the coracoid process of the scapula or simply retracted laterally.

As the axillary artery is mobilized, careful attention must be directed to avoid injury to the brachial plexus. In those instances where it is feasible to anastomose the vein to the extreme medial portion of the axillary artery, a tunnel is made into the chest cavity through the first interspace. It appears that the first interspace incision is preferable and less likely to cause a kinking of the graft. The first interspace is relatively large and oriented more in a coronal plane, and entry into the pleural space is more direct. Alternatively, a second small incision is made over the third rib in the midclavicular line, and the upper edge of the third rib is removed with rongeurs to allow an adequate opening into the pleural space for the vein graft. An anterior thoracotomy is made resecting the fourth or fifth costal cartilage. A limited opening is made into the peri-

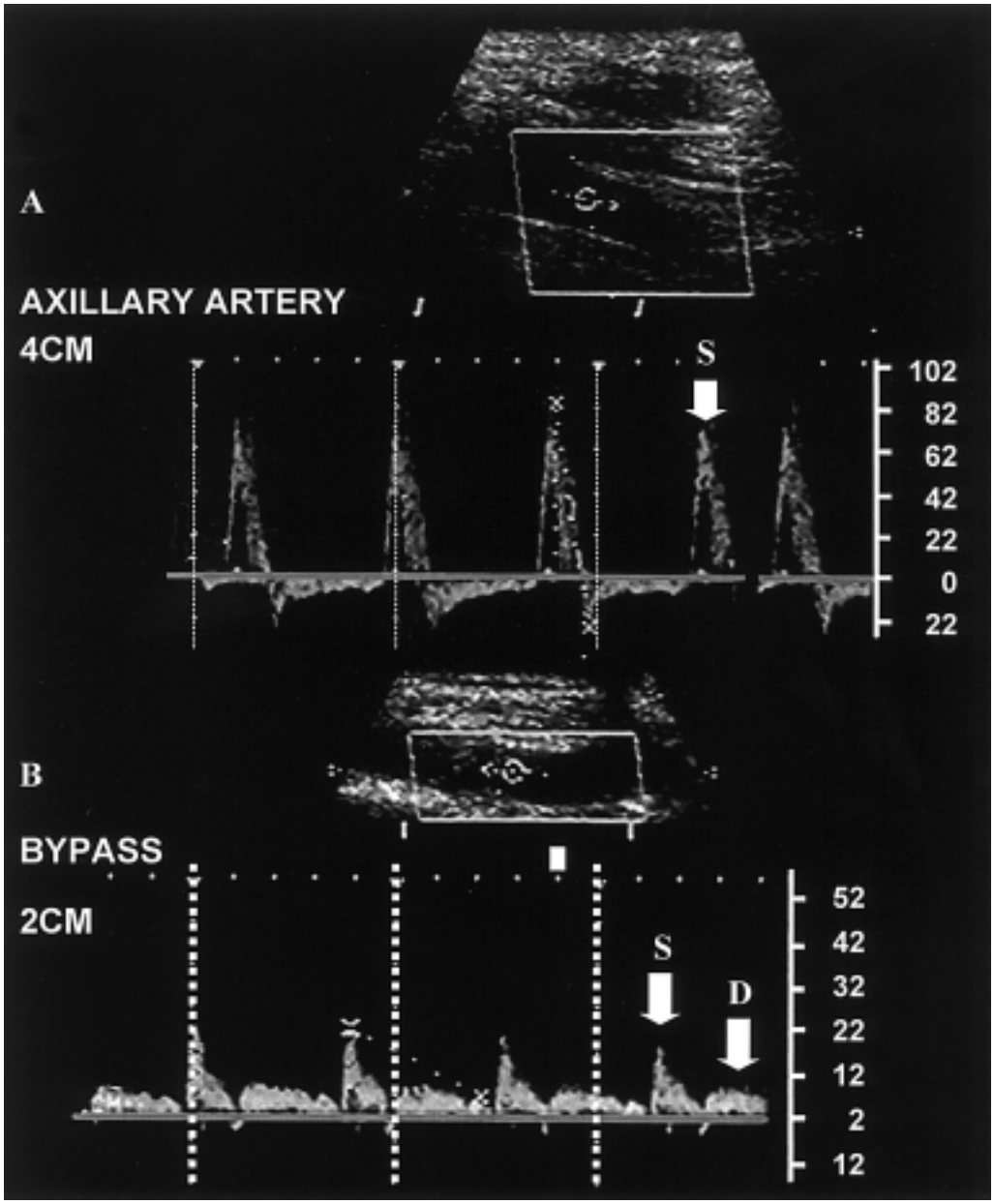

Figure 3. Doppler flow in both the axillary artery (A) and vein graft to the heart (B). Note that the flow in a systemic artery is monophasic, occurring exclusively in systole, whereas flow in a graft to a coronary artery is biphasic with a major diastolic component.

cardium, and the target vessel is surrounded with silastic vessel loops, both for stabilization and to decrease bleeding when the vessel is later opened. The patient is given 5,000 to 10,000 units of heparin systemically. The proximal anastomosis is made first, and the vein graft is passed through the previously made tunnel into the pleural space. The vein graft is draped over the apex of the lung and brought along the medial border of the left upper lobe following the usual course of a LIMA graft. Care is taken to avoid torsion of the graft. The lung is briefly hyperinflated, and the length of the graft is determined. The target vessel may be temporarily occluded for preischemic conditioning. If the target vessel is an old vein graft, there is some risk of atherosclerotic embolization during this maneuver, but we have not encountered this problem. The distal anastomosis is performed in the usual manner, using a blower to improve visibility.

For regrafting the circumflex distribution only, a posterolateral thoracotomy is used, and the proximal anastomosis(es) is placed on the descending aorta with the aid of a partial occlusion clamp. The graft(s) is brought distal to the pulmonary hilum after dividing the inferior pulmonary ligament.

When an OPCAB is performed, a standard repeat sternotomy is done. The axillary artery is exposed, and the extra-anatomic graft is tunneled as described above.

A stabilizing device is generally required only if the heart is extensively mobilized. Usually no protamine is administered. Temporary pacing wires are inserted, and the incisions are closed in the standard fashion after inserting a single chest tube.

RESULTS

Antegrade autogenous vein was used as the bypass conduit in all patients. In 2 patients in whom there was no remaining saphenous vein, a segment of lesser saphenous vein was used, and in another patient a segment of cephalic vein was used. All patients survived the operation, and none had evidence of a perioperative myocardial infarction. Two patients died of mesenteric infarction on the 2nd and 7th postoperative days. One morbidly obese man had postoperative paresthesia, but no motor deficit of the hand on the side of the axillary artery anastomosis. Seven months postoperatively, the paresthesia has decreased, but has not completely resolved. All survivors were discharged from the hospital free of angina. Early graft patency was demonstrated by noninvasive vascular laboratory testing and/or angiography (Figure 3, ◎) in all patients in whom the grafts originated from the axillary arteries. No attempt was made to visualize the grafts from the descending aorta.

Follow-up has ranged from 1 to 25 months. No other patients have died, and none have undergone additional surgical or catheter-based procedures. No patients have required hospitalization for recurrent angina. Two patients have occasional episodes of angina, but only 1 patient has angina that limits her lifestyle. In 4 patients, the extra-anatomic bypass grafts have apparently become occluded (by vascular laboratory testing), but none of these patients have angina.

DISCUSSION

Myocardial revascularization without CPB emerged as a procedure for a select group of low-risk patients—specifically those who needed a single bypass to the left anterior descending coronary artery. The techniques and technology of beating heart coronary artery bypass grafting are evolving rapidly and the indications and applications are broadening. Many of the seriously ill patients in this small series would probably not have been offered repeat myocardial revascularization had conventional coronary bypass grafting with sternotomy and CPB been the only option. There is appropriate concern about the long-term patency of grafts performed on the beating heart. The fact that 4 of 15 grafts from the axillary arteries have apparently become occluded in a short period of time is a cause for concern about the long-term fate of extra-anatomic bypass grafts. It is important that these developments be critically evaluated to determine what role they should have in the armamentarium of the cardiac surgeon.

CONCLUSIONS

Extra-anatomic, off-pump bypass from the axillary artery or descending aorta to 1 or more coronary arteries can be performed safely in seriously ill patients requiring a repeat bypass procedure. The early results, regarding relief of angina are encouraging. For patency determination, the grafts from the axillary arteries can be interrogated in the vascular laboratory.

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REVIEW AND COMMENTARY

1. Editorial Board Member JZ39 writes:

To take the vein from the axillary artery is a relatively novel concept. It should help with atherosclerosis, which may not be as severe there, and is certainly distal to the head vessels limiting chances for a stroke.

The Discussion needs to include information concerning the 2 patients who died from mesenteric ischemia. Did these patients with a graft from the descending die from emboli? Was TEE used to evaluate for atheromata?

Authors' Response by Michael Sinclair, MD

In Patient no. 1, the axillary artery (not the descending aorta) was used as the site for the proximal anastomosis. An inoperative TEE showed "arteriosclerotic plaquing of the descending aorta." Since the aorta was not manipulated, it is unlikely that the patient sustained intraoperative emboli. She did not have any hypotensive epidsodes or arrhythmias, intraoperatively or postoperatively. We speculate that termination of the preoperative heparin resulted in in situ thrombosis of the superior mesenteric artery, but have no proof for this hypothesis. On the second postoperative day, she developed an acute abdomen and an exploratory laparotomy revealed total infarction of the bowel from the ligament of Treitz to the terminal ileum. Support was withdrawn. An autopsy was not permitted.

Patient no. 16 did not have a TEE. A preoperative arteriogram showed no apparent atherosclerosis of the descending aorta. Like the previous patient, the intraoperative and postoperative course was uneventful until the second postoperative day. This patient developed fever, tachycardia, hypotension, and abdominal distention and tenderness. He went on to develop nausea and vomiting, lactic acidosis, and elevated lipase and amylase levels. A CAT scan of the abdomen was consistent with an ileus. He did not improve with fluid resuscitation and antibiotics. At the family's request, support (including chronic hemodialysis) was withdrawn. An autopsy was not permitted. The clinical diagnosis was mesenteric infarction.

2. Editorial Board Member AR11 writes

The manuscript itself is interesting and demostrates that off-pump procedures are limited only by the imagination of the surgeon. Within the body of the text, the reader is given several different approaches to the management of a patient requiring revascularization, for whom an on-pump procedure is not desired.

The authors, however, should modify their presentation to better assert their claims that this is indeed a "better" or even "warranted" choice of procedure. For example:

a) Even excluding the 2 patients who died of mesenteric ischemia, 7 of 16 patients (43.5%) would be scored as a "failed" revascularization based on either closed grafts or recurrent angina (with patent grafts). If the 2 deaths are included, this percentage increases to 50%.
b) The authors fail to show why these patients should have been selected for off-pump procedures. Only 4 of 18 patients (40%) had EFs and, aside from age, no other qualifying history is presented, although in the Discussion section the group is referred to as "seriously ill." Some confirming evidence would have been nice.
c) Why was it necessary to do left axillary artery grafting in the patient in whom OPCAB with sternotomy was performed? Couldn't the graft have been placed on the innominate or subclavian, both of which can be accessed via the sternotomy, rather than creating a second incision with tunneling thoracotomy? Some rationale for this approach is needed.

Authors' Response by Michael Sinclair, MD:

a) We do not assert that these procedures are "warranted" or "better" than standard on-pump, median sternotomy operations, but simply report our experience to date. We find it hard to agree with the concept that 7 patients were "failures" because of either recurrent angina (3) or apparently occluded graft (4). Time and space do not permit extensive clinical discussion of each case. All patients had unstable angina requiring at least 1 preoperative hospitalization. No patients required rehospitalization or other procedures for recurrent angina. All 3 patients with recurrent angina are managed medically and in 2 of the 3, the angina is not frequent. The apparent high rate of graft occlusion in vein grafts from the axillary arteries (4 of 15) in a relatively short follow-up is a cause of concern, and the lack of clinical correlation (ie, no recurrent angina in this group) is puzzling and requires further study. Only 1 patient had an arteriogram that confirmed that the graft was occluded and none had a postoperative stress test.
b) With regard to case selection, all patients except the OPCAB (Patient no. 14) and Patient no. 6 had a single "culprit" lesion that could not be treated safely with a catheter-based procedure. Patient no. 6 had a MIDCAB followed by an angioplasty or a right coronary artery lesion. We find it difficult to recommend repeat sternotomy with cardiopulmonary bypass for single-vessel disease. Age was another factor in case selection. Thirteen patients were a minimum of 70 years old and 4 were octogenarians. Multiple prior operations also

influenced our decision. Two patients had prior myocardial revascularizations and 1 patient had 3. Patient no. 1 had had a prior sternal wound infection that would be expected to make repeat sternotomy more risky. Poor left ventricular function was another relative indication for these procedures.

c) We did not use the innominate artery for a proximal anastomosis because of concern about the possibility of stroke when manipulating the innominate artery in a patient with a calcified ascending aorta. The right subclavian artery could be reached by extending the sternotomy, but the left would be difficult (at least for me) to reach. The left axillary artery was relatively easy to expose, but as pointed out by the reviewer, the graft had to be tunneled into the chest.

3. Editorial Board Member PB44 writes:

This is an innovative approach to finding a source for the top end. The article, however, needs more detail about the choice of this procedure. The authors mention a target vessel. Was this the only vessel bypassed? What percentage of redo cases for this service does this series represent?

There is no discussion about patient selection and coronary anatomy. What were the target vessels? What about other lesions that may have been present? Why exclude the 1 patient with a patent IMA?

Authors' Response by Michael Sinclair, MD:

In all cases except the OPCAB (Patient no. 14) and 1 of the LATMIDCABs (Patient no. 16), a single bypass was performed for a "culprit" lesion. As mentioned above, Patient no. 6 had a bypass to a saphenous vein graft to the LAD followed by an angioplasty/stent to the native RCA. The fact that she remains angina-free despite apparent occlusion of the extra-anatomic graft raises the possibility that a patent RCA may be responsible for her lack of symptoms. The cardiologists were unwilling to perform the procedure on the RCA until the heart was "protected" by revascularization of the anterior surface. These cases represent approximately 7% of the reoperations for myocardial revascularization at our institution during that time interval. The patient in whom the LIMA was used was excluded from this analysis because this report is limited to "extra-anatomic" bypass.

4. Editorial Board Member SC389 writes:

This is a very good option for redo patients that surgeons can have in their armamentarium.

We have done this approach without bringing the graft extra-anatomic. Is there any concern for graft compression in this position? Also, would the author comment on the intrathoracic course of the graft and concern for kinking or compression from the lung?

Authors' Response by Michael Sinclair, MD:

We are concerned about the potential for graft compression, torsion, or kinking with this approach. More recently, we have brought the graft medially through an opening in the first interspace. The first interspace is quite wide and oriented in more of a coronal plane. It is relatively easy to make a large opening by excising the intercostal muscle with electrocautery. This variation makes a more "direct shot" into the thoracic cavity with less potential for extrathoracic compression of the graft. (It also makes it more difficult to visualize the graft with ultrasound.) The graft is draped over the apex of the lung and brought medial, more or less paralleling the course of a LIMA graft. As mentioned in the text, it is important to inflate the lung to determine the proper length of the graft and orientation of the distal anastomosis.

5. Editorial Board Member TL41 writes:

The report and its conclusions are somewhat overstated. For example, the last sentence of the Abstract could more accurately be phrased: "The early results, with hospital mortality of 11%, recurrent angina in 19% of survivors, likely graft occlusion in 25% of survivors, and only 55% of all patients alive, with patent grafts and angina free at a median survival interval of 4 months, are discouraging."

The wording could be clearer in parts, e.g., what is meant by: "The vein is turned antegrade and the valves ..." in the Operative Technique?

Authors' Response by Michael Sinclair, MD

When a vein is harvested, an irrigation needle is placed in the distal end and the vein is flushed with heparinized saline to determine both that the tributaries have been successfully ligated and that the vein is patent. We consider this direction of flow to be retrograde, ie, toward the heart, the normal way blood flows through the vein. Since the proximal end of the vein is usually larger than the distal end, we routinely remove the irrigating needle from the distal end and insert it in the proximal end. While an assistant gently distends the vein, the surgeon inserts a rigid valvulotome into the vein, and while withdrawing the valvulotome, cuts each pair of valves encountered. The size match for proximal and distal anastomoses is usually better with this technique.

Other lesions were ignored or, in 1 case, the patient had an angioplasty of a right coronary lesion following our operation. One patient was excluded because the left internal mammary artery was grafted to the left anterior descending artery, and this report is about extra-anatomic revascularization. Because there is some concern about graft compression and kinking or compression of the lung, we hyperinflate the lung during the procedure.

The reviewer feels the results are discouraging; in our opinion, they are encouraging. We believe the operative technique section is quite clear.