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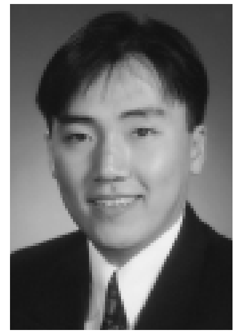
Noninvasive Graft Flow and Patency Assessment Following Minimally Invasive Direct Coronary Artery Bypass (MIDCAB) Grafting



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ABSTRACT

Objective: Assessment of graft patency following minimally invasive direct coronary artery bypass (MIDCAB) surgery is essential in order to determine the efficacy of this technique. This study was conducted to evaluate the role of intraoperative and postoperative noninvasive flow and velocity measurements to follow and predict graft performance.

Methods: Between April 1996 and July 1997, 130 patients had 133 grafts placed using MIDCAB techniques. Intraoperative transit-time ultrasound was used to assess graft patency and flow prior to wound closure. Also, serial transcutaneous Doppler examinations were performed to evaluate graft patency on the first postoperative day, at two weeks, and at three months. Peak values for systolic and diastolic waveforms were measured for both flow and velocity, and the diastolic-to-systolic ratio was calculated at each time interval. Recatheterization was performed selectively for inadequate ultrasound flow or Doppler velocity, or for patient symptoms.

Results: Seven (5.3 %) grafts developed stenosis or occlusion. When compared to normal grafts, mean intraoperative flows, flow ratios, and velocity ratios were lower. Mean postoperative diastolic peak velocity (DPV) to systolic peak velocity (SPV) ratio remained stable over time for normal grafts; however, grafts with stenosis or occlusion demonstrated a diminished DPV/SPV ratio.

Conclusions: Intraoperative transit-time ultrasound and outpatient transcutaneous Doppler examinations did not reach a predictive value for graft stenosis or occlusion following MIDCAB surgery in this series of patients. However, these data demonstrate trends that may help identify patients at an increased risk for unfavorable events, guiding the use of postoperative recatheterization in such patients.

INTRODUCTION

The number of minimally invasive direct coronary artery bypass (MIDCAB) procedures performed has increased rapidly since the first reported case in 1995. Advantages of MIDCAB grafting include smaller incisions and the avoidance of cardiopulmonary bypass, which may potentially reduce mortality and morbidity. Several authors have now reported encouraging results [Arom 1996, Calafiore 1996, Ribakove 1997, Stanbridge 1997, Subramanian 1997, Spooner 1998]. MIDCAB grafting can also provide economic advantages over conventional coronary artery bypass, due to reduction in postoperative length of stay and surgical supplies [Doty 1997].

Assessment of graft patency following MIDCAB grafting is essential to determine the efficacy of this technique. Use of intraoperative Doppler spectrum analysis of blood flow velocities for revascularization procedures performed with conventional cardiopulmonary bypass has been described [Hiratzka 1987]. Noninvasive methods can also provide valuable intraoperative information on graft flow, and characterize the patterns of coronary blood flow.

Postoperative noninvasive assessment of graft function via transcutaneous Doppler flow velocity evaluation may also be useful in graft assessment after coronary artery bypass grafting [Canver 1994]. The objective of this study is to evaluate the potential role of noninvasive flow and velocity measurements in the follow-up, and predict graft performance after MIDCAB procedures.

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Table 1. Patient Characteristics for Patients with Postoperative Graft Complications

Patient	Conduit	Target	Event
55 yr male	GEA	PDA	Small anastomotic stenosis 3 months postoperatively; successful percutaneous dilation
61 yr female	GEA	RCA	Anastomotic stenosis 3 months postoperatively; successful percutaneous dilation
63 yr male	GEA	RCA	Graft occlusion one week postoperatively coincidient with episode of atrial fibrillation. Successful percutaneous dilation
75 yr female	LIMA	LAD	Anastomostic stenosis 2 months postoperatively; successful percutaneous dilation
69 yr male	LIMA	LAD	Mild distal narrowing of LAD 3 months postoperatively; redo CABGx2 six months postoperatively
73 yr male	LIMA	LAD	Extrinsic compression of LIMA by lateral edge of pericardium on first postoperative day; required pericardial release
59 yr female	LIMA	LAD	Hematoma compression resulted in graft compression and occlusion 4 days postoperatively

Table 2. LIMA Graft Parameters for Event and Event-free Groups

	Event	Event-free
n	4	82
Mean intraop. flow	16.5 (8.2)	24.0 (14.5)
Mean SPV		
POD #1	13.4 (4.6)	10.2 (3.6)
2 week	10.3 (3.8)	11.1 (3.0)
3 month	11.3 (3.2)	10.2 (5.6)
Mean DPV		
POD #1	7.6 (3.4)	5.8 (2.5)
2 week	5.7 (2.7)	6.8 (2.6)
3 month	6.8 (3.9)	6.7 (3.5)
DPV/SPV ratio		
POD #1	0.58 (0.24)	0.56 (0.15)
2 week	0.53 (0.09)	0.61 (0.14)
3 month	0.57 (0.18)	0.65 (0.15)

MATERIALS AND METHODS

Graft Selection

One hundred thirty patients had 133 arterial grafts placed over a 15-month period from April 1996 to July 1997 at Sinai Hospital in Baltimore, Maryland. One hundred twenty-seven patients had single vessel grafting; 83 had left internal mammary artery (LIMA) grafting, and 44 had gastroepiploic artery (GEA) grafting. One patient had bilateral grafting with both left and right internal mammary (RIMA) arteries and one patient had both LIMA and GEA grafting. LIMA grafting was performed to the left anterior descending artery (LAD) in 84 patients, and to existing saphenous vein grafts (SVG) in two patients. RIMA grafting was performed to the right coronary artery (RCA) in one patient. GEA grafting was performed to the RCA in 25 patients, to the posterior descending artery (PDA) in 15 patients, and to the distal LAD in five patients.

Operative Technique

All patients underwent MIDCAB grafting without cardiopulmonary bypass on the non-arrested heart. LIMA grafts were placed via a small anterior thoracotomy in the fourth intercostal space for grafting of anterior surface targets. GEA grafts were placed via a small midline epigastric incision and routed over the liver into the pericardium for grafting of inferior surface targets. All grafts were placed using hand-held stabilization after heparinization and local coronary occlusion.

Noninvasive Graft Assessment

Grafts were assessed intraoperatively with hand-held transit-time ultrasound (Transonic Systems, Inc., Ithaca, NY). Absolute graft flow rates and waveforms were obtained for each graft. Transcutaneous Doppler spectra were obtained on the first postoperative day for all patients. Patients were then followed with clinic visits at two weeks, and three months. Transcutaneous Doppler flow evaluation was repeated at each visit to assess flow velocity and graft patency.

Data Analysis

Each Doppler evaluation was analyzed for peak systolic and peak diastolic value for a minimum of three consecutive waveforms. A mean peak systolic velocity and a mean diastolic peak velocity was then generated for each evaluation from these measurements. The diastolic peak velocity to systolic peak velocity ratio was also calculated for each Doppler evaluation.

Patients were assigned to two groups according to graft performance at last follow-up. Patients with graft stenosis or occlusion were assigned to the event group, while patients with patent grafts were assigned to the event-free group. Patients with inadequate flow on Doppler evaluation who did not have graft stenosis or occlusion on catheterization were also grouped in the event-free category. The groups were then compared using Fishers exact test for intraoperative flow rate, systolic peak velocity (SPV), diastolic peak velocity (DPV), and DPV/SPV ratio.

RESULTS

Seven (5.3%) patients had graft stenosis or occlusion during the follow-up period. Four of these patients received LIMA grafts and three patients received GEA grafts. Pertinent data for these patients are listed in Table 1 ( ). Representative data for intraoperative flow rates and postoperative Doppler evaluations are listed in Tables 2

Table 3. GEA Graft Parameters for Event and Event-free Groups

	Event	Event-free
n	3	42
Mean intraop. Flow	7.0 (6.9)	16.4 (14.7)
Mean SPV		
POD #1	8.8 (1.8)	11.4 (4.3)
2 week	9.7 (3.5)	12.1 (4.6)
3 month	13.1 (1.3)	12.5 (4.1)
Mean DPV		
POD #1	3.7 (0.6)	5.0 (2.6)
2 week	4.0 (1.0)	5.2 (2.4)
3 month	3.3 (2.3)	5.5 (2.5)
DPV/SPV ratio		
POD #1	0.43 (0.14)	0.45 (0.19)
2 week	0.45 (0.19)	0.44 (0.18)
3 month*	0.25 (0.15)	0.48 (0.22)

*p=0.05

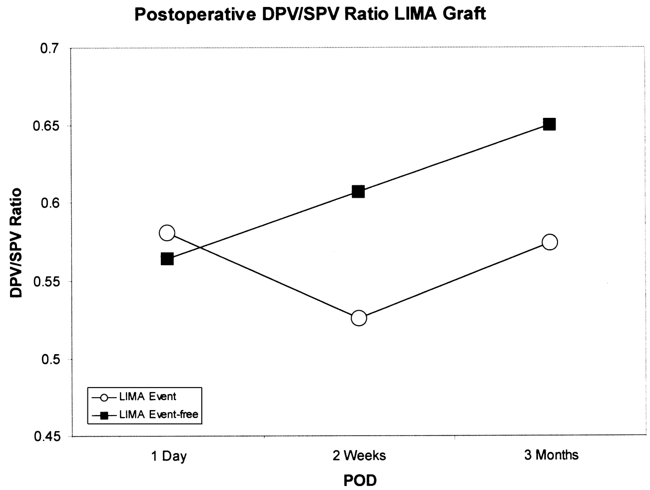

Figure 1. Postoperative DPV/SPV ratio for patients undergoing LIMA grafting

and 3 () for LIMA and GEA grafts, respectively. All patients had transcutaneous Doppler evaluation on the first postoperative day. In the GEA population, Doppler evaluation was performed on 32 patients at two weeks and 27 patients at three months. In the LIMA population, Doppler evaluation was performed on 73 patients at two weeks and 61 patients at three months.

For the GEA population, the mean intraoperative flow rate for the event group was 7.00 ± 6.93 compared to 16.38 ± 14.68 for the event-free group (p=0.28). The mean intraoperative flow rate for the LIMA event group was 16.50 ± 8.19 compared to 24.02 ± 14.50 for the event-free group (p=0.31). In the LIMA population, the event group had a decrease in DPV/SPV ratio at the two week evaluation, whereas the event-free group demonstrated an increase in DPV/SPV ratio (see Table 2 and Figure 1) (p=0.26). Both groups had an increase in the DPV/SPV ratio at three months. Two patients in the event group developed graft stenosis or occlusion within two weeks of operation, and two patients developed graft stenosis between the two week and three month follow-up visits. Figure 2a () shows the Doppler waveform tracing for a patient receiving a LIMA graft without postoperative graft complications at one year. Figure 2b shows the Doppler waveform tracing obtained from a patient who had developed symptoms by the two week follow-up and was subsequently found to have graft occlusion by catheterization. The absence of diastolic augmentation of flow is clearly demonstrated in this tracing.

Postoperative Doppler flow velocity comparisons demonstrated that for the GEA population, both the event group and the event-free group demonstrated comparable DPV/SPV ratios up to two weeks postoperatively (see Table 3, Figure 3). However, Doppler flow evaluations at the three month follow-up showed a marked decrease in the DPV/SPV ratio for the event group, whereas the DPV/SPV ratio increased in the event-free group (p=0.05). Two of the three patients in the GEA event group had developed symptoms between the two week and three month clinic visits, and were found to have diminished Doppler velocity on exam. The third patient in the GEA event group developed atrial fibrillation on postoperative day 1, and subsequent catheterization showed the GEA graft to be occluded near the anastomosis; the stenosis was successfully dilated percutaneously. Figure 4a () shows the Doppler waveform tracing for a patient with patent GEA graft three months postoperatively, with excellent diastolic augmentation of flow. Figure 4b shows the absence of diastolic augmentation of flow in a Doppler waveform tracing obtained

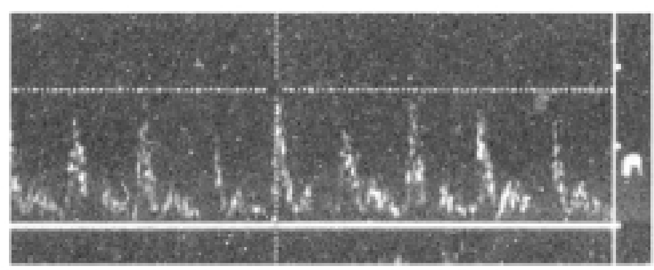

Figure 2a. Postoperative Doppler waveform tracing for patient with LIMA graft without complications at one year

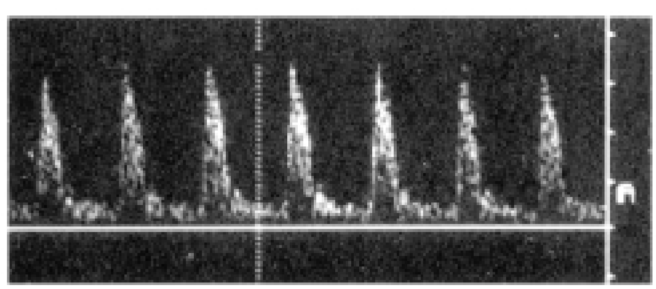

Figure 2b. Postoperative Doppler waveform tracing for patient with LIMA graft with graft occlusion at 2 weeks

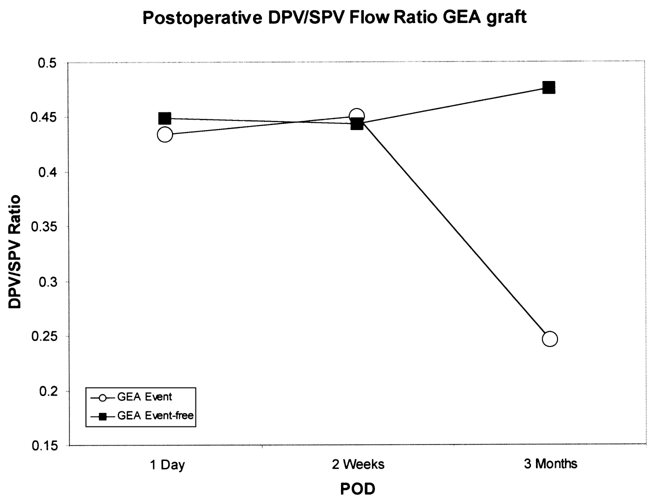

Figure 3. Postoperative DPV/SPV ratio for patients undergoing GEA grafting.

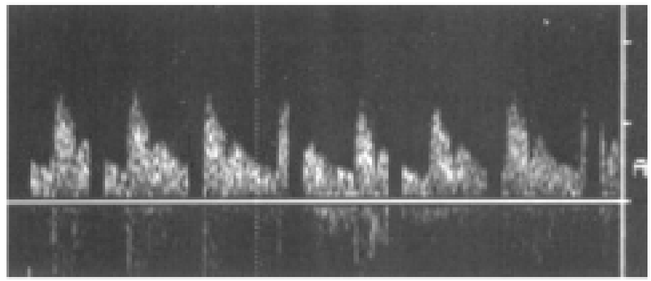

Figure 4a. Postoperative Doppler waveform tracing for patient with GEA graft without complications at one year

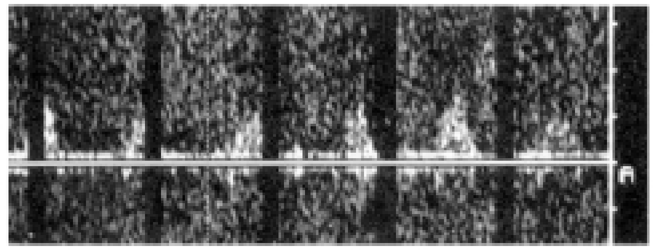

Figure 4b. Postoperative Doppler waveform tracing for patient with GEA graft with graft occlusion at 2 weeks

from a patient who had developed graft occlusion by the two week follow-up.

DISCUSSION

MIDCAB operations and off-pump coronary artery bypass (OPCAB) grafting through sternal incisions are being performed with increasing frequency. The body of literature that discusses the role of intraoperative and postoperative assessment of graft patency is accumulating. These studies are critical in the development of noninvasive methods that will evaluate the long-term efficacy of MIDCAB grafting, and identify variables that may predispose patients to developing postoperative graft complications. Coronary angiography remains the gold standard for evaluation of graft patency, but may not be indicated or desired in asymptomatic patients with no evidence of compromised myocardial perfusion. The role of noninvasive methods of graft assessment such as transcutaneous Doppler analysis has not been fully evaluated.

Intraoperative assessment of graft patency is essential for the detection of potentially reversible technical problems prior to leaving the operating room. A previous study by Canver and Dame demonstrated that transit-time ultrasound can be used to assess graft flow intraoperatively during conventional coronary artery bypass grafting (CABG) [Canver 1994]. The series of patients in this study provides a similar experience with patients undergoing MIDCAB grafting. Although the difference in intraoperative flow did not reach a predictive value in this small group of patients, the data shows provocative trends that may be significant in a larger clinical study.

Postoperative evaluation of the graft with transcutaneous Doppler can effectively identify acute graft occlusion, as demonstrated by the patient with graft impingement on postoperative day one. The DPV/SPV ratio has been shown by other authors to be an important prognostic indicator in predicting the performance of graft function in conventional CABG [Nishida 1994, Crowley 1995]. In this series of patients, there was a strong correlation between a decrease in DPV/SPV ratio on postoperative Doppler flow evaluation with graft failure, although this correlation also did not reach statistical significance in this series.

Coronary angiography continues to be the gold standard for evaluation of graft patency [Elbeery 1997, Gill 1997, Lazzara 1997, Possati 1998]. However, noninvasive Doppler flow velocity evaluation has gained popularity over recent years given the simplicity of the measurements. Previous clinical applications of this technique have reported difficulty in imaging the graft, with detection rates for LIMA and RIMA grafts varying from 47% to 79%, and detection rates for GEA conduits near 90% [Fusejima 1990, van Son 1993, Nishida 1994]. In this series of patients, there was a 100% detection rate for all patent grafts.

In conclusion, this small series of patients demonstrates that a decrease in the intraoperative transit-time flow, as well as a decrease in the DPV/SPV ratio are factors that may be associated with the development of graft stenosis or occlusion. Although these variables did not reach a predictive value for graft stenosis or occlusion following MIDCAB surgery in this small series, these trends may identify patients with an increased risk of developing an unfavorable event in larger patient populations. Our data also suggest that a well-functioning graft should demonstrate a slight increase in the DPV/SPV ratio over time as the graft accommodates to the coronary outflow. Conversely, a decreasing ratio signals a potential problem and is an example of how these noninvasive modalities can guide the clinician during routine follow-up of arterial conduits grafted with minimally invasive techniques.

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