*Original Article*

# Graft Flow Increases with Release of Stabilizing Device in Off-pump Coronary Surgery

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**Transit-time Doppler can be used for intraoperative assessment of graft patency, by measuring conduit flow, or from the calculation of a derivation of the spectral waveform. The optimal timing of measurement is when graft flows are maximal.**

**Fifteen patients underwent multivessel coronary bypass surgery without the use of cardiopulmonary bypass. Transit-time Doppler of 57 anastomoses was performed immediately before and after release of the Octopus stabilizing device, and mean graft flow was measured as over 5 consecutive beats. The graft flow increased after release of the stabilizing device for all grafts from 20.1±1.8 to 33.2±2.4 ml/min (P<0.001). When analyzed by individual grafts, and by coronary artery territory, the increase in flow remained significant. The timing of transit-time Doppler assessment of conduit flow should be performed immediately after release of the stabilizing device. (Ann Thorac Cardiovasc Surg 2003; 9: 384–8)**

**Key words:** transit-time Doppler, off-pump coronary artery bypass surgery, conduit flow

## Introduction

The prospect of intraoperative assessment of graft flow as a predictor of patency has been a goal sought by many, as it could facilitate immediate graft revision and lower the risk of graft failure. Transit-time Doppler allows instantaneous graft flow measurement. Based on the flow rate,[1-4] or a calculation derived from the instantaneous flow trace,[5-7] prediction of patency is made. Most series describe intraoperative revision with technical errors found and/or correction of poor flow subsequent to revision. There are few series systematically examining graft patency where intraoperative assessment was considered satisfactory.[6] Intraoperative alternatives to transit-time Doppler include intraoperative angiography, thermal coronary angiography,[8] hand held high frequency ultrasound probes (pulsed wave Doppler),[9,10] and use of an electromagnetic flow meter.[11] None of these methods has gained widespread acceptance.

Assessment of graft flow is of particular importance during the evolution of new surgical techniques, such as off-pump coronary artery bypass grafting (OPCABG), where the operator may wish to check patency after each anastomosis. The effect of retraction and stabilization may influence graft flow, as the resistance to graft flow may be increased by the mechanical pressure exerted by the stabilizing device distal to the anastomosis. A low graft flow in this setting could lead the surgeon to wrongly assume that the graft was defective. Maximal graft flow should occur when arteriolar resistance distal to the anastomosis is minimal, which is likely to occur following a period of ischemia to the vascular bed.

Our aim was to identify the effect on transit-time Doppler assessment of graft flow during the application and release of a stabilizing device used in “off-pump” coronary artery bypass surgery.

## Materials and Methods

Following approval from the Royal Melbourne Hospital Human Ethics Committee, written informed consent was obtained from 27 patients undergoing off-pump coronary

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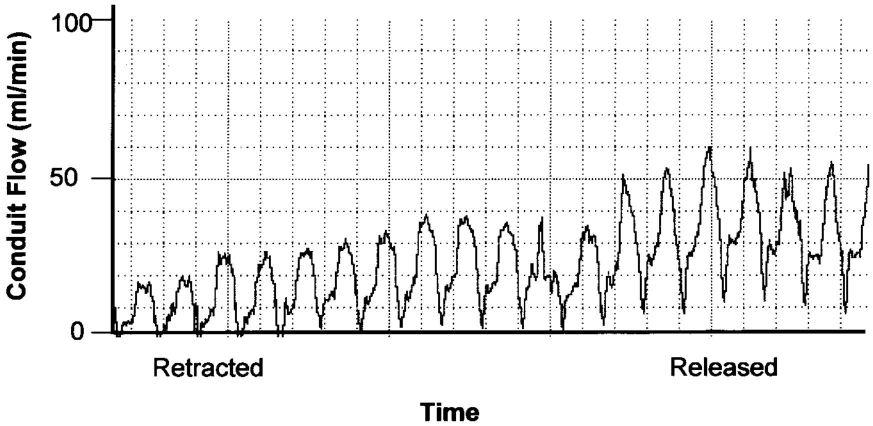


**Fig. 1.** Transit-time Doppler tracing of conduit flow before and after release of the stabilizing device.

artery bypass surgery, performed by a single surgeon.

**Surgical technique**

All patients underwent multivessel revascularization without the use of cardiopulmonary bypass. A Y graft was constructed using the left internal mammary artery (LIMA) and the radial artery (RA).[12] The LIMA was used to graft the left anterior descending artery (LAD) territory and the RA used for the remaining territories. The Octopus III stabilizing device (Medtronic, Inc., Minneapolis, MN, USA) was used in all cases. This device uses a combination of suction and direct pressure on the myocardium immediately adjacent to the coronary artery at the site of anastomosis, to stabilize the heart.

**Flow measurement**

*Equipment*

Intraoperative blood flow measurements were performed using H2MB or H3MB (2.5 or 3.0 mm) handle-style, perivascular transit-time Doppler flow probes connected to an HT207 dual channel flowmeter (Transonic Systems Inc., Ithaca, NY, USA). Probes are placed around the vessel to be measured and sterile gel is used for acoustic coupling (Aquasonic 100, Parker Laboratories, Inc., Orange, NJ, USA). In the case of the LIMA, some dissection of tissues around the artery was usually required to facilitate passage of the probe around the artery. Mean blood flow (ml/min) was calculated from a sample of 5 heartbeats. Continuous recordings of arterial pressure and blood flow were stored for off-line analysis using WINDAQ data acquisition and playback software (DATAQ Instruments, Inc., Akron, OH, USA). Mean arterial pressure (MAP, mmHg) was measured simultaneously with pressure transducers positioned at mid-axillary level.

*Segmental graft flow measurement*

In each graft segment flow (ml/min) was measured by placing the Doppler probe immediately proximal to the anastomosis. Measurements were taken after completion of the anastomosis whilst the stabilizing device remained in position (Retracted) and immediately after the removal of the stabilizing device (Released) (Fig. 1). For analysis of grafts grouped according to coronary territory, the intermediate artery was considered within the circumflex (Cx) territory.

*Validation of transit-time Doppler measurements*

Transit-time Doppler has been previously validated in cardiac surgery patients.[4,13] Prior to grafting, the transit-time Doppler method was compared with flow measured by the collection of blood in a beaker over 6 seconds from the freely flowing ends of the composite grafts (manual method).

Patients were excluded where there was more than a 35% variance between the Doppler flow and the manual flow. We allowed this magnitude of variance to account for errors inherent in clinical measurements and because blood was collected for only 6 seconds. Subsequent to grafting, segmental graft flows were excluded if the quality of the trace did not allow adequate analysis for 5 beats.

**Statistical analysis**

The statistical analyses were performed using SPSS for Windows v11.0.0 (SPSS Inc., Chicago, IL, USA). All values are expressed as mean ± 1 standard error of the mean (SEM). Differences were assessed by 2-tailed, paired samples t-tests, with adjustment for multiple hy-

**Table 1. Validation of initial Doppler flow**

| | Transit-time Doppler flow (ml/min) | Manual flow (ml/min) | P | P' |
|---|---|---|---|---|
| LIMA open | 94.0±15.3 | 83.5±11.2 | 0.095 | 0.285 |
| RA open | 202.9±21.3 | 180.4±17.1 | 0.097 | 0.285 |
| LIMA and RA open | 237.5±19.1 | 215.3±15.8 | 0.141 | 0.285 |

LIMA open is flow measured with the left internal mammary artery open and the radial artery clamped. RA open is flow measured with the radial artery open and the left internal mammary artery clamped. LIMA and RA open is flow measured with both conduits open. Manual flow was calculated from the volume of blood collected in 6 seconds. P' is adjusted statistic for testing three comparisons using the Ryan-Holm Bonferroni stepdown procedure.

**Table 2. Transit-time Doppler flow by graft**

| Grafts (n) | Retracted flow (ml/min) | Non retracted flow (ml/min) | MAP (mmHg) | P | P' |
|---|---|---|---|---|---|
| D1 (8) | 20.9±4.8 | 40.0±5.8 | 88.9±3.2 | <0.001 | 0.001 |
| D2 (5) | 34.6±11.7 | 59.4±13.3 | 89.4±3.11 | <0.001 | 0.001 |
| LAD (12) | 23.0±2.8 | 33.3±4.5 | 91.1±4.1 | 0.02 | 0.020 |
| M1 (10) | 18.8±2.4 | 32.9±2.3 | 84.4±4.3 | <0.001 | <0.001 |
| M2 (6) | 13.5±3.7 | 25.7±6.5 | 81.7±4.7 | 0.01 | 0.021 |
| M3 (2) | 11.0±7.0 | 12.0±4.0 | 81.5±8.5 | 0.795 | – |
| M4 (1) | 10.0 | 22.0 | 74.0 | – | – |
| PDA (9) | 19.0±5.2 | 30.9±6.0 | 73.2±2.8 | 0.001 | 0.004 |
| Ix (2) | 10.0±2.0 | 12.5±2.5 | 78.0±7.0 | 0.126 | – |
| LVBr (1) | 9.0 | 12.0 | 90.0 | – | – |
| Distal LAD (1) | 10.0 | 22.0 | 74.0 | – | – |

D, diagonal arteries; LAD, left anterior descending artery; M, marginal arteries; PDA, posterior descending artery; Ix, intermediate artery; LVBr, left ventricular branch artery; MAP, mean arterial blood pressure.
The number of grafts is represented by (n). P' is the adjusted statistic for testing three comparisons 11 comparisons using the Ryan-Holm Bonferroni stepdown procedure.

pothesis testing by the Ryan-Holm Bonferroni stepdown procedure (P'), to correct for family-wise Type 1 error.[14] Significance was considered present if P'≤0.05.

## Results

Twenty-seven patients were recruited to the study. Eleven patients were excluded because the difference in flow between transonic and manual methods was >35%. In one patient the study was abandoned because of hemodynamic instability. Sixty-three grafts were performed in 15 patients. In four patients, flow tracings for six anastomoses were of poor quality and were excluded, leaving 57 grafts for analysis. There were 13 males and 2 females with mean age 63.7±1.6 years and mean body surface area 1.94±0.04 $m^2$. There was a mean of 3.2 grafts performed per patient. There were no significant postoperative complications. Creatinine kinase was 457.2±69.12 IU/L and Troponin I was 4.61±0.97 $\mu$g/L. Hospital stay was 6.4±0.5 days.

The manual and transit-time flows for the free graft are shown in Table 1. For those included in the study, there was no significant difference in flow between transit-time Doppler and manual methods (P'=0.285). The flow of the composite conduit was 237.5±19.1 ml/min, range 105-340 ml/min. The mean arterial pressure for all grafts was 84.7±1.6 mmHg (range: 60-120 mmHg).

The graft flow increased following release of the stabilizing device from a mean of 20.1±1.8 ml/min to 33.2±2.4 ml/min (P<0.001). This was true for most of the coronary branches (Table 2). Not all coronary arteries had significant flow increase, due to small sample size. We additionally analyzed flows according to coronary artery territory (Table 3) and found significant increase in all territories [P'<0.001 for LAD and Cx territories, and P'=0.001 for right coronary artery (RCA) territory].

The mean increase in graft flow after release of the stabilizing device was 13.1±1.3 ml/min (38.6±4.0%). In

**Table 3. Transit-time Doppler flow by coronary artery territory**

| Territory (n) | Retracted flow (ml/min) | Non retracted flow (ml/min) | MAP (mmHg) | P | P' |
|---|---|---|---|---|---|
| LAD (26) | 24.8±3.0 | 40.3±4.0 | 90.4±2.2 | <0.001 | <0.001 |
| RCA (10) | 18.0±4.8 | 29.0±5.7 | 74.9±3.0 | 0.001 | 0.001 |
| Cx (21) | 15.3±1.8 | 26.4±2.7 | 82.4±2.6 | <0.001 | <0.001 |

MAP, mean arterial blood pressure.
The number of grafts in each coronary territory is represented by (n). P' is the adjusted statistic for testing three comparisons using the Ryan-Holm Bonferroni stepdown procedure.
LAD, left anterior descending artery; RCA, right coronary artery, Cx, circumflex.

four anastomoses (two patients), there was a decrease in graft flow following Octopus release, and an associated fall in MAP. The magnitude of fall was 2 ml/min (MAP 95-90 mmHg), 3 ml/min in two anastomoses (MAP 105-90 mmHg, and 70-64 mmHg) and a fall of 14 ml/min (MAP 68-64 mmHg).

## Comment

Our main finding was that conduit flow increased after release of the stabilizing device. This suggests that the Octopus device stabilizes the myocardium by compression as well as suction (rather than suction alone). The reduced conduit flow during stabilization may be caused by an increase in regional vascular resistance caused by mechanical compression of the myocardium. Flow increases following removal of the device are suggestive of a reduction in regional vascular resistance. It is possible, that reduced heart retraction may increase cardiac output, contributing to increased graft flow.

The most important use of intraoperative graft flow assessment is to detect a defective anastomosis, allowing immediate revision. This should reduce the risk of graft failure.

The prediction of graft patency using transit-time Doppler is based on the raw flow measured,[1-4] or a calculation derived from the raw flow trace.[5-7] It is important, therefore, to perform the measurements when measure graft flow is maximal.

Of interest was that there was a fall in flow in four anastomoses following release of the stabilizing device. This phenomenon has been previously observed. The most likely explanation appeared to be a high graft flow immediately after completion of the anastomosis when considerable myocardial ischemia was evident during the construction of the anastomosis. There may have been considerable reperfusion of the regional vascular bed by the time the stabilizer was released. Another possibility is that the mean arterial pressure and cardiac output decreased following Octopus release. Indeed in the four anastomoses where graft flow fell, MAP also decreased but only by a small magnitude.

The exclusion of 11 patients because of differences between Doppler and manually calculated flows highlights two important limitations in the use of transit-time Doppler technologies. Firstly, the probes become increasingly unreliable with repeated use (as was the case in our series, having been used during previous studies). Secondly, the movement of the conduit may impair the acoustic coupling sufficiently to impair accurate measurement of graft flows in some instances. Most of the LIMA grafts required limited dissection of the satellite veins in order to facilitate application of the probe. Failure to do so could compromise the accuracy of the measurement or potentially lead to localized spasm of the conduit during the application of the probe. Finally, any calcification within the conduit will impede the ultrasound signal. Although not specifically recorded in this study, some of the six graft flow measurements found to be unsatisfactory were associated with calcification in the radial artery conduit. It is also possible that MAP or cardiac output may have altered in the short time between the retracted and released measurements.

This study suggests that graft assessment should be performed after release of the stabilizing device in off-pump coronary artery bypass surgery.

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