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Intraoperative Flow Rate Measurements of T-Grafts: Calculating a Flow Reserve

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ABSTRACT

Objective: To evaluate the inflow of the left internal thoracic artery (LITA) and the effect of adding a radial artery T-graft to distal LITA flow, and to calculate the LITA flow reserve.

Methods: Twenty-two patients underwent myocardial revascularization using the radial artery-LITA T-graft in which intraoperative flow measurements were recorded. An ultrasonic flowmeter was used to directly measure flow rates in the T-graft: 1) before completion of the distal anastomoses to measure maximum flow rates (free flow), and 2) after completion of distal anastamoses.

Results: The mean free flow rates of the LITA alone, radial artery graft alone, and T-graft (total flow) were 104 ± 70, 151 ± 89, and 230 ± 102 ml/min, respectively. The mean flow rates on bypass of the distal LITA, radial artery graft, and T-graft after the distal anastomoses were completed were 24 ± 16, 32 ± 27, and 63 ± 29 ml/min, respectively. The mean T-graft flow off bypass was 66 ± 29 ml/min. The mean flow reserve was 70%.

Conclusion: The LITA has a flow reserve by which proximal flow rates will increase to accommodate the addition of a radial artery T-graft without compromising LITA flow distal to the T anastomosis.

INTRODUCTION

Cardiothoracic surgeons have used the T-graft technique for coronary revascularization for almost a decade with promising results [Calafiore 1994, Tector 1994a, Tector 1994b, Calafiore 1995, Barner 1998]. However, some still have concerns about hypoperfusion and inadequate inflow from the left internal thoracic artery (LITA) to revascularize multiple areas of the myocardium. Inadequate inflow could compromise flow in the LITA distal to the T anastamosis, which could limit flow to the left anterior descending artery (LAD) [Barner 1996]. Therefore, some surgeons reserve T-grafts for cases of severely diseased aortas or dilated cardiomyopathies when maximum length of conduit is required [Dietl 1995]. Surgeons experienced with T-grafts report that hypoperfusion occurs as a result of technical factors and not from inadequate inflow. These technical factors include spasm, stretching or kinking of the conduit, or narrowing of the distal anastomoses[Tector 1994b, Calafiore 1995]. We measured intraoperative flow rates in the radial artery-LITA T-graft to evaluate the inflow of the LITA and the effect of adding a radial artery T-graft to distal LITA flow, and to calculate a flow reserve. This article is a report of our findings.

MATERIALS AND METHODS

From September 1997 to February 1998, 22 patients underwent myocardial revascularization using a radial artery-LITA T-graft. Intraoperative flow measurements were recorded in all of these proceedures. There were 18 men and 4 women with a mean age of 57.5 years (range, 34–82

Table 1. Summary of patient characteristics (n = 22 patients)

Characteristic	n (%)
Unstable angina	11 (50)
Hypertension	9 (41)
Diabetes mellitus	7 (41)
Congestive heart failure	3 (14)
Acute MI	3 (14)
Prior MI	2 (9)
Prior CABG	2 (9)
COPD	2 (9)

MI = myocardial infarction; CABG = coronary artery bypass grafting; COPD = chronic obstructive pulmonary disease.

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Table 2. Distal anastomoses(total = 45) of the radial artery graft (n = 22 patients)

Vessel Grafted	n (%)
Diagonal	9 (20)
Obtuse marginals	4 (53)
Distal circumflex	4 (9)
Right coronary	2 (4)
Posterior descending	6 (13)

years). Patient characteristics are listed in Table 1 (◉) Patients selected for T-grafts had unsuitable saphenous veins or were younger and would benefit from arterial revascularization.

Operative Highlights

The radial artery (RA) was harvested with an ultrasonic scalpel [Psacioglu 1998] using a technique similar to that described by Reyes and colleagues [Reyes 1995]. The proximal anastomosis was created so that the angle between the RA and the internal thoracic artery (ITA) was 90 degrees, similar to the technique described by Tector [Tector 1994b]. After completion of the proximal anastomosis, the T-graft was injected with a solution of verapamil and nitroglycerine. The distal LITA was anastomosed to the LAD in all patients except one patient who had undergone a previous coronary artery bypass grafting (CABG) and had an ungraftable LAD. In this one patient the distal anastomosis of the LITA was to the diagonal branch of the LAD. The most frequent targets of the RA graft were the diagonal branch of the LAD, the obtuse marginal branches, and the posterior descending artery. Table 2 (◉) lists the sites of the distal anastomoses of the RA grafts. The mean number of bypasses by the T-graft was 3.1 ± 0.9. Thirteen (59%) patients had additional bypasses to the right coronary artery (RCA). Of these patients, saphenous vein grafts were used in 10 patients, radial artery grafts were used in two patients, and one patient had a pedicled gastroepiploic artery bypass to the RCA. Flow rates in grafts other than the T-grafts were not recorded.

Equipment and Data Collection

A Transonic HT107 Medical Flowmeter and flow probes (Transonic Systems, Inc, Ithaca, NY) were used to measure intraoperative flow rates. A description of the method and accuracy of the device have been published previously [Canver 1994].

Flow measurements were first obtained in the native LITA after the intercostal branches were ligated. Next, the distal LITA was taken down and the RA-LITA anastomosis was created. Flow measurements were then recorded in the LITA proximal to the anastomosis under three conditions: 1) RA clamped, distal LITA open, 2) RA open, distal LITA clamped, and 3) RA and distal LITA both open. These measurements were made before initiating cardiopulmonary bypass (CPB) by allowing blood to spill freely into the pericardium, which was then suctioned to the pump reservoir. After the distal anastomoses were completed, flow measurements were made in the proximal LITA, the distal LITA, and RA (proximal to the first, if any, side-to-side anastamosis.) These measurements were made while on CPB. The final measurement was made in the proximal LITA off CPB immediately before closing the chest.

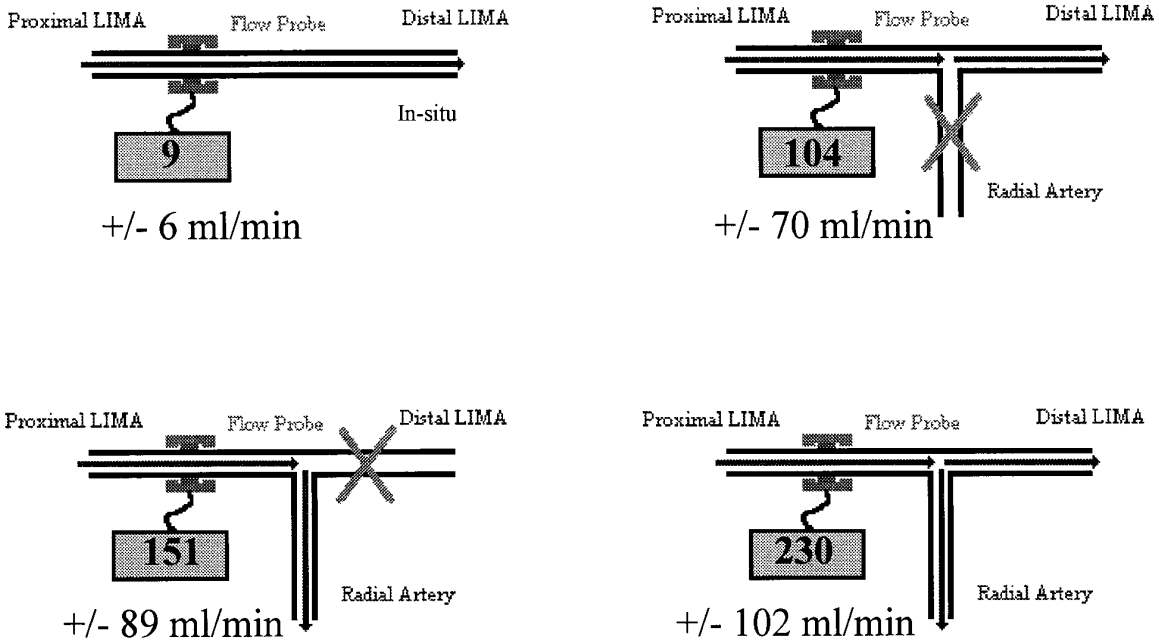

Figure 1. Flow rate measurements in the in-situ LITA and T-graft prior to completion of the distal anastamoses. LIMA = left internal thoracic (mammary) artery; Ml/min = milliliters / minute

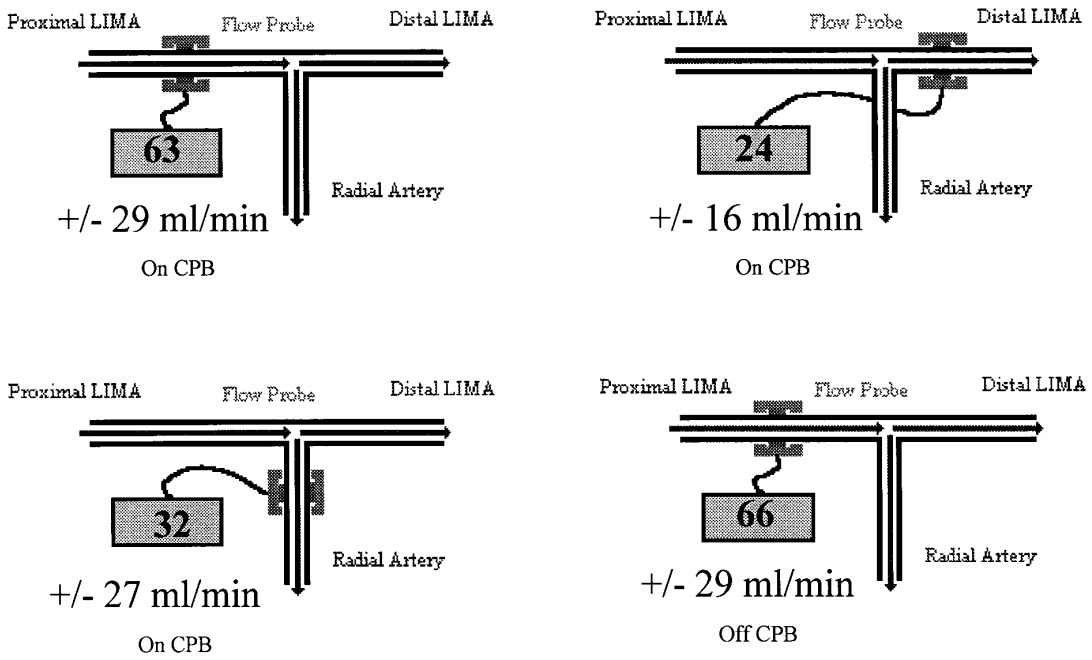

Figure 2. Flow rate measurements in the T-graft after completion of the distal anastamoses. LIMA = left internal thoracic (mammary) artery; ml/min = milliliters / minute; CPB = cardiopulmonary bypass

RESULTS

The mean flow rate in the native LITA was 9 ± 6 ml/min. The mean flow rate measured in the proximal LITA with: 1) the RA clamped and the distal LITA open was 104 ± 70 ml/min, 2) the RA open and the distal LITA clamped was 151 ± 89 ml/min, and 3) the RA and distal LITA open was 230 ± 102 ml/min. Figure 1 (◎) is a summary of these results. The mean flow rate after completion of the distal anastomoses in the: 1) proximal LITA was 63 ± 29 ml/min, 2) distal LITA was 24 ± 16 ml/min, and 3) proximal RA was 32 ± 27 ml/min. The mean flow rate measured in the proximal LITA off bypass was 66 ± 29 ml/min. Figure 2 (◎) is a summary of these results.

Follow-Up

All patients were seen one and six months after surgery. There were no deaths or myocardial infarctions. No patients experienced angina; two (9%) patients experienced shortness of breath on exertion. Eighteen patients (82%) had a follow-up thallium scan, stress echocardiogram, or exercise electrocardiogram. All studies were stable or improved compared to preoperative studies, and none showed signs of ischemia.

DISCUSSION

We have made several observations from the data. First, the flow in the proximal LITA increased by a mean factor of 1.9 with the addition of the RA graft. Second, the flow measured in the proximal LITA just before closing the chest was a mean of 30% ± 11% of the maximum flow rate measured into a zero resistance (open flow) environment, therefore suggesting a mean flow reserve of 70%. Barner reminds us that initial flow rates in grafts do not necessarily represent the myocardial demand as there is competitive flow in the native coronary arteries [Barner 1998]. We found similar flow rates in the distal LITA-LAD segment when compared with flow rates of non-T-LITA grafts to the LAD as reported by others [Canver 1994, Nasu 1995, Oda 1998]. Appropriately, our mean flow rate observed in the proximal LITA was approximately twice the flow rates measured by others. With these data we are confident that RA graft does not compromise flow through the distal LITA to the LAD. Barner adds that as atherosclerosis progresses in the native coronary arteries, the demands on the bypass grafts increases [Barner 1998]. With a 70% flow reserve, the LITA has the capacity to provide increased flow as native coronary atherosclerosis progresses. Our data suggest that the proximal LITA has the flow reserve to supply multiple areas of myocardium, and we support the use of T-grafts. We await the long-term patency results from those more experienced with the technique.

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