Predicting Early Coronary Artery Bypass Graft Failure by Intraoperative Transit Time Flow Measurement

Yoshiyuki Tokuda, MD, Min-Ho Song, MD, PhD, Yuichi Ueda, MD, PhD, Akihiko Usui, MD, PhD, and Toshiaki Akita, MD, PhD

Department of Cardiovascular Surgery, Gifu Prefectural Tajimi Hospital, Tajimi, Gifu, and Department of Cardiothoracic Surgery, Nagoya University Graduate School of Medicine, Showa-ku, Nagoya, Aichi, Japan

Background. **A primary limitation of using transit time flow measurement to predict early graft failure in coronary artery bypass grafting has been the lack of cutoff values for objective criteria.**

Methods. **We analyzed a total of 261 grafts that were evaluated by intraoperative transit time flow measurement and underwent early postoperative coronary angiography within 3 months of surgery. Based on the control angiography, failing grafts were defined as occluded or patent grafts with greater than 50% stenosis or poor flow characteristics. Normal and failing graft indicators were compared according to the graft territories.**

Results. **According to the receiver operating characteristic curve analysis for the grafts to left coronary arteries, a mean flow of 15 mL/min or less, a pulsatility index of 5.1 or higher, and a backward flow of 4.1% or higher were found to be the optimal cutoff criteria to predict early graft failure. Similarly, for the grafts to right coronary arteries, the cutoff values were 20 mL/min, 4.7, and 4.6%, respectively. A systolic dominant flow curve pattern was a risk factor only in grafts to the left coronary arteries. Negative predictive values of these cutoff criteria ranged from 0.91 to 0.96, whereas positive predictive values ranged from 0.31 to 0.80.**

Conclusions. **Using these criteria, transit time flow measurement may be a useful method to predict early graft failure. However, surgeons should be aware of the low positive predictive values to avoid unnecessary graft revision.**

(Ann Thorac Surg 2007;84:1928–34)

Early graft patency can influence the outcome, either early or late, of coronary artery bypass grafting, and, as such, quality control of the anastomoses is critical [1, 2]. Although postoperative angiography still represents the gold standard for anatomic evaluation, it would be ideal to have an easy and quick method for intraoperative assessment of the quality of the anastomoses. Several methods, including manual palpation of the graft, the use of electromagnetic flow meters and Doppler flow meters, transit time flow measurement (TTFM), and intraoperative angiography with indocyanine green, have been used to assess graft patency [3–5]. Among them, TTFM is reported to be a suitable method for quick and reproducible intraoperative assessment of graft function, independent of graft size [5–8]. Although many reports validate the usefulness of TTFM compared with other methods, the cutoff values of TTFMs, to distinguish those grafts with impaired flow from those with normal flow, are not well established. We aimed to define the optimal criteria for TTFM, and their cutoff values, to predict early graft failure. For this purpose, receiver operating characteristic (ROC) curve analysis was applied with early angiographic control.

Accepted for publication July 12, 2007.

Address correspondence to Dr Tokuda, Department of Cardiovascular Surgery, Gifu Prefectural Tajimi Hospital, 5-161 Maehata, Tajimi, Gifu, 507-8522, Japan; e-mail: tokuda@mxb.mesh.ne.jp.

Patients and Methods

As this study aimed to evaluate TTFM with early angiographic control, we enrolled patients who underwent coronary artery bypass graft surgery as well as both intraoperative TTFM and postoperative angiography within 3 months of surgery. All 123 patients (92 men and 31 women with a mean age of 66.5 $\pm$ 7.8 years) who underwent both TTFM and early angiography between 2002 and 2006 were enrolled and reviewed retrospectively. During this period, 147 patients underwent coronary artery bypass graft surgery, and 142 of these 147 patients underwent intraoperative TTFM. In Japan, it is common practice to perform early postoperative angiography to confirm graft patency, even without ischemic symptoms. Thus, the 123 patients in this study included patients with (n = 5) and without (n = 118) postoperative ischemic signs. Because postoperative angiography was performed as per the usual clinical practice of the hospital, no angiography was undertaken specifically for the purposes of this study.

The approval of this retrospective study was obtained on the March 15, 2007, from the Ethics Committee of the

Published by Elsevier Inc

0003-4975/07/$32.00
doi:10.1016/j.athoracsur.2007.07.040

Abbreviations and Acronyms

LCA = left coronary artery
NP = negative predictive value
%BF = percentage of backward flow
PI = pulsatility index
PPV = positive predictive value
Qmax = maximum flow recorded in one cardiac cycle
Qmean = mean flow across five cardiac cycles
Qmin = minimum flow recorded in one cardiac cycle
RCA = right coronary artery
ROC = receiver operating characteristics
TIMI = Thrombolysis in Myocardial Infarction study
TTFM = transit time flow measurement

Departments of Cardiovascular Surgery and Cardiology of Gifu Prefectural Tajimi Hospital. The Committee waived individual consent for the study.

Operative Procedures and Bypass Grafts

Coronary artery bypass graft surgery was performed in the standard manner, either with cardiopulmonary bypass (n = 85 [including 4 beating on-pump cases]) or without (n = 39). Combined procedures included mitral valve plasty (n = 9), ascending aortic replacement (n = 1), mitral valve replacement (n = 1), Dor procedure (n = 2), aortic valve replacement (n = 2), and tricuspid annuloplasty (n = 2).

Sequential anastomoses, and other anastomoses distal to the sequential anastomoses, were excluded from the analysis as the graft flow through the proximal sequential and distal anastomoses could affect each other. Also, the interpretation of the graft flow pattern was difficult and complicated. After excluding sequential anastomoses and their distal anastomoses, 261 grafts in 123 patients, evaluated by both intraoperative TTFM and early postoperative angiography, were submitted for analysis. These included 92 venous grafts and 169 arterial grafts. The type of conduits and the target territories of the grafts are shown in Table 1. The left or right internal thoracic artery, saphenous vein graft, radial artery, and gastroepiploic artery were used as the conduits.

Intraoperative Flow Measurement

Intraoperative flow measurement for all grafts was performed just before sternal closure using a transit time flowmeter (BF1001; Medi-Stim AS, Oslo, Norway) on the distal portion of the graft body. Mean blood pressure was maintained between 70 and 90 mm Hg during the flow measurement, and a properly fitted probe was used with acceptable contact between the probe and the graft (acoustic coupling index > 50%). In patients with a Y-composite graft, flow was measured separately in each arm of the Y-composite graft. Six grafts were revised after the initial TTFM because of suspected anastomosis problems. In these cases, the final flow measurement after the revision was used for analysis.

The following values were obtained by TTFM analysis using the flowmeter: mean flow calculated across five cardiac cycles (Qmean), maximum flow recorded in one cardiac cycle (Qmax), minimum flow recorded through one cardiac cycle (Qmin), pulsatility index (PI) as the ratio between the difference (Qmax – Qmin/Qmean), and the percentage of backward flow (%BF) as the percentage of the flow through the graft directed backward across the anastomotic site (area below zero) compared with the total forward flow (area above zero) of the same cardiac cycle. The Qmin is a negative number if there is backward flow. The flow curve pattern was classified according to the dominancy based on the maximal flow value: systolic dominant when peak systolic flow exceeded peak diastolic flow by 10%; diastolic dominant or balanced when peak systolic flow did not exceed peak diastolic flow by 10% [5].

Postoperative Angiography

The postoperative angiography was performed 16.2 ± 12.6 days after surgery. Visual assessment of the angiography was made by two or more cardiologists and the results were classified according to the following system: (1) normal widely patent, less than 50% stenosis at any location in the graft, proximal anastomosis, distal anastomosis, or immediate 1 cm of target vessel, and normal Thrombolysis In Myocardial Infarction III (TIMI III) flow characteristics; (2) abnormal patent, with greater than 50% stenosis at any location in the graft, proximal or distal anastomosis, or immediate 1 cm of target vessel, or poor flow characteristics (non–TIMI III flow); or (3) occluded. Based on the angiography results, grafts were divided into two groups: group A (normal), and group B (failing grafts—abnormal or occluded) [4].

Statistical Analysis

Comparisons between the two groups were performed using unpaired *t* tests for continuous variables or the χ^2 test or Fisher's exact test for categorical variables. Univariate logistic regression was used to obtain odds ratios

Table 1. Coronary Artery Bypass Grafts and Their Target Arteries

	LAD	Diag	LCx	RCA	Total
ITA	111 (8,1)	5 (0,0)	6 (1,2)	2 (0,0)	124 (9,3)
SVG	3 (0,0)	5 (1,0)	40 (4,3)	44 (3,5)	92 (8,8)
RA	1 (0,0)	2 (1,0)	28 (3,2)	1 (0,0)	32 (4,2)
GEA	0	0	0	13 (1,1)	13 (1,1)
Total	115 (8,1)	12 (2,0)	74 (8,7)	60 (4,6)	261 (22,14)

The first number in parentheses indicates the number of abnormal grafts, and the second number indicates occluded grafts, according to the early postoperative angiography. Patent grafts with greater than 50% stenosis or poor flow characteristics are classified as *abnormal* grafts.

Diag = diagonal artery; GEA = gastroepiploic artery; ITA = internal thoracic artery; LAD = left anterior descending artery; LCx = left circumflex artery; RA = radial artery; RCA = right coronary artery; SVG = saphenous vein graft.