Graft flow assessment using a transit time flow meter in fractional flow reserve–guided coronary artery bypass surgery

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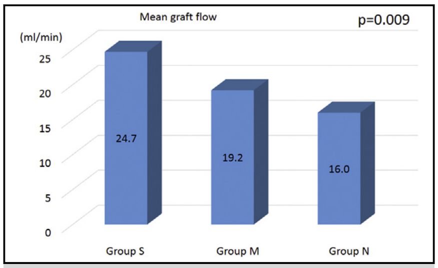
ABSTRACT

Objective: To evaluate the relationship between preoperative severity of coronary stenosis occurring with fractional flow reserve (FFR), and the intraoperative bypass graft flow pattern.

Methods: In all, 72 patients were enrolled in this retrospective study. The FFR value of the left anterior descending artery was evaluated, and data on "in situ" bypass grafting from the internal thoracic artery to the left anterior descending artery were assessed. Patients were divided into 3 groups according to preoperative FFR values (Group S: FFR $<$ 0.70; group M: 0.70 $\leq$ FFR $<$ 0.75; and group N: FFR $\geq$ 0.75).

Results: In groups S, M, and N, respectively, mean graft flow was 24.7 $\pm$ 10.6 mL/minute, 19.2 $\pm$ 14.0 mL/minute, and 16.0 $\pm$ 9.7 mLmL/minute; pulsatility index was 2.35 $\pm$ 0.6, 3.02 $\pm$ 1.1, and 5.51 $\pm$ 8.20; and number of patients with systolic reverse flow was 3 (6.8%), 5 (35.7%), and 4 (28.6%). Significant differences were observed in graft flow (P = .009), pulsatility index (P = .038), and proportion of systolic reverse flow (P = .023) among the 3 groups. In all patients, graft patency was confirmed with intraoperative fluorescence imaging; postoperative graft patency was confirmed with multislice computed tomography or coronary angiography in 69 patients (follow-up interval: 213 days). Early graft failure occurred in 1 patient.

Conclusions: As coronary stenosis severity increased, graft flow increased, pulsatility index decreased, and proportion of patients with systolic reverse flow increased. In mild coronary artery stenosis, the chance of flow competition between the native coronary artery and the bypass graft increased. (J Thorac Cardiovasc Surg 2015;149:1622-8)



Graft flow increased with the severity of coronary stenosis.

Central Message

Flow competition between coronary artery and bypass graft may occur in mild coronary artery stenosis. Not only the anatomic evaluation of coronary stenosis but also the functional assessment using fractional flow reserve should 1be considered.

Perspective

These findings are important in coronary artery bypass surgery to achieve an effective bypass grafting. "In situ" internal thoracic artery graft was considered to be useful in mild coronary stenosis as it could act as a viable graft with long-term no-flow patency. In this study, graft flow assessment was limited to "in situ" internal thoracic artery to left anterior descending artery graft. It is necessary to evaluate in other graft and other coronary territory in a diverse coronary patients in the future.

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Coronary artery bypass surgery is a well-established procedure for patients with myocardial ischemia. For coronary surgery, target coronary arteries are selected mainly according to anatomic, as opposed to functional, severity of the stenosis. However, the purpose of coronary revascularization is to improve myocardial ischemia; therefore, the functional aspects of myocardial ischemia should be considered.

Recent reports have revealed that percutaneous coronary intervention based on functional evaluation via a measure of fractional flow reserve (FFR) achieves excellent results. In the FAME (FFR Versus Angiography for Multivessel Evaluation) study,[1] FFR-guided percutaneous coronary intervention significantly reduced the rate of mortality and myocardial infarction for lesions, at 2 years, but only if the FFR was $\leq$0.80. In addition, the 5-year results of the DEFER (for deferral of percutaneous coronary intervention) study[2] indicated that outcomes were excellent after

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Abbreviations and Acronyms

FFR = fractional flow reserve
ITA = internal thoracic artery
LAD = left anterior descending
MSCT = multislice computed tomography
TTFM = transit time flow meter

deferred percutaneous coronary intervention of an intermediate coronary stenosis (defined as a lesion with an FFR $\geq$ 0.75).[2] These results indicate that functional evaluation may lead to desirable results in coronary revascularization. Recently, an effort was undertaken to introduce FFR-guided revascularization into cardiac surgery,[3] but the question of whether a cutoff value of 0.75 in FFR is adequate for coronary surgery has not been addressed. Botman and colleagues[3] reported that the incidence of graft occlusion 1 year after surgery was >10% in patients with FFR values of $\geq$0.70.

The efficacy of coronary artery bypass grafting, unlike percutaneous coronary intervention, relies on the bypass graft flow dominating the native coronary flow. To be an efficient bypass, the graft flow must exceed the native coronary flow. This study was designed to assess the efficacy of FFR evaluation in coronary artery bypass grafting, via evaluation of the relationship between the preoperative severity of the coronary artery stenosis, as assessed by FFR, and the intraoperative graft flow and graft flow pattern.

METHODS

Patient Groups

A total of 72 patients who were eligible for coronary artery bypass grafting were enrolled in this retrospective study. Patients underwent coronary angiography and FFR-based functional evaluation of mild-to-moderate stenosis of the left anterior descending (LAD) artery. Patients were divided into 3 groups, according to their preoperative FFR value. Group S (FFR < 0.70) had the most-severe coronary stenosis; Group M (0.70 $\leq$ FFR < 0.75) had mild stenosis; and Group N (FFR $\geq$ 0.75) had functionally nonstenotic lesions.

In situ internal thoracic artery (ITA)-to-LAD artery bypass was performed. Mean graft flow, pulsatility index, diastolic filling, and systolic reverse flow were evaluated, using a transit time flow meter (TTFM), for each group during surgery. In addition, the patency of the bypass graft was assessed postoperatively. Patient characteristics are shown in Table 1.

Fractional Flow Reserve Measurement

Measurements of FFR were made only in cases of mild-to-moderate lesions, in which determination of whether significant stenosis is present in patients undergoing coronary angiography is difficult. Measurement of FFR was not performed in cases of severe coronary stenosis.

Intracoronary pressure was measured using a 0.014-inch pressure guide-wire (PressureWire Aeris, St Jude Medical, Inc, St Paul, Minn). First, the proximal coronary pressure was recorded by the guiding catheter. Calculation of FFR was made as the mean distal coronary pressure divided by the mean aortic pressure during maximal hyperemia. Maximal hyperemia was induced[4,5] by the intravenous continuous infusion of adenosine 5′-triphosphate (ATP) administered at 150 to 180 μg/kg/minute.

Surgical Strategy

Revascularization of the coronary artery was performed with or without cardiopulmonary bypass. An in situ ITA (both right and left ITA) was used as a bypass graft to the LAD artery area. No Y or T grafts were used in this study.

Intraoperative Graft Flow Measurement

Intraoperative graft flow measurement was performed using a TTFM (VeriQ System, Medistim, Oslo, Norway). The usefulness of graft flow measurement is mentioned in the ESC-EACTS (European Society of Cardiology and European Association for Cardio-Thoracic Surgery) guidelines.[6] Graft flow measurements were performed just before chest closure and after hemodynamic stabilization. The parameters evaluated with use of the TTFM were mean bypass graft flow, pulsatility index, diastolic filling, and systolic reverse flow.[7-9]

Mean bypass graft flow. Mean graft flow is expressed in mL/minute and is useful for indicating how a bypass is flowing. But it is a poor indicator of the quality of the anastomosis, because the index is influenced by many variables, such as systolic blood pressure, vascular resistance, graft quality, coronary microvascular resistance, and anastomotic quality. Several articles regarding intraoperative bypass graft flow have been published; a mean graft flow of >20 mL/minute is considered a good graft.[7-10]

Pulsatility index. The pulsatility index is expressed as an absolute value and is considered to be a good indicator of the anastomotic flow pattern, and consequently, of anastomotic quality. This value is obtained by dividing the numeric difference between the maximum flow and the minimum flow by the mean flow: Pulsatility index = (maximal flow – minimum flow / mean flow). The index should range from 1 to 5 in a good graft[6]; an index <3.0 is an adequate value for a good graft.[9,10] The adequate and backward flow patterns by the TTFM measurements are shown in Figure 1.

Diastolic filling. Diastolic filling indicates the proportion of diastolic graft flow during the entire graft flow. Because coronary artery flow physiologically occurs during diastole, diastolic filling in a proper graft should range from 45% to 80%. Diastolic filling of <25% is considered to an inadequate graft.[9]

Systolic reverse flow. Reverse, or backward, flow during the systolic phase indicates flow competition between the bypass graft and the native coronary artery. Backward flow indicates that the flow through the graft is directed backward across the anastomotic site. Reverse flow is measured as the percentage of the area below the zero line, compared with the total flow area. A backward flow value of $\geq$3.0% can be considered a cutoff value that predicts early graft failure.[8]

Intraoperative Graft Imaging

In all patients, intraoperative fluorescence graft imaging was performed. The Photodynamic Eye (PDE; Hamamatsu Photonics K.K., Shizuoka, Japan) was used in our institution. This system is based on the fluorescence of indocyanine green when it is illuminated by laser energy. After intravenous injection of indocyanine green, fluorescence generated in the blood is captured by a camera, and the vessels are visualized. The usefulness of intraoperative fluorescence imaging for coronary surgery has been reported elsewhere.[11-13]

Intraoperative Graft Revision

Graft revision was considered when both TTFM and fluorescence imaging assessment indicated improper results. In patients with a high pulsatility index, with no flow, as indicated by fluorescence imaging, graft revision was considered. If the graft flow was confirmed in the anastomotic

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