Noninvasive Assessment of Left Internal Mammary Artery Graft Patency Using Duplex Doppler Echocardiography From Supraclavicular Fossa

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Objectives. The purpose of this study was to clarify the usefulness of duplex Doppler echocardiography from the supraclavicular fossa for assessment of left internal mammary artery graft patency.

Background. A noninvasive method to assess coronary artery bypass graft patency would be useful for clinical diagnosis and long-term follow-up of graft outcome.

Methods. Duplex Doppler echocardiography from the supraclavicular fossa was performed in 56 consecutive patients who underwent postoperative cardiac catheterization studies, including quantitative angiography. All patients underwent coronary artery bypass graft surgery using the left internal mammary artery graft to the left anterior descending coronary artery.

Results. The left internal mammary artery graft and its flow were detected in 55 (98%) of the 56 patients with duplex Doppler echocardiography from the supraclavicular fossa. According to the quantitative angiographic data, the patients were assigned to three groups: group A (36 patients) with a normal left internal mammary artery graft (<50% diameter stenosis), group B (9 patients) with intermediate (50% to 75% diameter) graft stenosis and group C (10 patients) with severe (>75% diameter) graft stenosis. The diastolic/systolic peak velocity ratio was smaller in group C than in groups A and B (p < 0.05), but there was no significant difference between groups A and B. A diastolic/systolic peak velocity ratio <0.6 predicted severe left internal mammary artery graft stenosis (>75% diameter stenosis) with a sensitivity and specificity of 100% and 80%, respectively. The diastolic fraction of time-velocity integral was smaller in group C than in groups A and B (p < 0.05), but there was no significant difference between groups A and B. A diastolic fraction <0.5 predicted significant left internal mammary artery graft stenosis (>75% diameter stenosis) with a sensitivity and specificity of 90% and 100%, respectively.

Conclusions. Duplex Doppler echocardiography from the supraclavicular fossa is useful for noninvasive assessment of left internal mammary artery graft patency.

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Methods

Study patients. We studied 56 consecutive patients who underwent coronary artery bypass grafting using the left internal mammary artery graft to the left anterior descending coronary artery and had a postoperative cardiac catheterization study, including quantitative angiography, during the period May 1991 to August 1992. There were 47 men and 9 women, aged 35 to 70 years (mean 55.8). Twenty-eight patients underwent coronary artery bypass grafting because of angina pectoris and 28 patients because of postmyocardial infarction angina. Before bypass grafting, the viability of the anterior wall was confirmed in all patients by stress radionuclide imaging. Bypass grafting was performed at the midportion of the left anterior descending coronary artery in all patients. The time interval between bypass grafting and catheterization was 9.9 ± 1.6 months (range 1 to 81). All patients had sinus rhythm.

Left internal mammary artery graft blood flow measurements using duplex Doppler echocardiography. Supraclavicular duplex Doppler echocardiographic examinations (Fig. 1)
Figure 1. Duplex Doppler echocardiographic approach from the supraclavicular fossa. The ultrasound beam is directed toward the caudal site from the transducer placed on the supraclavicular fossa with the patient in the supine position.

were performed 1 to 4 days (mean 1.7) before postoperative cardiac catheterization with a Hewlett-Packard Sonos 1000 with a 5-MHz transducer, as reported previously (2). When the left internal mammary artery graft was observed on the two-dimensional echocardiogram, the sample volume was located on the graft, and graft blood flow was detected using pulsed wave Doppler echocardiography (Fig. 2). As in the previous study, the sample volume length was reduced to 0.6 mm, and the high pass filter was minimized. The sample volume was positioned as distal as possible from the visible proximal portion of the left internal mammary artery graft on the two-dimensional echocardiogram to direct the Doppler beam as parallel as possible to the longitudinal axis of the graft. Slight adjustments in cursor alignment were performed to achieve optimal recording of left internal mammary artery graft flow velocity signals. Doppler recordings were considered optimal when the signal of highest audible frequency, maximal velocity and most clearly defined spectral velocity envelope was obtained. We made no angle correction in this study. When left internal mammary artery graft flow was recorded as the biphasic blood flow curve, the systolic and diastolic peak velocities and systolic and diastolic time-velocity integrals were measured with on-line calipers (Fig. 3). Several measurements were made and averaged over the five cardiac cycles. The diastolic/systolic peak velocity ratio and diastolic fraction of time-velocity integral were calculated.

Angiographic analysis of the left internal mammary artery graft. After the intravenous administration of either nitroglycerin (0.1 to 0.3 mg) or isosorbide dinitrate (1 to 3 mg) left internal mammary artery graft angiograms in four directions were obtained in each patient. Using a SF catheter for reference, digital calipers (Cardio 500, Kontron Instruments) were used to calculate vessel diameter and percent diameter stenosis from a magnified image obtained in the most stenotic view. In this study, left internal mammary artery graft stenosis at the site of anastomosis with the coronary artery was also measured. According to quantitative angiographic data, the patients were assigned to three study groups: group A had a normal left internal mammary artery graft (<50% diameter stenosis), group B had intermediate (50% to 75% diameter) graft stenosis and group C had severe (>75% diameter) graft stenosis.

Statistical analysis. Doppler variables for the three study groups are expressed as mean value ± SD. The groups were compared with two-way analysis of variance (ANOVA) for Doppler measurements from the supraclavicular fossa.
When the ANOVA resulted in a p value < 0.05, the results were considered significant.

Results

Detection of left internal mammary artery graft blood flow. In 55 (98%) of the 56 patients, the parallel echo of the left internal mammary artery graft was visualized on the two-dimensional echocardiogram from the supraclavicular fossa, and blood flow in the graft was detected with pulsed wave Doppler echocardiography. The distance between the sample volume and the origin of the left internal mammary artery graft was 1.3 ± 0.5 cm (mean ± SD). The left internal mammary artery graft flow pattern obtained consisted of two phases of flow corresponding to systole and diastole, as reported previously (3-10). Except for nine patients, diastolic flow was dominant in the time-velocity integral (Fig. 4). In this study, the ultrasound beam was directed toward the caudal site from the left supraclavicular fossa. Therefore, flow going away from the transducer was recorded with pulsed Doppler echocardiography, and flow was depicted as going below the zero flow line.

Angiographic analysis of the left internal mammary artery graft. There were II patients with severe (>75% diameter) stenosis, including 4 with total occlusion and 2 with 99% stenosis in the left internal mammary artery graft. No stenosis was found in the proximal site of the graft where flow velocities were measured. In one of the four patients with total occlusion in the left internal mammary artery graft, graft flow was not detected. Except for this patient, the study patients were assigned to three groups: group A, 36 patients with a normal left internal mammary artery graft (<50% diameter stenosis); group B, 9 patients with intermediate (50% to 75% diameter) graft stenosis and group C, 10 patients with severe (>75% diameter) graft stenosis.

Comparison of Doppler variables. In Table I and Figure 5, Doppler variables of left internal mammary artery graft flow are summarized. The diastolic/systolic peak velocity ratio and the diastolic fraction of time-velocity integral in group C were significantly smaller than values in the other two groups (p < 0.05 for both), but there was no significant difference between groups A and B.

Relation between angiographic and Doppler echocardiographic data. The relation between the diastolic/systolic peak velocity ratio of left internal mammary artery graft flow and percent diameter stenosis of the graft is shown in Figure 6 (left). A diastolic/systolic peak velocity ratio <0.6 predicted severe (>75% diameter) left internal mammary artery graft stenosis with a sensitivity and specificity of 100% and 80%, respectively. The relation between the diastolic fraction of time-velocity integral and percent diameter stenosis of the graft is also shown in Figure 6 (right). A diastolic fraction <0.5 predicted severe (>75% diameter) left internal mammary artery graft stenosis with a sensitivity and specificity of 90% and 100%, respectively.

Discussion

In the present study, we revealed that the new approach from the supraclavicular fossa using duplex Doppler echocardiography is feasible for noninvasive assessment of left internal mammary artery graft patency.

Comparison with previous studies. A noninvasive method to evaluate the patency of the left internal mammary artery graft would be useful for clinical diagnosis and long-term follow-up of graft outcome. Since Gould et al. (3) described pulsed Doppler echocardiography and applied this method to the study of coronary artery bypass grafts, some investigators have carried out the noninvasive detection of coronary artery bypass graft flow using the pulsed Doppler technique from the chest wall (3-8). However, direct ultrasound assessment of bypass graft flow has not been widely recom-
mended as a clinical tool for evaluating graft patency because many problems have been reported with regard to sensitivity and specificity for graft flow detection. Because the detection rate of graft flow using this technique was unsatisfactory in the past, evaluation of graft patency was quite difficult. Failure to image a graft does not indicate graft failure unless an earlier study showed a patent graft. Fusejima et al. (6) measured blood flow velocity in the distal site of left internal mammary artery grafts. In their report, the sensitivity for graft blood flow detection was 79%. This difficulty in detecting flow in the left internal mammary artery is due to the graft’s narrow lumen and pulsatile movement. Kyo et al. (7) measured blood flow velocity in the proximal site of left internal mammary artery grafts. They used the parasternal approach, and the sensitivity for left internal mammary artery graft blood flow detection was 55%. De Bono et al. (8) reported similar measurement of left internal mammary artery graft flow. They used the parasternal and supraclavicular approaches, and the sensitivity for left internal mammary artery graft blood flow detection was 61%. In our study the sensitivity for left internal mammary artery graft flow detection was 98%. For the anatomic reasons mentioned previously (2), the supraclavicular approach seems to be superior to the parasternal approach for detecting left internal mammary artery graft flow. Because of its satisfactory high sensitivity for detection of left internal mammary artery graft vessel and graft flow, duplex Doppler echocardiography from the supraclavicular fossa is thought to be useful as a clinical tool for evaluating graft patency.

In one patient, the left internal mammary artery graft was not visualized on the two-dimensional echocardiogram. This may have been due to technical reasons, such as attenuation of echocardiographic signals. We used a 5-MHz transducer in the supraclavicular fossa approach. In patients whose left internal mammary artery branches from a more proximal site of the left subclavian artery than is usual, deeper depth and greater tissue interference from the supraclavicular fossa would make it difficult to obtain adequate images of the fine structure of the graft. Kyo et al. (7) and De Bono et al. (8) used a 7.5-MHz transducer in their studies, so that greater attenuation may have occurred and prevented graft flow detection with two-dimensional echocardiography.

No stenosis was found angiographically in the proximal site of the left internal mammary artery graft. Therefore, augmentation of flow velocity at the site of stenosis was not observed in our study. The method we used was designed to record velocity changes that reflect an increased resistance to flow at some points distal to the recording site. This type of analysis was used in a previous study of peripheral arteries (11). The most frequently used indexes were the resistance index (or Pourcelot index) and the pulsatility index. In these studies on peripheral artery flow, the peak (mean) systolic and end-diastolic velocities were used to determine those indexes. However, in recent studies on coronary artery flow, peak (mean) systolic and diastolic velocities were used (9,10). Blood flow in the left internal mammary artery graft was similar to coronary artery flow because the graft was functioning normally. Therefore, we used peak diastolic velocity (maximal velocity of the diastolic wave) in our study.

Limitations of the study. One limitation of this technique is the estimation of the Doppler incident angle for absolute measurement of graft flow velocity. In this study, as in other Doppler studies (12-15), Doppler recordings were considered optimal when the signal of highest audible frequency, maximal velocity and most clearly defined spectral velocity envelope was obtained. As Hatle (16) emphasized, once a signal with a relatively dense high velocity spectral representation is obtained, the angle between the Doppler beam and the direction of flow can be assumed to be minimal. We previously reported significant correlation between supraclavicular and Doppler catheter measurements (2). Using the diastolic/systolic peak velocity ratio and the diastolic frac-
Figure 6. Relation between diastolic/systolic peak velocity ratio (DPV/SPV) of left internal mammary artery graft flow and percent diameter stenosis of the left internal mammary artery graft (left) and the relation between diastolic fraction of time velocity integral (D/F/DI+SI) and percent diameter stenosis of the left internal mammary artery graft (right). A diastolic/systolic peak velocity ratio <0.6 predicts severe left internal mammary artery graft stenosis (>75% diameter stenosis) with a sensitivity and specificity of 100% and 80%, respectively. A diastolic fraction <0.5 predicts severe left internal mammary artery graft stenosis (>75% diameter stenosis) with a sensitivity and specificity of 90% and 100%, respectively.

Because the portion of the coronary circulation accessible to this method is limited to the proximal site of the left internal mammary artery graft, blood flow in the recipient left anterior descending coronary artery was not assessed. It has been reported that competing residual blood flow from the proximal coronary artery reduces rest left internal mammary artery flow and that no-flow patency of the left internal mammary artery graft is possible. Kitamura et al. (17) have reported that the left internal mammary artery graft may continuously maintain anatomic patency even under no-flow situations and may function properly later as a graft when the native coronary flow decreases. These findings may modify assessment of left internal mammary artery graft patency by left internal mammary artery graft flow measurement using the supraclavicular approach. Further studies concerning the competition between the recipient native coronary artery flow and left internal mammary artery graft flow are required.

In this study, the diastolic component of the left internal mammary artery graft flow was reduced in patients with severe (>75% diameter) stenosis. However, there was no significant difference between the left internal mammary artery graft flow in patients with intermediate (50% to 75% diameter) stenosis and that in patients with a normal left internal mammary artery graft. Even with significant graft lumen narrowing, rest left internal mammary artery graft flow must be maintained. Previous Doppler studies of native coronary artery flow showed that coronary flow reserve measured as a ratio of peak hyperemic coronary blood flow to rest coronary blood flow can be useful in assessing coronary artery stenosis (18,19). Noninvasive measurement of the left internal mammary artery graft flow velocities during vasodilator stress, such as intravenous dipyridamole administration, and subsequent determination of coronary flow reserve would help to identify graft stenosis of intermediate severity. However, measurement of stress blood flow velocities may increase the difficulty of the examination. Further studies concerning the flow reserve of the left internal mammary artery graft measured with this method are needed.

Conclusions. Despite these limitations, supraclavicular duplex Doppler echocardiographic assessment of the left internal mammary artery graft has the clear advantage of being less invasive and having fewer complications than cardiac catheterization studies. Because the technique is completely noninvasive, it is a realistic method for assessing patency of the graft over time. This technique may also represent a valuable method for physiologic or pharmacologic investigations.

References