Assessment of Internal Thoracic Artery Patency With Transesophageal Echocardiography During Coronary Artery Bypass Graft Surgery

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Objective: The purpose of this study was to evaluate intraoperative transesophageal echocardiography (TEE) for assessing patency of internal thoracic artery grafts.

Design: A retrospective study.

Setting: A university hospital.

Participants: Fifty-one consecutive patients who underwent coronary artery bypass graft (CABG) surgery using the left internal thoracic artery (LITA)–to–left coronary artery were examined postoperatively with coronary angiography (CAG).

Interventions: None.

Measurement and Main Results: The authors measured blood flow velocity using TEE after anastomosis of a LITA graft. Intraoperative TEE findings and routine CAG results were compared to evaluate the quality of TEE assessment. The LITA was detected in 45 of 51 patients (88%) intraoperatively with TEE. Peak and mean velocities and velocity time integral ratios were determined by dividing each diastolic value by its corresponding systolic value. The peak velocity ratio was 0.51 ± 0.04 (range, 0.40–0.59) in the presence of stenosis and 1.14 ± 0.10 (range, 0.58–3.87) in its absence (p = 0.0289), whereas mean velocity ratios were 0.62 ± 0.05 (range, 0.45–0.72) and 1.27 ± 0.10 (range, 0.66–4.08) (p = 0.0223), respectively, and velocity time integral ratios were 0.83 ± 0.09 (range, 0.64–1.05) and 2.83 ± 0.29 (range, 0.91–8.35) (p = 0.0224), respectively. The critical values for peak and mean velocities and velocity time integral ratios were 0.60, 0.73, and 1.06, respectively, whereas the sensitivity for each was 100% and the specificity was 92%, 94%, and 89%, respectively.

Conclusions: The authors concluded that the intraoperative assessment of LITA patency with TEE was a markedly useful and powerful tool for anesthesiologists during CABG surgery.

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KEY WORDS: transesophageal echocardiography, internal thoracic artery, velocity ratio, velocity time integral ratio, critical values, intraoperative assessment, coronary artery bypass graft surgery

MATERIALS AND METHODS

The retrospective study protocol was approved by the authors’ institutional ethical committee. Fifty-one consecutive patients who underwent CABG surgery involving the LITA–to–left anterior descending coronary artery between January 2003 and July 2004 and who were examined with CAG were studied. The patients consisted of 36 men and 15 women, with a mean age of 64 years (range, 44–83). Invasive arterial blood pressure was monitored in all patients before the induction of anesthesia. General anesthesia was induced with fentanyl (10 μg/kg), propofol (0.5 mg/kg), and pancuronium (0.1 mg/kg). Maintenance was performed with an infusion of propofol (2–4 mg/kg/h), boluses of fentanyl (total, 30–60 μg/kg), and pancuronium. Patients routinely received nitroglycerin (0.25–0.5 μg/kg/min) for the dilation of coronary arteries and the prevention of LITA spasm. The surgical procedures included on-pump CABG surgery (40 patients), off-pump CABG surgery (4 patients), and on-pump CABG surgery with either aortic valve replacement (2 patients), mitral valve replacement (2 patients), mitral valve replacement with tricuspid annuloplasty and maze operation (1 patient), mitral valve plasty and maze operation (1 patient), or maze operation (1 patient). The surgery was elective in 34 patients and urgent in 17. The number of distal anastomoses was 3.0 ±
The duration of surgery and anesthesia were 418 ± 70 minutes and 506 ± 79 minutes, respectively. In 47 patients who underwent on-pump CABG surgery, aortic cross-clamping and cardiopulmonary bypass times were 110 ± 29 minutes and 157 ± 48 minutes, respectively. Some patients required inotropic support after cardiopulmonary bypass, including dopamine in 49 patients, dobutamine in 6 patients, and norepinephrine in 1 patient. Vasodilators were used for myocardial protection during and after cardiopulmonary bypass in some patients, including nicardipine in 2 patients, nicorandil in 1 patient, and diltiazem in 1 patient.

The assessment of LITA patency during the operation was performed with TEE by using a biplane probe (EUB-555; Hitachi Co Inc, Tokyo, Japan) after surgical anastomosis, with the ultrasonic frequency set at 5 MHz. First, the aortic arch was visualized in the upper esophageal long-axis view. A short-axis view of the left subclavian artery became apparent as the probe was withdrawn with upward flexion under the guidance of color Doppler flow mapping, with a pulse repetition frequency of about 2 KHz. As the probe was further withdrawn while keeping the subclavian artery in the center of the screen, the horizontal portion of the left subclavian artery became visible. The distal side of the left subclavian artery then was carefully observed to determine the origin of the LITA (Fig 1). The LITA can be distinguished from other branches by detecting nonpulsatile flow in the diastolic phase. After identification of the LITA, it was clamped (Fig 2) and blood flow was measured by using pulsed-wave Doppler, with videotape recordings made for subsequent analysis. In cases of on-pump CABG surgery, a test clamp was performed after the administration of protamine on termination of cardiopulmonary bypass, whereas in cases of off-pump CABG it was performed immediately after anastomosis. As soon as possible at this point, the authors measured blood velocity through the LITA graft to avoid the influence of cardiopulmonary bypass, surgical procedure, and hemodynamic instability. Measurements of both velocity and velocity time integral were performed during videotape playback after the operation using the package for off-line internal measurement analysis included with the recording unit (Aloka Co, Ltd, Tokyo, Japan).

Measured parameters were as follows: distance from the esophagus to the LITA, depth of the probe tip, peak and mean velocity ratios, and velocity time integral ratio (Fig 3). Peak and mean velocity ratios were determined by dividing the peak diastolic velocity by peak systolic velocity and the mean diastolic velocity by mean systolic velocity, respectively. The velocity time integral ratio was determined by dividing the diastolic velocity time integral by the systolic velocity time integral. The parameters used for calculations were obtained by averaging over 5 cardiac cycles.

The authors evaluated the patency of the LITA graft by using CAG and echocardiography to assess multiple projections postoperatively. This was performed in all cases by a single cardiologist who was unaware of the intraoperative echocardiographic findings. Stenosis was assessed as “present” when the degree of internal diameter narrowing was greater than 75% and when this was apparent in at least 1 projection. Patients were divided into 2 groups according to the presence or absence of stenosis.

Values are expressed as the mean ± standard deviation. Statistical analyses were conducted by using an unpaired Student t test and Fisher exact probability test. A probability value less than 0.05 was considered statistically significant. Receiver operating characteristic (ROC) curves...
were constructed to determine the critical values of velocity time integral ratios and peak and mean velocities.

RESULTS

The authors analyzed 45 of 51 (88%) patients in whom the LITA was identified by TEE. Their mean height and weight were 159 ± 1 cm (range, 142-178) and 58 ± 1 kg (range, 37-81), respectively. The depth of the probe tip averaged 21 ± 1 cm (range, 16-25), and the mean distance from the esophagus was 26 ± 1 mm (range, 13-38).

Of the 45 patients in whom the LITA was identified, 4 were excluded from subsequent analysis because of intra-aortic balloon pumping that impaired TEE analysis (3 patients) or the finding that the LITA had been anastomosed to the coronary vein (1 patient). In the remaining 41 patients, 5 had stenosis, whereas 36 had no abnormal findings of anastomosis or occlusion. The degree of stenosis was 90% in 3 of 5 patients and 75% (at the anastomosis) in the remaining 2. Furthermore, 3 patients had a string LITA with anastomotic stenosis. Of 41 patients in whom the LITA was identified by TEE, the cardiac rhythms were sinus in 37 patients, atrial paced in 3, and ventricular paced in 1. On the other hand, in the 6 patients in whom the LITA was unsuccessfully visualized, postoperative CAG revealed 75% stenosis at the anastomosis in 1 patient and revealed that the LITA graft was occluded in 2 patients in the proximal vicinity of the LITA. A summary of the patients enrolled in the present study is presented in Figure 4.

The calculated velocity ratios (peak and mean velocities and velocity time integral ratios) in the presence or absence of stenosis are shown in Figure 5A through C. Each ratio in the presence of stenosis was significantly lower than that in the absence of stenosis (0.51 ± 0.04 vs. 1.14 ± 0.10, 0.62 ± 0.05 vs. 1.27 ± 0.10, and 0.83 ± 0.09 vs. 2.69 ± 0.29, respectively). Typical flow patterns in the LITA graft are shown to indicate the absence (Fig 6A) and presence (Fig 6B) of stenosis.

By comparing the values of each parameter derived using TEE and CAG, the authors determined the critical values necessary for a sensitivity of 100%. For peak and mean velocities and velocity time integral ratios, these critical values were found to be 0.60, 0.73, and 1.06, respectively, and those for perfect specificity were 92%, 94%, and 89%, respectively. The areas under the ROC curve, determined by using the peak and mean velocities and the velocity time integral ratios to differentiate between the presence and absence of stenosis, were 0.98 (95% confidence interval [CI], 0.94-1.02; \( p < 0.001 \)), 0.98 (95% CI, 0.94-1.02; \( p < 0.001 \)), and 0.96 (95% CI, 0.90-1.02; \( p < 0.001 \)), respectively. In the 6 patients in whom all of these parameters were less than the critical values, 5 had stenosis in the LITA graft. On the other hand, there was no stenosis in the LITA graft in any patient in whom at least 1 of the parameters was greater than the critical value.

DISCUSSION

In the present study, the peak and mean velocities and the velocity time integral ratios in LITA grafts with stenosis were significantly smaller than in those without stenosis. The authors also determined the critical values for the previously mentioned parameters that would yield 100% sensitivity because an important goal of this study was to investigate determinants for the detection of stenosis and occlusion in LITA grafts intraoperatively using TEE. Those critical values were equal to the cutoff values shown by ROC curves, which indicated that the authors’ method had high levels of sensitivity and specificity. Thus, the authors consider that the evaluation of LITA graft patency during surgery with TEE is reliable. To the best of the authors’ knowledge, this is the first report of critical values for LITA graft patency using TEE during CABG surgery. In a study that used transthoracic echocardiography, Takagi et al. reported that the LITA graft was detected in 55 of 56 patients (98%) with Doppler echocardiography from the supraclavicular
fossa. If the peak diastolic/systolic velocity ratio was less than 0.6, sensitivity and specificity of predicted severe LITA graft stenosis were 100% and 80%, respectively. Calafiore et al reported that the LITA graft was detected in all 100 patients (100%) with Doppler echocardiography from the first or second intercostal space. If the peak and mean diastolic/systolic velocity ratios were equal to or greater than 1.0, specificities of predictions that the LITA graft were normal were 80% and 87%, respectively. The anastomosis was restricted but not occluded in cases in which both peak and mean velocity ratios were less than 1 but greater than 0.6. If both ratios are not at least 0.6, the anastomosis or conduit may become occluded. Hata et al reported that the LITA graft was detected in all of 66 patients (100%) with Doppler echocardiography from the apical approach. The peak and mean diastolic/systolic velocity ratios associated with problematic LITA grafts were significantly lower than those seen with healthy grafts (0.98 ± 0.12 vs 1.67 ± 0.24 and 0.87 ± 0.10 vs 1.65 ± 0.21, respectively). The authors observed no stenosis in LITA grafts when at least 1 of the parameters of peak and mean velocity ratios and velocity time integral ratio was greater than its corresponding critical value. Therefore, the authors conclude that all 3 parameters should be measured and assessed and that LITA graft patency cannot be properly evaluated with only one of these parameters. In addition, when all of these values are below the critical levels, the LITA should be investigated by other means, such as with an ultrasonic or electromagnetic flowmeter. Coronary flow velocity may be assessed by using a variety of tools, such as a Doppler catheter, Doppler guidewire, epicardial probe, transthoracic probe, transesophageal probe, or electromagnetic flowmeter, and the results can provide useful clinical and physiologic information. However, each of these except for a transesophageal probe requires interruption of the surgical procedure or is difficult to apply.
during an operation. Nevertheless, it is important to find any stenosis or occlusion intraoperatively in order to reanastomose the graft. TEE is now routinely used in many cardiac centers because of its ability to provide continuous, noninvasive, and high-quality intraoperative monitoring of cardiac function. The assessment of graft flow in a LITA using TEE has many advantages, including its minimal interruption of the surgical procedure.

The authors did not compare diastolic and systolic velocities because the angle of blood flow to the ultrasound beam far exceeded the recommended range of 30° or less. In general, an angle less than 30° keeps the error within 14% based on a simplified Bernoulli equation. The successful visualization rate of 88% in the present study was similar to previous findings obtained by using transthoracic echocardiography, which reported success rates of 55% to 100% for blood flow detection in LITA grafts. A clamping technique for identifying the LITA is essential to differentiate it from other vessels. If the distal subclavian artery and diastolic dominant Doppler flow can be detected, as shown in Figure 1, there is a strong possibility of identifying the LITA, whereas the artery is difficult to find and distinguish without the guidance provided by diastolic continuous flow. Before anastomosis, the diastolic flow through the LITA to the coronary arteries is near 0, but after the anastomosis it increases dramatically along the pressure gradient between the subclavian artery and left ventricle during the diastolic phase. Diastolic LITA flow in the presence of stenosis or occlusion is near 0 because the hemodynamic state of the graft in this case is approaching that observed in an anastomotic vessel. Calafiore et al reported that peak and mean diastolic-to-systolic velocity ratios in healthy volunteers were similar to the ratios in patients in whom the conduit was occluded. The authors found occluded and/or stenosed LITA grafts in 3 of the 6 patients in whom the LITA could not be observed. Failure to visualize the LITA in these patients was likely caused, at least in part, by a decrease in diastolic blood flow. The authors do still assess the LITA flow using TEE, and, when the LITA cannot be detected or when velocity and velocity time integral ratios are near the critical values, the authors confirm the LITA flow using duplex Doppler cardiography. When stenosis and/or occlusion is confirmed, the authors recommend that the cardiac surgeon perform a reanastomosis.

The present study has some important limitations. First, blood flow velocity through the LITA graft may vary depending on general flow conditions immediately after weaning from CPB. Several other factors such as cardiac output, heart rate, preload, afterload, left ventricular diastolic function, vasoactive drugs, cardiac rhythm, and surgical procedure may affect the velocity in the LITA graft as well. These factors also complicate the intraoperative assessment of the graft. Therefore, the authors recommend assessing the graft when the hemodynamics are as stable as possible. Second, there were a small number of patients in this study with stenosis at the anastomosis site. A greater number of patients should be studied to clarify the present results. Third, there was a delay between assessment and postoperative CAG. The cause of stenosis in the LITA may be closed- chest hemodynamic changes, graft thrombosis, and/or local spasm, but all cases of LITA stenosis in this study were at the site of anastomosis to the LAD, suggesting that the stenosis detected by CAG occurred intraoperatively and was not because of closed-chest hemodynamics or graft thrombosis.

In conclusion, the authors detected LITA grafts in 45 of 51 patients (88%) using TEE. The peak velocity, mean velocity, and velocity time integral ratios were significantly lower in cases with LITA stenosis as compared with those without stenosis. The critical values for these ratios were 0.60, 0.73, and 1.06, respectively, which provided a sensitivity of 100% for each and specificities of 92%, 94%, and 89%, respectively. The authors concluded that intraoperative assessment of LITA patency using TEE is of significant benefit and gives anesthesiologists a powerful tool for use during CABG surgery.

REFERENCES