Assessment of Regional Left Ventricular Function During Exercise Test with Pulsed Tissue Doppler Imaging

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To investigate whether mitral annular velocity, measured by tissue Doppler imaging (TDI), is able to get a feasible quantitative evaluation of global and regional left-ventricular function during exercise test, 29 patients with previous uncomplicated myocardial infarction were studied by exercise echocardiography. All patients underwent coronary arteriography within 10 days of stress echocardiography. All of them were in sinus rhythm and had no right or left bundle branch block or significant mitral regurgitation as observed by left ventriculography. A total of 12 patients had anteroseptal and/or posteroseptal wall asynergies and left anterior descending involvement; 9 patients had lateral and/or posteroinferior asynergies and left circumflex coronary artery involvement; 8 patients had inferior and posteroseptal wall asynergies and right coronary artery involvement. Twelve subjects of same age and sex with normal cardiovascular findings were selected as a control group. TDI sample volumes were set on the mitral annuli corresponding to anteroseptal, posterior, posteroseptal, lateral, anterior, and inferior wall in 4-chamber, 2-chamber, and long-axis views. There was a significant correlation between the left-ventricular ejection fraction (0.41 ± 0.8) and the means of the systolic (S) values (6.1 ± 0.9 cm/sec, r = 0.83, p <0.01). The mean S at the sites corresponding to the infarct regions (5.5 ± 0.4 cm/sec) was significantly lower than the control group (11 ± 0.8 cm/sec, p <0.001). After stress, in patients with multivessel disease, S values corresponding to remote regions were significantly lower (p <0.01) compared with control subjects. Thus, the parameters obtained from mitral annular velocities with pulsed TDI in patients with previous myocardial infarction reflect left ventricular asynergy corresponding to the infarct regions and reversible regional dysfunction after exercise.
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Although exercise stress echocardiography[1–8] has become widely utilized, variability in the visual interpretation of wall-motion assessment has been demonstrated. Quantitative standardization of stress echo data interpretation, such as establishing endocardial velocity thresholds by the recently developed tissue Doppler imaging (TDI), has the potential to decrease interobserver variability.[9–18] Mitral anular motion velocities recorded with TDI at different sites are expected to give valuable information in patients with left ventricular asynergy.[19–26] Thus, we investigated whether mitral annular velocity measured by TDI is able to get a feasible quantitative evaluation of global and regional left ventricular function during exercise test.

MATERIAL AND METHODS

Population: A total of 29 patients (16 men and 7 women) with previous uncomplicated myocardial infarction were enrolled in this study. All patients underwent coronary arteriography within 10 days of stress echocardiography. All of them were in sinus rhythm and had no right or left bundle branch block or significant mitral regurgitation as observed by left ventriculography. Twelve patients had anteroseptal and/or posteroseptal wall asynergies and left anterior descending involvement; 9 patients had lateral and/or posteroinferior asynergies and left circumflex coronary artery involvement; 8 patients had inferior and posteroseptal wall asynergies and right coronary artery involvement. Twelve subjects of same age and sex with normal cardiovascular findings were selected as a control group.

Echocardiography: Two-dimensional echocardiograms and pulsed tissue Doppler tracings were recorded with commercially available instruments (Toshiba Power Vision SSA-380A, Toshiba Corp., Tokyo, Japan and Vingmed GE System Five, Hopten, Norway). Rest and exercise 2-dimensional echocardiography was performed before and just after upright bicycle exercise. The results were reviewed by an experienced echocardiographer without knowledge of the angiographic findings. Segmental regional wall-motion analysis was performed with use of a standard 16-segment model. A normal response to exercise was defined by increased wall motion and an abnormal response by worsening or unimproved wall motion after adequate exercise and heart rate response.

TDI sample volumes were set on the mitral annuli (Figure 1) corresponding to anteroseptal, posterior, posteroseptal, lateral, anterior, and inferior wall in 4-chamber, 2-chamber, and long-axis views. The acoustic power and filter frequencies were set to the

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lowest values possible and the sample volumes were set at the mitral annulus (width of approximately 8 mm). Systolic (S), early, and late diastolic waves were recorded at baseline and after stress at a speed of 10 cm/sec with simultaneous electrocardiographic tracings, and the means of the measurements obtained during 5 consecutive beats were determined.

To assess intraobserver variability, 1 investigator reanalyzed the TDI studies in 10 patients. Ten randomly selected and previously recorded studies were assessed by a second investigator to obtain interobserver reproducibility of the same set of measurements. Results of intra- and interobserver variability were expressed[27] as the mean difference between observations divided by their average measurement.

Statistical analysis: Data were expressed as mean $\pm$ SD. The magnitude of the group differences was assessed by Student's *t* test, and correlations between paired values were obtained by linear regression analysis. Significance was determined as $p < 0.05$.

RESULTS

No significant differences in the mean age, heart rate, and blood pressure among the groups were found. There was a significant correlation between the left ventricular ejection fraction (0.41 ± 0.8) and the means of the S values (6.2 ± 0.9 cm/sec, $r = 0.83$, $p < 0.01$). The mean S at the sites corresponding to the infarct regions (5.5 ± 0.4 cm/sec) was significantly lower (Figure 2) than the control group (11 ± 0.8 cm/sec, $p < 0.001$). After stress, in patients with multivessel disease, S values corresponding to remote regions were signicantly lower ($p < 0.01$) compared with control subjects (Figure 3).

A good reproducibility was found for the parameters determined using pulsed TDI. Intraobserver variability was 0.07 ± 0.003 for rest S waves and 0.08 ± 0.005 for peak stress S waves. The corresponding values for interobserver variability were 0.09 ± 0.004 and 0.11 ± 0.002, respectively.

DISCUSSION

Our study shows that the parameters obtained from mitral annular velocities with pulsed TDI in patients with previous myocardial infarction reflect left ventricular asynergy corresponding to the infarct regions and reversible regional dysfunction after exercise.

Stress echocardiography: Exercise echocardiography has evolved into a highly sensitive and specific modality for detecting the presence, extent, and regional vascular distribution of coronary artery disease in a variety of patient groups, including those being screened for an initial diagnosis or preoperative clearance, those who have undergone surgical or percutaneous revascularization, and those who have sustained a previous myocardial infarction, in whom this test also assists in risk stratification.[4–8]

This technique can identify multivessel disease with a clinically useful degree of accuracy, and echocardiographic images add independent and incremental value to clinical and exercise variables alone. In a logistic regression model, variables such as history of

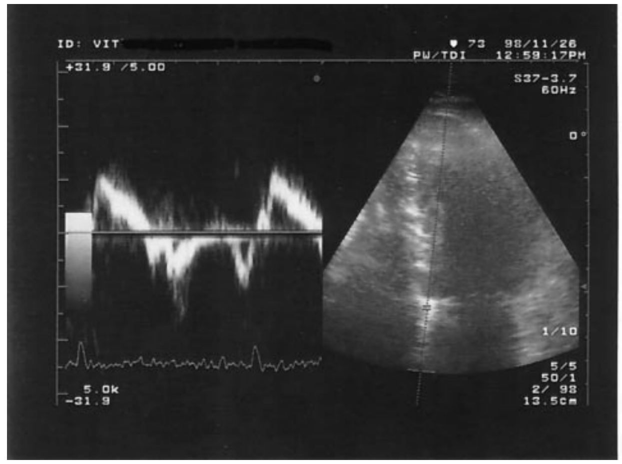

FIGURE 1. Pulsed tissue Doppler imaging with sample volume set on the endocardial portion at the mitral annular site adjacent to the base of the ventricular septum.

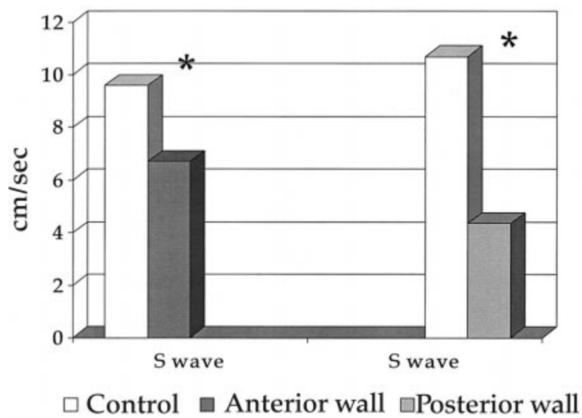

FIGURE 2. Bar graphs showing rest systolic (S)-wave values in control subjects and in patients with anterior and posterior myocardial infarction. *p <0.001.

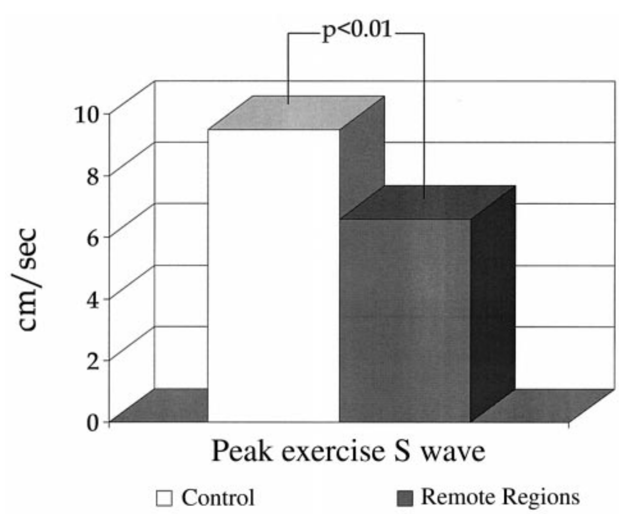

FIGURE 3. Bar graphs showing peak exercise S-wave values in control subjects and in patients at remote regions from myocardial infarction.

myocardial infarction, ST segment depression ≥2 mm, and number of abnormal regions on the postexercise echocardiographic images were independently related to the presence of myocardial infarction.[3]

TDI quantitative assessment: The TDI method was developed to assess ventricular wall motion velocity quantitatively in patients with various types of heart disease.[13–18] Because the motion velocity of ventricular wall generally is much lower than the blood flow velocity in the ventricular cavity throughout the cardiac cycle, it also has a low frequency shift. Moreover, because the amplitude of Doppler signals derived from myocardial tissue is approximately 40 dB larger than that derived from blood flow, the wall motion velocity alone can be displayed by bypassing the high-pass filter that eliminates low Doppler shifts.

It has been stressed that the advantage of determining mitral annular descent velocity by pulsed TDI is that it represents the sum of the longitudinal axial displacement of all myocardial fibers from base to apex in an imaging plane.[23] A close relation between mitral annular descent velocity and radionuclide left ventricular ejection fraction was found in patients with various heart diseases.[21] Fukuda et al[26] examined the relation between mitral sites corresponding to infarct regions and left ventricular ejection fraction. In our study, we evaluated the TDI pulsed parameters with exercise echocardiography and observed a close relation to regions supplied by obstructed coronary arteries.

Mitral annular motion and velocity were markedly decreased after stress at sites corresponding to the infarct wall in patients with previous myocardial infarction, as well as at sites corresponding to remote regions in patients with multivessel disease. Thus, the presence or absence of left ventricular regional asynergy was quantitatively assessed both at baseline and after stress.

Limitations: Peak velocities recorded by pulsed TDI are affected by motion of the entire heart. To eliminate this influence, a method using the transmural velocity gradient is being tested and will be soon in clinical use.[13,28,29] However, wall motion velocities measured by pulsed TDI can be rapidly analyzed with a conventional instrument (despite its overestimation of these values), which makes this method useful for comparisons between normal and diseased hearts, especially after stress. Futhermore, mitral annular motion may be influenced both by left ventricular systolic function and left atrial pressure, although none of our patients presented with significant mitral regurgitation. Finally, mitral annular motion velocity may also be affected by the presence of collateral coronary circulation and/or predominance in either of the vessels involved, even if our study population included patients with previous myocardial infarction and defined regional wall motion abnormalities.

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