Preoperative Longitudinal Left Ventricular Function by Tissue Doppler Echocardiography at Rest and During Exercise Is Valuable in Timing of Aortic Valve Surgery in Male Aortic Regurgitation Patients

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Background: The aim of this study was to evaluate if left ventricular (LV) systolic function by tissue Doppler echocardiography at rest and during exercise preoperatively could predict postoperative LV function and thereby be useful in the timing of aortic valve surgery in patients with severe aortic regurgitation.

Methods: In 29 patients (median age, 59 years; interquartile range, 39-64 years), echocardiography, tissue Doppler echocardiography, and radionuclide ventriculography were performed preoperatively and postoperatively at rest and during supine bicycle exercise.

Results: Preoperative ejection fraction (EF) was 62%. Patients formed two groups, with basal LV peak systolic velocity (PSV) 5.9 cm/s preoperatively as the cutoff value between low and high PSV. Preoperatively, patients with low PSV had lower PSV during exercise ($P < .005$), EF during exercise ($P < .05$), and atrioventricular plane displacement (AVPD) at rest ($P < .005$) and during exercise ($P < .05$) than those with high PSV. Postoperatively, patients with low PSV had smaller AVPD at rest ($P < .05$), AVPD during exercise ($P < .01$), and PSV during exercise ($P < .01$).

Conclusion: In patients with chronic aortic regurgitation with EFs and LV dimensions not fulfilling criteria for surgery according to guidelines, preoperative PSV and AVPD at rest and during exercise detected postoperative LV dysfunction. (J Am Soc Echocardiogr 2010;23:387-395.)

Keywords: Aortic valve insufficiency, Left ventricular function, Cardiac surgery, Tissue Doppler echocardiography, Exercise echocardiography

Symptoms and preoperative left ventricular (LV) systolic function are the main predictors of outcomes and long-term survival after aortic valve replacement (AVR) in patients with severe aortic regurgitation (AR). Surgery is therefore currently recommended when LV systolic dysfunction or symptoms evolve in patients with AR. LV ejection fraction (EF) < 50% at rest, LV end-systolic dimension > 55 mm, and LV end-diastolic dimension > 75 mm are the most used indicators of LV systolic dysfunction when planning surgery in asymptomatic patients.[1] However, these parameters have limitations in predicting early LV dysfunction.

It has been shown that LV systolic dysfunction can be identified before EFs have declined in asymptomatic patients with AR through the examination of LV longitudinal motion.[2] The longitudinal contraction of the left ventricle is performed by longitudinal myocardial fibers connected anatomically with the atrioventricular ring and located in the subendocardium.[3] The importance of these fibers for LV pump function was first described in the 1980s.[4,5] Because of the volume overload associated with AR, these subendocardial cells are exposed early to stress that initiates a fibrotic process.[1] Clinically, this can be measured as lowered atrioventricular plane displacement (AVPD) and interpreted as early myocardial dysfunction.

In the analysis of longitudinal myocardial function, tissue Doppler echocardiography (TDE) is a valuable technique. It can give information about regional as well as global LV systolic and diastolic function through the quantification of myocardial velocity.[5,6] Color TDE has also proven to be a feasible tool for the quantitative assessment of LV response to supine exercise.[5,7,8]

Exercise echocardiography has been proposed as a noninvasive, safe, and inexpensive method in the assessment of regurgitant valvular lesions.[9] Moreover, LV systolic function during exercise has been suggested as an approach to find early signs of LV deterioration in patients with AR.[10] A previous study showed that preoperative exercise echocardiography is a better predictor of postoperative LV function than resting indices in patients with AR.[11] It has also been found that LV long-axis contraction at rest measured by TDE is reduced in patients with AR with poor exercise responses.[12,13]

It is of utmost importance that patients with AR be operated in time to prevent the development of irreversible LV dysfunction. Conventional echocardiography at rest may be insufficient for the

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early detection of LV dysfunction in states of volume overload, as in chronic AR. Our hypothesis was that color TDE and exercise data would provide precise and sensitive information of LV function in patients with AR and that these methods could be developed into clinically useful tools for better timing of surgery. There are limited data concerning tissue Doppler echocardiographic parameters at rest and during exercise in patients with AR preoperatively and postoperatively. Consequently, the aims of this study were to (1) explore the effects of aortic valve surgery on LV systolic function in patients with chronic AR by TDE and (2) assess potential tissue Doppler echocardiographic indicators for postoperative subnormal LV performance related to preoperative measures.

METHODS

Patients

Patients with severe chronic AR referred for aortic valve surgery on fulfillment of criteria according to guidelines were included in the study.[1] Diagnosis and severity of AR were determined on the basis of an integrated echocardiographic evaluation, taking LV dimensions, vena contracta width, backflows in the descending aorta, and forward stroke volume into consideration.[14] In addition the progression of severity or hemodynamic impairment, judged from progressive LV dilatation, indication of declining LV function despite a normal EF and the appearance of symptoms were regarded as additional indications for surgery.

Exclusion criteria were active endocarditis, previous heart surgery, aortic stenosis, concomitant valve disease, or coronary artery disease. Twenty-nine men met these criteria. These patients also participated in a radionuclide ventriculographic study.[15]

The ethics committee of the Faculty of Health Sciences at the University of Linköping approved the study. The patients received information and gave their informed consent before being enrolled into the study.

Echocardiography

All patients were studied by the same investigator at rest and during exercise 2 days before and 6 months after surgery. Two-dimensional echocardiography and color TDE were performed (GE Vivid 5 or 7; GE Medical Systems, Wauwatosa, WI). The patients were examined in a semisupine left lateral position on an Ergoselect 1200EL ergometer (Ergoline, Bitz, Germany). The exercise examination was submaximal, with a starting load of 50 W and an increase after 5 minutes to 100 W. To study steady-state physiology, echocardiographic and color tissue Doppler echocardiographic images were recorded after 5 minutes at a workload of 100 W. Blood pressure and heart rate were registered. Echocardiography and color tissue Doppler echocardiographic images were recorded during two RR intervals at rest and during exercise at 100 W.

Apical 4-chamber and 2-chamber views by TDE were saved for offline analysis using EchoPAC (GE Medical Systems). All offline analysis was performed by the same investigator. Myocardial velocity profile was obtained from the basal segments of the lateral, septal, inferior, and anterior LV walls at rest and during exercise at 100 W. The peak systolic velocity (PSV) was measured at the highest velocity recorded within the systolic interval on electrocardiography. Velocities recorded during isovolumetric contraction were excluded. From the 4 walls, the mean PSV was calculated.

To evaluate global diastolic function, the early (e′) and atrial (a′) waves during diastole were identified in the myocardial velocity profiles. Because of difficulty in identifying and separating the e′ and a′ waves during exercise, these measurements were not included. The e′/a′ ratio was calculated.

Tissue tracking is a modality of color TDE that visualizes the myocardium by a graded display of 7 color bands, with each color representing a displacement distance. This makes it possible to quickly and easily perform a visual estimation of AVPD. By integrating the velocity signal at the junction of the valve and ventricular wall at 4 positions (septal, lateral, anterior, and inferior), the AVPD distance was measured as the distance between the maximum and minimum values. The mean AVPD of the 4 sites was calculated.

From digitally stored images, systolic AVPD was measured by M-mode echocardiography at the same 4 positions as with tissue tracking. The measurements were carried out as previously described by Carlhäll et al.[16] The mean systolic AVPD was calculated.

Radionuclide Ventriculography

Radionuclide ventriculography with multiple gated acquisition was performed 2 days before planned surgery and 6 months postoperatively. Using a GE XR/T gamma camera (GE Medical Systems), supine multigated blood pool imaging was first performed at rest and during exercise. The initial workload was 50 W, which was increased to 100 W. Xeleris Functional Imaging Workstation, EF Analysis (GE Medical Systems) was used to measure EF.

Statistical Analysis

Data are expressed as median (interquartile range). Nonparametric analyses were used because of skewed data. Preoperative and postoperative and rest and exercise data were compared using Wilcoxon's signed rank test. The Mann-Whitney *U* test was used to analyze differences between the groups with high and low PSVs. Correlation between measurements of preoperative longitudinal function and postoperative EF, LV dimensions, and LV volumes were determined using Spearman's ρ.

Missing data due to missing images were handled as true missing data, while missing values due to patients' incapability to perform exercise because of their heart conditions were replaced by zeroes in Wilcoxon's matched-pairs tests and by approximated low values in the Mann-Whitney analysis, to preserve information about the low performance group of patients. Bland-Altman analysis was used to evaluate the agreement between tissue tracking and M-mode echocardiography.[17] To evaluate interobserver and intraobserver variability, studies from 10 randomly selected patients were analyzed preoperatively and postoperatively separately by two observers and remeasured by the first observer. Mean differences and reproducibility coefficients (1.96 × SD) were calculated.

Data analysis was performed using SPSS version 15.0 (SPSS, Inc, Chicago, Illinois). Significance was defined as $P \leq .05$.

RESULTS

Baseline Characteristics

Clinical and echocardiographic features of the patients are summarized in Tables 1 and 2, respectively. The etiology of AR was cusp prolapse in 19 patients, degenerative in 6, dilatation in 2, and rheumatic in 1. Sixteen patients had bicuspid aortic valves. Twenty-seven patients underwent AVR surgery, and 2 had aortic valve reconstructive surgery. Three patients were not studied postoperatively, 1 because of postoperative complications, 1 who did not wish to be