Intraoperative Transesophageal Echocardiography Using a Quantitative Dynamic Loading Test for the Evaluation of Ischemic Mitral Regurgitation

Avinoam Shiran, MD, Amnon Merdler, MD, Ehab Ismir, Rony Ammar, MD, Amnon Y. Zlotnick, MD, Dan Aravot, MD, Horia Lazarovici, MD, Eli Zisman, MD, Reuven Pizov, MD, and Basil S. Lewis, MD, *Haifa, Israel*

Background: **Intraoperative transesophageal echocardiography may underestimate ischemic mitral regurgitation (MR) as a result of the unloading effect of general anesthesia on the left ventricle (LV). An intraoperative loading test could prove useful to avoid underestimation of ischemic MR.**
Methods: **We prospectively studied 30 patients with ischemic MR referred for coronary artery bypass, mitral valve surgery, or both. Transthoracic echocardiography was performed 1.6 ± 1.6 days preoperatively, and intraoperative transesophageal echocardiography after induction of general anesthesia before and after LV loading. Preload was adjusted using fluids (if pulmonary occlusion pressure < 15 mm Hg), and the afterload increased using intravenous phenylephrine aiming at systolic blood pressure of 160 mm Hg. MR severity was estimated using color Doppler, pulmonary venous flow, and the proximal isovelocity surface area method.**
Results: **Preoperative median MR grade was 2 (interquartile range 1-3), effective regurgitant orifice area was 0.16 ± 0.17 cm^2, and regurgitant volume was 23 ± 23 mL. Intraoperative MR grade decreased to 1.5 (1-2.25), effective regurgitant orifice area to 0.13 ± 0.16 cm^2, and regurgitant volume to 21 ± 26 mL (*P* = .02, *P* = .06, and *P* = .18). After LV loading, MR grade increased to 3 (1-4), effective regurgitant orifice area to 0.21 ± 0.24 cm^2, and regurgitant volume to 39 ± 38 mL (*P* ≤ .005). All patients with preoperative +3 MR or greater had +3 MR or greater after loading whereas most patients with +1 MR had +1 MR. Of the 11 patients with preoperative +2 MR, 6 had +3 and 2 had +4 MR.**
Conclusions: **A quantitative loading test with fluids and phenylephrine is useful to avoid underestimation of ischemic MR by intraoperative transesophageal echocardiography, and may detect significant MR in some patients who had unloaded LVs and nonsignificant MR during their preoperative assessment.** (J Am Soc Echocardiogr 2007;20:690-697.)

Ischemic mitral regurgitation (MR) results from left ventricular (LV) remodeling secondary to myocardial infarction and ischemia, which cause mitral valve (MV) leaflet tethering, annular dilatation, and malcoaptation of the leaflets.[1-4] Ischemic MR is independently associated with increased mortality and poor outcome.[5-7] Accurate assessment of the severity of MR is crucial for optimal selection of patients who may benefit from MV repair or replacement, and transesophageal echocardiography (TEE) is optimal for the assessment of MV anatomy and MR severity.[8] Intraoperative TEE, however, may underestimate the degree of ischemic MR because of the unloading effect of general anesthesia on the LV,[9-13] and it has been recommended to rely on preoperative assessment of the valve rather than on intraoperative measurements.[9,11,12]

In most studies, the ventricular loading conditions during intraoperative TEE were not adjusted, and in some studies not reported.[9,11,12] Furthermore, some patients presenting with pulmonary edema and who later have mild MR at rest may have significant ischemic MR during stress.[14] Although the use of an intraoperative loading challenge has been reported and is routinely used in some centers, a prospective study of such a loading test in patients with ischemic MR using quantitative techniques has not been reported to date.[15,16] The aim of the current study was to compare intraoperative TEE using a quanti-

From the Departments of Cardiovascular Medicine, Cardiothoracic Surgery (R.A., A.Y.Z., D.A.), and Anesthesiology (H.L., E.Z., R.P.), Lady Davis Carmel Medical Center, and the Ruth and Bruce Rappaport Faculty of Medicine, Technion–Israel Institute of Technology.

Reprint requests: Avinoam Shiran, MD, Department of Cardiovascular Medicine, Lady Davis Carmel Medical Center, 7 Michal St, Haifa 34362, Israel (E-mail: *shiranad@012.net.il*).

0894-7317/$32.00

doi:10.1016/j.echo.2006.11.004

tative loading test to the preoperative assessment of ischemic MR. We hypothesized that such a test would avoid underestimation of ischemic MR both intraoperatively and preoperatively.

METHODS

Patient Population

Patients with ischemic MR (at least mild) referred for echocardiography before coronary artery bypass surgery, MV surgery, or both were prospectively enrolled in the study. Exclusion criteria were: (1) nonischemic MR (such as flail, myxomatous or rheumatic MV); (2) prosthetic valve; (3) transient MR associated with acute ischemia; (4) hemodynamic instability despite appropriate medical therapy and intra-aortic balloon pump counter pulsation; (5) more than mild aortic valve disease; and (6) inadequate transthoracic echocardiogram (TTE). The study protocol was approved by the local ethics committee and all patients signed an informed consent form.

Preoperative TTE

Preoperative TTE was performed 1.6 ± 1.6 days before surgery, using a commercially available echocardiographic system (Sonos 5500, Agilent Technologies, Palo Alto, Calif) and a 1- to 3-MHz broadband transducer. A complete echocardiographic study was performed using standard views and techniques.

MV anatomy was assessed using 2-dimensional echocardiography from multiple parasternal and apical views. MR was assessed using color flow Doppler after optimizing gain setting, and mitral inflow and pulmonary venous flow using pulsed wave Doppler.[17] Systolic pulmonary artery pressure was estimated using maximal tricuspid regurgitant flow velocity and estimated jugular venous pressure. Quantitative assessment of MR was performed using the proximal isovelocity surface area (PISA) method from the apical 4-chamber or apical long-axis views.[17,18] The flow convergence area was magnified, and the color flow baseline shifted in the direction of the flow (usually to about 30 cm/s) to achieve an optimal hemispheric shape of the flow convergence area. Continuous wave Doppler of the MR jet was recorded from an apical view (usually 4-chamber view) after aligning the ultrasound beam with the MR jet. Blood pressure (BP) and heart rate were recorded at the time of preoperative TTE.

Intraoperative TEE

First, intraoperative TEE was performed after the induction of general anesthesia and placement of a pulmonary artery catheter and before first incision (TEE1). Using the same ultrasound machine used for TTE and a multiplane broadband (4-7 MHz) TEE probe, a complete TEE examination was performed and the MV assessed using 2-dimensional, color flow Doppler, and pulsed wave Doppler of mitral inflow and both pulmonary veins. MR was quantitatively assessed using the same PISA method.

Second, TEE was repeated after optimizing LV loading conditions. If pulmonary artery occlusion pressure was less than 15 mm Hg, intravenous (IV) fluids were infused until it reached 15 mm Hg. Systolic BP was then increased to approximately 160 mm Hg using IV phenylephrine, and TEE repeated (TEE2). BP, heart rate, pulmonary artery, and occlusion pressure were recorded at both TEE1 and TEE2. Images from preoperative and both intraoperative studies were digitally stored separately on magneto-optic disks for offline analysis.

Echocardiographic Analysis

All echocardiographic studies were analyzed by two observers who were unaware of the loading conditions (loaded vs unloaded) or the preoperative studies when reading the intraoperative studies. MR grade (0-4) was determined qualitatively based on MR jet size and shape by color Doppler and mitral inflow and pulmonary venous flow by pulsed Doppler.[17] Effective regurgitant orifice area (EROA) and regurgitant volume (RVol) were estimated using the PISA method.[17,18] Each data point was averaged from at least 3 cardiac cycles. Final values of EROA and RVol were the average of the estimates of the two observers. In cases of disagreement between observers, final MR grade was determined by consensus.

Reproducibility of MR Assessment

Intraobserver and interobserver agreement for MR grade was 85% and 80%, respectively (no more than 1 grade difference between observations). Absolute difference for the same observer was 0.016 ± 0.015 cm^2 for EROA and 2.8 ± 2.5 mL for RVol. Absolute difference between the two observers was 0.04 ± 0.05 cm^2 for EROA and 6.7 ± 9.9 mL for RVol. There was an excellent correlation between the two different measurements of the same observer ($r = 0.99$, $P < .0001$ for both EROA and RVol) and between measurements of the two observers ($r = 0.96$, $P < .0001$ for both EROA and RVol).

Statistical Analysis

The primary end point of the study was the comparison of MR grade, EROA, and RVol intraoperatively in the loaded state (TEE2) with preoperative TTE. The secondary end point was the comparison of the same parameters intraoperatively in the unloaded state (TEE1) with preoperative TTE. Continuous variables were compared using a paired *t* test. MR grade and subgroup analysis of EROA and RVol were compared using Wilcoxon signed rank test. Interobserver and intraobserver agreement for MR grade was defined as the percentage of agreement between observations. The reproducibility of quantitative MR assessment (EROA and RVol) was determined using the mean of absolute difference of measurements ± SD and linear regression for interobserver and intraobserver comparison.[19] A 2-tailed probability of less than .05 was considered to be statistically significant.