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Aortic Regurgitation: Ventricular Response after Aortic Valve Replacement

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Tabayashi, K., Sadahiro, M., Yaginuma, G., Ito, Y., Endo, M., Akimoto, K., Suzuki, Y. and Mohri, H. *Aortic Regurgitation: Ventricular Response after Aortic Valve Replacement*. Tohoku J. Exp. Med., 1990, **160** (2), 109-115 —— This study was designed to evaluate the usefulness of the ratio of the preoperative regurgitant stroke volume to left ventricular end-diastolic volume (RSV/LVEDV) for assessing the left ventricular function preoperatively. In 26 patients with aortic regurgitation (AR), the percent decrease in LVEDV was compared with the preoperative RSV/LVEDV, ejection fraction (EF), LVEDV, left ventricular end-systolic volume (LVESV) or left ventricular end-diastolic pressure (LVEDP). There was a significant correlation between the percent decrease in LVEDV and RSV/LVEDV. Patients with RSV/LVEDV of more than 0.26 had a significantly smaller postoperative left ventricular end-diastolic volume index (LVEDVI) and left ventricular end-systolic volume index (LVESVI), and a grater postoperative EF than patients with smaller RSV/LVEDV. All but one patient with RSI/LVEDVI larger than 0.0016 LVEDVI had normal postoperative LVEDVI. Based on these findings, it is concluded that the RSV/LVEDV is an useful indicator for preoperative evaluation of left ventricular functions in patients with AR. Surgical intervention for patients with AR should be recommended before the RSI/LVEDVI drops to less than 0.0016 LVEDVI, to expect good postoperative ventricular responses. ——— aortic regurgitation; RSV/LVEDV

Some patients with aortic regurgitation (AR) go for many years without any serious cardiovascular symptom until they develop irreversible left ventricular (LV) dysfunction. The appropriate timing for operative intervention in asymptomatic patients has been discussed by many investigators (Rahimtoola 1977; Henry et al. 1980b). It is important to learn preoperatively the expected LV function after aortic valve replacement (AVR). Decision of the proper operative timing can thus be made. Various methods have been used to evaluate the LV function in patients with AR (Cunha et al. 1980; Henry et al. 1980a; Bonow et al. 1988; Gassch et al. 1983; Levine and Gassch 1983). But, it has not been throughly clarified which parameters is more reliable to decision making of

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the appropriate timing for operative intervention in the patients with long standing AR and to assessing the post AVR LV response.

This study was aimed to evaluate the usefulness of the ratio of the preoperative regurgitant stroke volume to left ventricular end-diastolic volume (RSV/LVEDV) for assessing the postoperative LV function in patients with AR.

Materials and Methods

Twenty-six patients with angiographic evidence of AR comprised the study group. Patients were divided into the following two groups by the value of RSV/LVEDV. The group A consisted of 10 patients in whom RSV/LVEDV was less than 0.25. The group B consisted of 16 patients in whom RSV/LVEDV was more than 0.26. Patients with a gradient across the aortic valve over than 20 mmHg, other heart valve dysfunctions severe enough to require valve replacement, or previous valvular surgery were excluded. Their ages ranged from 21 to 66 years with a mean of 48.8 years. All patients underwent AVR. Artificial valves used and numbers of patients were the Bjork-Shiley valve in 24, the Angell-Shiley valve in 1, and the Duromedics valve in 1. AVR was performed using a standard cardiopulmonary bypass with systemic hypothermia of 28°C, topical cardiac cooling, and antegrade or retrograde infusions of a 4°C oxygenated crystalloid potassium cardioplegic solution.

All patients received preoperative left heart catheterization and echocardiography. Left ventriculography was done in bi-plane right anterior oblique and left anterior oblique positions and recorded on 35 mm cine films at a speed of 50 frames/sec. LV volume was calculated by the area-length method. Postoperative cardiac catheterization was done at a range of 4 to 84 months with a mean of 23.0 months after AVR.

The thermodilution method was used to measure the cardiac output. Hemodynamic indices were calculated from the following equations:

1) $\mathrm{EF}=\dfrac{\mathrm{LVEDV}-\mathrm{LVESV}}{\mathrm{LVEDV}}\times 100$

2) $\mathrm{RSV}=\mathrm{TSV}-\mathrm{FSV}$

3) $\mathrm{RF}=\dfrac{\mathrm{RSV}}{\mathrm{TSV}}\times 100$

4) $\dfrac{\mathrm{RSV}}{\mathrm{LVEDV}}=\dfrac{\mathrm{TSV}-\mathrm{FSV}}{\mathrm{LVEDV}}$

where EF is ejection fraction in %, LVEDV in left ventricular end-diastolic volume in ml, LVESV is left ventricular end-systolic volume in ml, RSV is regurgitant stroke volume in ml/beat, TSV is total stroke volume in ml/beat, FSV is forward stroke volume in ml/beat, and RF is regurgitant fraction in percentages.

Statistical Analysis

Values are expressed as means ± S.D. The regression line was obtained by the method of least squares. Comparison of variables were made with the unpaired t-test. Differences were considered to be statistically significant at a p value less than 0.05.

Results

Relationship between the percent decrease in LVEDV and RSV/LVEDV or preoperative EF is depicted in Fig. 1. The percent decrease in LVEDV correlated well with the RSV/LVEDV ($r=0.75$, $p<0.01$), but not with the EF.

Relationships of the percent decrease in LVEDV to the preoperative

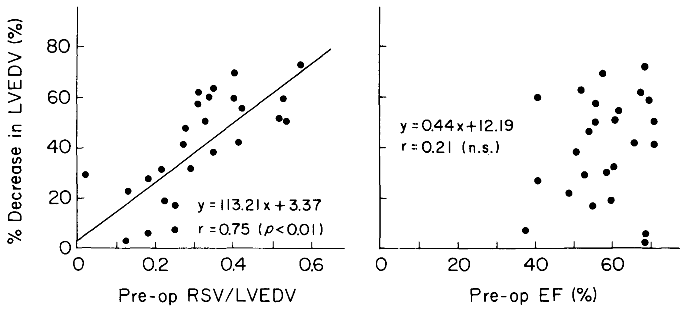

Fig. 1. Relations of % decrease in LVEDV to pre-op RSV/LVEDV and pre-op EF. % Decrease in LVEDV correlated well with pre-op RSV/LVEDV, but not with pre-op EF. LVEDV, left ventricular end-diastolic volume; pre-op, pre-operative; RSV, regurgitant stroke volume; EF, ejection fraction; n.s., not significant.

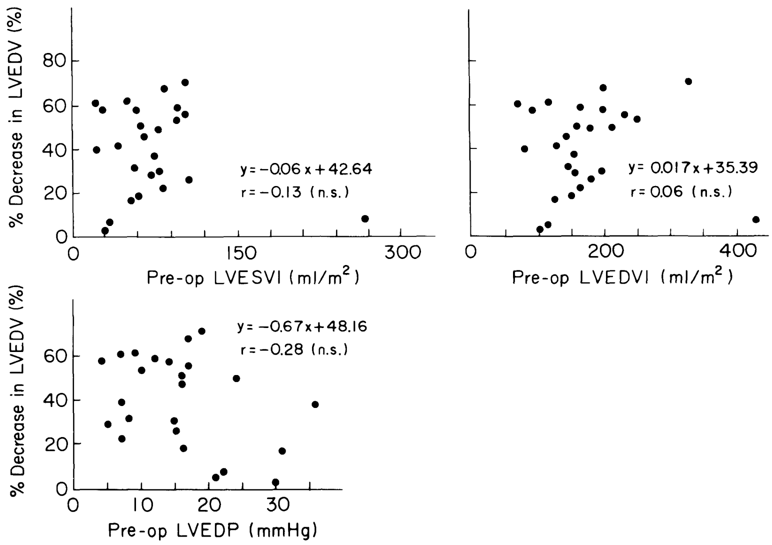

Fig. 2. Relations of % decrease in LVEDV to pre-op LVESVI, pre-op LVEDVI and pre-op LVEDP. There was not significant correlation between % decrease in LVEDV and pre-op LVESVI, LVEDVI or LVEDP. LVESVI, left ventricular end-systolic volume index; LVEDVI, left ventricular end-diastolic volume index; LVEDP, left ventricular end-diastolic pressure. Other abbreviations are the same as those in Fig. 1.

LVESVI, LVEDVI and LVEDP are shown in Fig. 2. The percent decrease in LVEDV showed no significant correlation with the LVESVI, LVEDVI or LVEDP.

There was no significant difference in the RF and RSV between the group A (RSV/LVEDV of less than 0.25) and group B (RSV/LVEDV of more than 0.26) (Table 1).

TABLE 1. *Comparison of group A and group B on the RF, RSV and % decrease in LVEDV*

	RSV/LVEDV		p-Value
	Group A (≦0.25)	Group B (≧0.26)	
RF (%)	44±14	56±12	n.s.
RSV (ml/m^2)	40±29	64±29	n.s.
% Decrease in LVEDV	16±11	52±11	0.01

Values are expressed as means±S.D. RF, regurgitant fraction; RSV, regurgitant stroke volume; LVEDV, left ventricular end-diastolic volume; n.s., not significant.

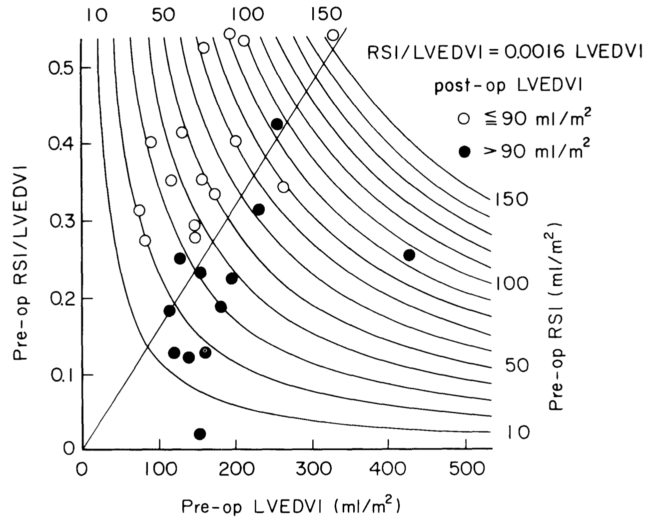

Fig. 3. Relation of pre-op RSI/LVEDVI to pre-op LVEDVI using isopleths of pre-op RSI. Open symbol (○) indicates post-op LVEDVI of less than 90 ml/m^2, and closed symbol (●) shows post-op LVEDVI of more than 90 ml/m^2. Open and closed symbols were separated by the straight line of RSI/LVEDVI=0.0016 LVEDVI. RSI, regurgitant stroke index; post-op, postoperative. Other abbreviations are the same as those in Fig. 2.

The postoperative LVEDVI in the group A was significantly greater than that in the group B ($p<0.01$, Table 2). The postoperative LVESVI in the group A were significantly higher than that in the group B ($p<0.05$). The postoperative EF in the of group A was significantly lower than that in the group B ($p<0.05$).

Using isopleths of the regurgitant stroke index (RSI), relationships between preoperative RSI/LVEDVI and preoperative LVEDVI are presented in Fig. 3. Patients were divided by the equation of RSI/LVEDVI=0.0016 LVEDVI. All but one patient with a normal postoperative LVEDVI showed RSI/LVEDVI

TABLE 2. *Comparison of group A and group B on the post-op LVEDVI, LVESVI and EF*

	RSV/LVEDV		
	Group A ($\leqq 0.25$)	Group B ($\geqq 0.26$)	p-Value
Post-op LVEDVI (ml/ml^2)	116 ± 15	83 ± 22	0.01
Post-op LVESVI (ml/m^2)	47 ± 25	24 ± 10	0.05
Post-op EF (%)	55 ± 18	71 ± 9	0.05

Values are expressed as means$\pm$S.D. LVEDVI, left ventricular end-diastolic volume index; LVESVI, left ventricular end-systolic volume index; EF, ejection fraction; post-op, post-operative; Other abbreviations are the same as those in Table 1.

larger than 0.0016 LVEDVI, whereas all but two patients with postoperative LVEDVI larger than 90 ml/m^2 showed the RSI/LVEDVI smaller than 0.0016 LVEDVI.

DISCUSSION

It is known that LV dysfunctions may exist in asymptomatic patients with AR (Rahimtoola 1977; Henry et al. 1980b). The valve replacement for such asymptomatic patients before subjective symptom develops has been proposed with increasing frequency (Rahimtoola 1977; Gassch et al. 1983). Although various indicators to evaluate the LV function in patients with AR have been reported, precise guidelines based on such functional evaluation to learn the proper timing of surgery are not yet available. Henry et al. (1980b) has recommended to operate patients having a left ventricular end-systolic dimention of 55 mm or greater, even clinical symptom during exercise was suboptimal in patients who had had the preoperative sympton was absent. Similarly, Tan et al. (1988) reported that the LV response to postoperative endsystolic volume index greater than 100 ml/m^2. Since both Henry and Tan's studies were done using M-mode echocardiography, however, underestimation of the LV dimensions, overestimation of ejection phase indices and abnormal postoperative septal motion can be made creating many problems in decision making for surgical intervention (O'Rourke and Crawford 1980). Gassch et al. (1983) reported that measurements of the end-diastolic or end-systolic dimensions in a patient are relatively poor indicators for assumption of the subsequent postoperative course, while the combination of the end-systolic and end-diastolic dimensions or the end-systolic dimension and end-diastolic radius/thickness ratio corrected for systolic pressure, are very useful prognostic clues. But, this report also has potential limitations in factor measurements since an echocardiography had been applied.

Levine and Gassch (1983) have made retrospective analyses and suggested that the RSV/LVEDV may be an useful index for the LV function assessment in patients with AR. Bonow et al. (1988) demonstrated that in a group of patients with a normal preoperative EF, the RSV/LVEDV was highly associated with the postoperative reduction in the LV end-diastolic dimension, while patients with a subnormal preoperative EF, theratio did not correlate well. In our current studies, the preoperative RSV/LVEDV correlated well with the postoperative decrease in the LVEDV, even if in patients with a subnormal preoperative EF. The increased LV end-diastolic volume in AR patients has two causative components that may be separated after valve replacement. The one component is the dilatation due to the regurgitation which represents the major part of the reversible dilatation after the valve replacement, and the other is the dilatation due to myocardial dysfunction which may persist after the AVR (Levine and Gassch 1983). These studies has suggested that the preoperative ventricular response to AVR could be predicted by the preoperative RSV/LVEDV. It is also suggested that the evaluation of the preoperative RSV/LVEDV can provide the way to distinguish the volume overload itself from the chronic malefic effects of hemodynamic burden on the ventricle.

The postoperative LVEDVI is predictable by the equation of the preoperative RSI/LVEDVI=0.0016 LVEDVI. Normal postoperative LVEDVI can be expected by the preoperative RSI/LVEDVI of more than 0.0016 LVEDVI. Thus, it can be recommended that AR patients should be operated before his preoperative RSI/LVEDVI dropps less than 0.0016 LVEDVI to achieve good postoperative ventricular response.

In conclusion, the present study has demonstrated that the percent decrease in the postoperative LVEDV was significantly related with the preoperative RSV/LVEDV, but not with preoperative EF, LVEDV, LVESV or LVEDP. Patients with a preoperative RSV/LVEDV more than 0.26 had a smaller postoperative LVEDV and LVESV and a higher postoperative EF than those with a preoperative RSV/LVEDV less than 0.25. An operative intervention should be made before the RSI/LVEDVI becomes less than 0.0016 LVEDVI.

References

1) Bonow, R.O., Dodd, J.T., Maron, B.J., O'Gard, P.T., White, G.G., McIntosh, C.L., Clark, R.E. & Epstein, S.E. (1988) Long-term serial changes in left ventricular function and reversal of ventricular dilatation after valve replacement for chronic aortic regurgitation. *Circulation*, **78**, 1108-1120.

2) Cunha, C.L., Guiliani, E.R., Fuster, V., Seward, J.B., Brandenburg, R.O. & McGoon, D.C. (1980) Preoperative M-mode echocardiography as a predictor of surgical results in chronic aortic insufficiency. *J. Thorac. Cardiovasc. Surg.*, **79**, 256-265.

3) Gassch, W.H., Carroll, J.D., Levine, H.J. & Criscitiello, M.G. (1983) Chronic aortic regurgitation: Prognostic value of left ventricular end-systolic dimension and end-diastolic radius/thickness ratio. *J. Am. Coll. Cardiol.*, **1**, 775-782.

4) Henry, W.L., Bonow, R.O., Borer, J.S., Ware, J.H., Kent, K.M., Redwood, D.R.,

McIntosh, C.L., Morrow, A.G. & Epstein, S.E. (1980a) Observations on the optimum time for operative intervention for aortic regurgitation. I. Evaluation of the results of aortic valve replacement in symptomatic patients. *Circulation*, **61**, 471-483.

5) Henry, W.L., Bonow, R.O., Rosing, D.R. & Epstein, S.E. (1980b) Observations on the optimum time for operative intervention for aortic regurgitation. II. Serial echocardiographic evaluation of asymptomatic patients. *Circulation*, **61**, 484-492.

6) Levine, H.J. & Gassch, W.H. (1983) Ratio of regurgitant volume to end-diastolic volume. A major determination of ventricular response to surgical correction of chronic volume overload. *Am. J. Cardiol.*, **52**, 406-410.

7) O'Rourke, R.A. & Crawford, M.H. (1980) Timing of valve replacement in patients with chronic aortic regurgitation. *Circulation*, **61**, 493-495.

8) Rahimtoola, S.H. (1977) Early valve replacement for preservation of ventricular function. *Am. J. Cardiol.*, **40**, 472-474.

9) Tan, S. (1988) Left ventricular response to exercise in patients undergoing aortic valve replacement for aortic regurgitation. *Nippon Kyobu Geka Gakkai Zasshi*, **36**, 860-869. (Japanese)