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Postoperative Regression of Left Ventricular Dimensions in Aortic Insufficiency: A Long-Term Echocardiographic Study

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The ability of preoperative M-mode echocardiography to predict the clinical course and the decrease in left ventricular size was assessed in 42 patients after uncomplicated valve replacement for isolated aortic insufficiency. During follow-up study, one patient died of chronic heart failure. The New York Heart Association functional class of the 41 survivors improved from 2.4 to 1.2. All patients had a preoperative M-mode echocardiogram.

Serial echocardiographic measurements, available in 33 patients, showed a sustained decrease in left ventricular end-diastolic dimension after the first postoperative year from 73 ± 8 to 57 ± 9 mm at 6 to 12 months and to 53 ± 9 mm at 3 years postoperatively ($p < 0.01$). Left ventricular cross-sectional area decreased from 31 ± 8 to 26 ± 7 cm^2 and then to 23 ± 5 cm^2 at the latest follow-up study ($p < 0.01$). At 3 years postoperatively, M-mode echocardiograms were available in 37 patients: 24 had a normal left ventricular dimension (group 1), while 13 still had an enlarged left ventricle (group 2). The clinical course in these two groups was similar. The best preoperative predictor of persistent left ventricular enlargement was the end-diastolic dimension ($p < 0.05$), whereas fractional shortening and the end-diastolic radius/thickness ratio were not predictive.

It is concluded that: 1) uncomplicated valve replacement for chronic aortic insufficiency is followed by a benign clinical course; 2) the reduction in left ventricular size may continue beyond the first postoperative year; 3) persistence of moderate left ventricular enlargement after surgery does not indicate a poor clinical prognosis; and 4) preoperative M-mode echocardiographic variables are poor predictors of clinical outcome and regression in left ventricular size.

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A cohort of preoperative variables derived from clinical (1,2), noninvasive (3–8) and invasive investigations (9–14), mostly related to left ventricular function, have been identified as predictors of perioperative risk and late outcome in patients after valve replacement for chronic aortic insufficiency. However, results from our institution and others (15–18) suggested that preoperative left ventricular dysfunction does not preclude a favorable clinical course and regression in left ventricular dimensions in the majority of these patients. These results were possibly explained by patient selection, improved techniques of perioperative myocardial preservation and the use of less obstructive prosthetic valves (15–17).

Persistence of left ventricular enlargement in the first months after valve replacement has been suggested as an indicator of irreversible left ventricular dysfunction and poor survival (2–5). These conclusions were reached on the basis of observations in small patient groups followed up for 1 year or less (3–5,8) and are at variance with those of Toussaint et al. (19), who observed continued regression in left ventricular dimensions at the latest follow-up study on serial angiographic studies at 8 and 27 months postoperatively.

In this study, changes in left ventricular dimension at 6 to 12 months and 3 years postoperatively in consecutive patients who underwent valve replacement for chronic isolated aortic insufficiency were compared with preoperative echocardiographic measurements to predict the long-term clinical course (median follow-up period 5 years) and left ventricular dimension 3 years after valve replacement.

Methods

Patients. From January 1973 to January 1981, 42 patients (median age 45 years, range 19 to 66; 27 male) with

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symptomatic aortic insufficiency who underwent uncomplicated aortic valve replacement fulfilled the following criteria: chronic aortic regurgitation, absence of associated aortic stenosis (peak transvalvular gradient < 20 mm Hg) or other significant valvular disease and absence of obstructive coronary artery disease. The occurrence of perioperative myocardial infarction was also considered a criterion for exclusion. All patients had a good quality preoperative M-mode echocardiogram and at least one postoperative echocardiogram. All except one patient underwent preoperative cardiac catheterization and cineangiocardiography. Selective coronary arteriography was performed in 34 patients (all patients with chest pain and those older than 40 years of age). The insufficiency was of rheumatic origin in 12 patients, and due to endocarditis in 10, syphilis in 3, Marfan's syndrome in 1, ankylosing spondylitis in 1 and unknown factors in 15. All patients were symptomatic before surgery; 23 were in New York Heart Association functional class II, 16 in class III and 3 in class IV. Myocardial protection during surgery was provided by coronary artery perfusion and topical hypothermia in the first 9 patients and by cold potassium cardioplegia and topical hypothermia in the subsequent 33 patients. Thirty patients received a Björk-Shiley tilting disk prosthesis, two a Starr-Edwards prosthesis, eight a Hancock xenograft bioprosthesis, two an Angell-Shiley tissue valve and one a St. Jude medical prosthesis. There were no perioperative or early deaths.

Preoperative and follow-up echocardiograms. The following measurements from the M-mode echocardiogram were performed: 1) left ventricular end-diastolic diameter (EDD), defined as the distance between the left-sided endocardial surface of the interventricular septum and that of the posterior wall at the onset of the Q wave of the electrocardiogram; 2) left ventricular end-systolic diameter (ESD), defined as the smallest left ventricular diameter; 3) fractional shortening, defined as

$$\left(\frac{EDD - ESD}{EDD}\right) \times 100;$$

4) left ventricular cross-sectional area, an index of left ventricular hypertrophy, derived from left ventricular end-diastolic diameter and posterior wall thickness (PWTh):

$$\left(\frac{EDD}{2} + PWTh\right)^2 - \left(\frac{EDD}{2}\right)^2;$$

and 5) left ventricular radius/thickness ratio, defined as

$$\left(\frac{EDD}{2}\right) \div PWTh \ (4).$$

M-mode echocardiograms were recorded using standard techniques (20) with the patients in the supine or slight lateral decubitus position. To minimize the variability in left ventricular measurements due to body positions, serial echocardiograms were obtained in the same position in preoperative and postoperative studies. Serial measurements were made with the observer blinded to previous echocardiographic measurements.

Patient groups. All 42 patients had a preoperative and postoperative M-mode echocardiogram. On the basis of the availability of an echocardiographic study 3 years after their valve replacement, 37 patients were classified into two groups: 24 patients with normal left ventricular end-diastolic diameter (≤55 mm) and normal cross-sectional area (≤26 cm^2) (group 1) and 13 with persistent left ventricular enlargement, defined as end-diastolic diameter greater than 55 mm or cross-sectional area greater than 26 cm^2, or both (group 2). Of these 37 patients, 33 had also had an echocardiographic study 6 to 12 months postoperatively. Only the pre- and early postoperative echocardiograms were available in the other five patients (Table 1). Clinical follow-up data (median duration 5 years, range 3 to 9) were obtained in all patients.

Data analysis. Analysis of variance was performed to analyze serial changes in echocardiographic dimension. Paired *t* test was used to compare preoperative with postoperative measurements and unpaired *t* test was used to compare different patient groups.

Table 1. Pre- and Postoperative Clinical and Echocardiographic Data From Five Patients Without a Late Postoperative Echocardiogram

Preoperative			Early Postoperative		Late Postoperative	
EDD (mm)	CSA (cm^2)	NYHA Class	EDD (mm)	CSA (cm^2)	NYHA Class	Follow-Up (yr)
68	27	II	55	20	I	3
85	33	II	50	25	I	6
65	45	II	50	18	I	5
100*	42	II	100	34	Death	2
82	28	III	70	30	I	3

*Patient who died 2 years after valve replacement surgery. CSA = cross-sectional left ventricular area; EDD = end-diastolic left ventricular dimension; NYHA = New York Heart Association.

Receiver operating characteristic curves were utilized to compare the relative predictive accuracy of the different preoperative echocardiographic variables for persistent postoperative left ventricular enlargement. The theory of these curves and the principles of their composition have been extensively described (21). In these curves, the sensitivity and the specificity of each test are plotted, where sensitivity is the fraction of correct classifications of patients who satisfy the "end point" criteria, and specificity is the fraction of correct classifications of all patients who satisfy the "non end point" criteria. These curves, when generated for different tests, provide a direct comparison of the various test results over the entire range of measurements and allow selection of the most advantageous cutoff points when using a single test. The best cutoff point for each test is defined as that value which provides the highest sensitivity and specificity.

After the identification of the optimal cutoff point for the prediction of persistent late postoperative left ventricular enlargement, the predictive accuracy of each preoperative echocardiographic variable was evaluated in terms of its predictive value of a positive test (true positive/all positive tests), predictive value of a negative test (true negative/all negative tests) and efficiency (true positive + true negative tests/all patients).

Results

Clinical course. Clinical follow-up data of 5 years (range 3 to 9) from all patients were available and showed that the functional class improved in all. Four patients were in class II and 37 were free of symptoms (class I) during their normal daily activities. One patient died from progressive heart failure 2 years after valve replacement. Preoperatively, he was in functional class III and he had the largest left ventricular echocardiographic dimensions (left ventricular end-diastolic diameter 100 mm, end-systolic diameter 85 mm, fractional shortening 15%, cross-sectional area 42 cm^2 and radius/thickness ratio 4.1) (Table 1). Despite an uncomplicated valve replacement, symptoms and left ventricular dimensions did not decrease postoperatively, indicating irreversible myocardial dysfunction.

Serial postoperative changes in left ventricular dimensions. Of five patients, only the pre- and early postoperative echocardiograms were available for analysis. The results and their late postoperative functional class are presented in Table 1. Serial echocardiographic measurements were available preoperatively and 6 to 12 months and 3 years postoperatively in 33 patients. The results for left ventricular end-diastolic diameter, cross-sectional area and radius/thickness ratio are summarized in Table 2. Individual data for end-diastolic diameter and cross-sectional area are represented in Figures 1 and 2. On average, end-diastolic diameter decreased by 22% and cross-sectional area by 16% within the first postoperative year. There was an additional decrease of 8 and 11%, respectively, 3 years postoperatively. This persistent late decrease in left ventricular dimension was seen in the patients who still had left ventricular enlargement 6 to 12 months postoperatively.

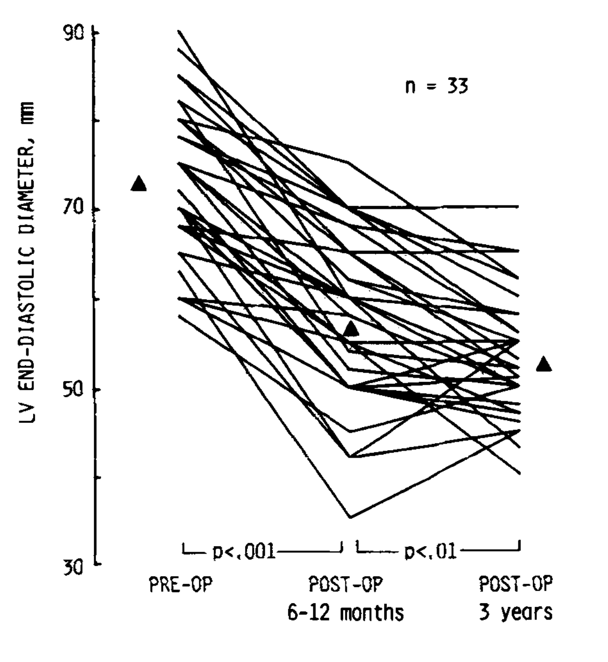
Table 2. Serial Postoperative Changes in Left Ventricular Dimensions in 33 Patients

	Preoperative	Postoperative (6 to 12 mo)	Postoperative (3 yr)
EDD (mm)	73 ± 8	57 ± 9*	53 ± 9†
CSA (cm^2)	31 ± 8	26 ± 7*	23 ± 5†
R/Th ratio	3.2 ± 0.5	2.4 ± 0.5*	2.3 ± 0.3

*p = 0.01 versus preoperative; †p = 0.01 versus postoperative at 6 to 12 months. R/Th = radius/thickness ratio; other abbreviations as in Table 1.

Preoperative versus postoperative echocardiographic data 3 years after valve replacement. An M-mode echocardiogram 3 years after valve replacement was available in 37 patients. End-diastolic diameter decreased by 27% (from 73 ± 8 to 53 ± 6 mm, $p < 0.001$) and cross-sectional area by 26% (from 31 ± 8 to 23 ± 5 cm^2, $p < 0.001$). Twenty-four patients had normal left ventricular dimensions, defined as an end-diastolic diameter of 55 mm or less and a cross-sectional area of 26 cm^2 or less (group 1), while 13 had persistent left ventricular enlargement (group 2). Postoperatively, the median end-diastolic diameter was 50 mm (range 43 to 55) in group 1 and 58 mm (range 50 to 70) in group 2. The median postoperative cross-sectional

Figure 1. Serial echocardiographic changes in left ventricular (LV) end-diastolic diameter 6 to 12 months and 3 years after aortic valve replacement. POST-OP = postoperative data; PRE-OP = preoperative data. The **arrowheads** indicate mean values.



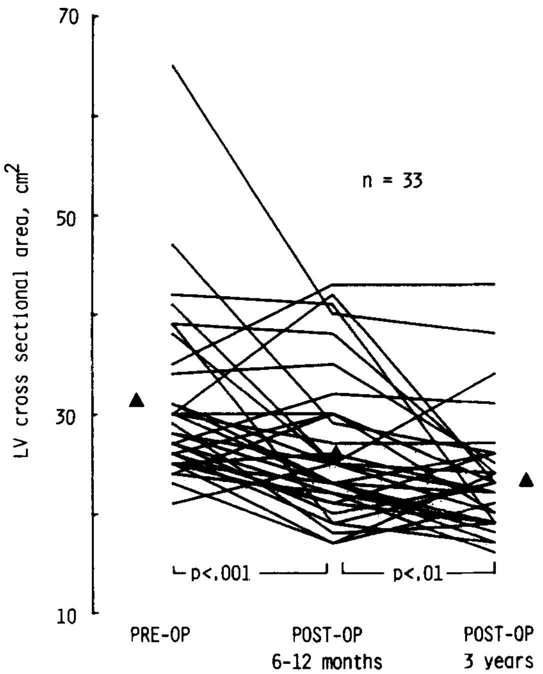


Figure 2. Serial echocardiographic changes in left ventricular cross-sectional area 6 to 12 months and 3 years after aortic valve replacement. Abbreviations as in Figure 1.

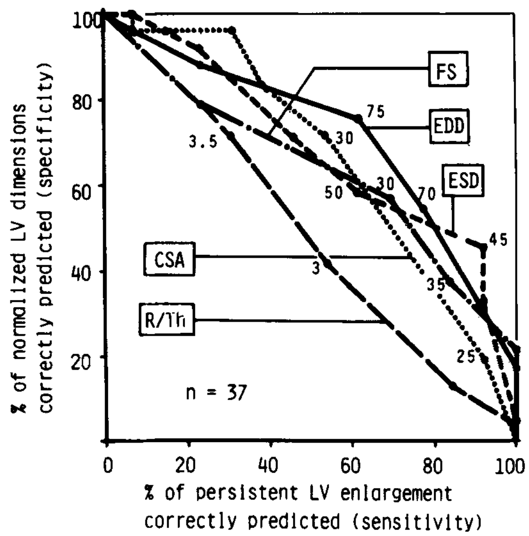


Figure 3. Receiver operating curves indicating specificity (correctly predicted normalized left ventricular [LV] dimensions postoperatively) versus sensitivity (correctly predicted persistent left ventricular enlargement postoperatively) of preoperative echocardiographic variables to predict left ventricular dimension 3 years postoperatively. The best single predictor was left ventricular end-diastolic diameter (EDD), while the left ventricular radius/thickness ratio (R/Th) had no predictive value. CSA = cross-sectional left ventricular area; ESD = end-systolic left ventricular dimension; FS = fractional shortening; numbers inside the figure indicate the mean measurement for each variable.

area was 20 cm² (range 14 to 26) in group 1 and 26 cm² (range 22 to 43) in group 2. Three patients in group 1 and one in group 2 were in functional class II at the late follow-up study; the other patients were asymptomatic (class I).

Prediction of persistent left ventricular enlargement 3 years postoperatively from preoperative clinical and echocardiographic data. Age, duration of symptoms and functional class before surgery were not predictive of persistent postoperative left ventricular enlargement. Preoperative echocardiographic data in patients with and without persistent postoperative cardiomegaly are summarized in Table 3. End-diastolic diameter, end-systolic diameter and cross-sectional area were larger in patients with persistent enlargement of the left ventricle, whereas fractional shortening and radius/thickness ratio were not predictive.

The receiver operating curves indicating the sensitivity and specificity of the single preoperative echocardiographic measurements to predict left ventricular dimensions 3 years postoperatively are represented in Figure 3. The results show that the end-diastolic diameter had a higher predictive value than the end-systolic diameter, fractional shortening and cross-sectional area, whereas radius/thickness ratio was not predictive of persistent left ventricular enlargement. The predictive accuracy of selected and clinically applied cutoff

Table 3. Preoperative Echocardiographic Data in 37 Patients With Normal Postoperative Left Ventricular Dimensions 3 Years Postoperatively (group 1) or Persistent Left Ventricular Enlargement (group 2)

	Group 1 (n = 24)			Group 2 (n = 13)			
	Mean	SD	Range	Mean	SD	Range	p Value
EDD (mm)	71	8	58 to 90	77	6	65 to 88	0.03
ESD (mm)	49	10	32 to 68	56	8	40 to 73	0.04
FS (%)	31	7	20 to 45	27	7	9 to 38	NS
CSA (cm²)	29	6	21 to 47	35	11	25 to 65	0.04
R/Th ratio	3.1	0.5	1.9 to 4.1	3.1	0.6	2.1 to 4.4	NS

ESD = left ventricular end-systolic diameter; FS = left ventricular minor axis fractional shortening; other abbreviations as in Tables 1 and 2.

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Table 4. Predictive Accuracy of Preoperative Echocardiographic Variables for the Postoperative Persistence of Left Ventricular Enlargement

	EDD >75 mm	ESD >50 mm	FS <30%	CSA >30 cm²	R/Th >2.5	EDD ≥ 75 mm and ESD ≥ 50 mm
Sensitivity	61	61	69	54	84	92
Specificity	75	58	58	71	13	50
PV+	57	44	47	50	34	50
PV−	78	74	78	74	60	92
Efficiency	70	59	62	65	38	65

All values are expressed in percent. PV+ = predictive value of a positive test; PV− = predictive value of a negative test; other abbreviations as in Tables 1 and 2.

points of individual echocardiographic variables are summarized in Table 4. Using a combination of two preoperative echocardiographic variables, the highest predictive accuracy was achieved by an end-diastolic diameter of 75 mm or greater and an end-systolic diameter of 50 mm or greater. This combination yielded a 92% predictive value when the test was negative. However, there was a 50% false positive rate owing to 12 patients who, despite a preoperative end-diastolic diameter of 75 mm or greater and end-systolic diameter of 50 mm or greater, had normal left ventricular dimensions at the late follow-up study.

Discussion

The discrepancy between symptoms and left ventricular function in patients with chronic aortic insufficiency is well known (5). Some investigators (3) recommend early valve replacement in asymptomatic or mildly symptomatic patients with early signs of left ventricular dysfunction, to allow for a return to normal of postoperative left ventricular function and reversal of left ventricular size. Although improved techniques of perioperative myocardial protection (22) have reduced the surgical risk, morbidity related to the implanted prosthetic valve remains a long-term problem (23). In addition, there is controversy about the prognostic value of preoperative left ventricular function (2–4,15–18) and the time course of postoperative changes in left ventricular dimensions (5,8,19). Continued reduction in left ventricular size has been observed after the first 8 months after valve replacement (19).

In this study, there was no operative death and no perioperative myocardial infarction. This is possibly related to the myocardial protection during surgery by cold potassium cardioplegia. The one patient who died during follow-up study had an extremely large preoperative echocardiographic dimension that failed to decrease despite an uncomplicated surgical procedure. The other patients showed a sustained regression in left ventricular dimensions during follow-up study, which in many patients extended beyond the first year after valve replacement. These findings are in agreement with the data of Toussaint et al. (19), who performed serial angiographic examinations at 8 and 27 months postoperatively. Three years after valve replacement, 24 (65%) of 37 patients had normal echocardiographic left ventricular dimensions.

Predictive value of preoperative left ventricular dimensions. These results are similar to those reported by Gaasch et al. (4,5), who found a normal end-diastolic diameter in 25 of 32 patients 1 year after surgery. However, in contrast to their observation of the high predictive value of the preoperative radius/thickness ratio, we found this the poorest predictor of persistent left ventricular enlargement

Table 5. Preoperative and Serial Postoperative Data From Seven Patients With a Preoperative Radius/Thickness Ratio of 4 or More

			Left Ventricular End-Diastolic Dimension (mm)		
R/Th Ratio	Cardioplegia	Prosthetic Valve	Preoperative	Postoperative (6 to 12 mo)	Postoperative (3 yr)
4.1	No	Björk-Shiley	75	60	43
4.4	Yes	Starr-Edwards	80	75	62
4.1*	Yes	Hancock	100	100	(death)
4.1	Yes	Hancock	82	70	(no echocardiogram)
4.0	Yes	Hancock	80	—	50
4.0	Yes	Hancock	90	60	50
4.0	Yes	Björk-Shiley	80	65	53

*Patient who died 2 years postoperatively. Abbreviations as in previous tables.

3 years after surgery (Fig. 3). A possible explanation for this discrepancy is that we had longer echocardiographic follow-up data. The serial echocardiographic measurements in the seven patients with a preoperative radius/thickness ratio greater than or equal to 4 are represented in Table 5; in four of the seven, the end-diastolic diameter normalized 3 years postoperatively.

In our experience, the most reliable single preoperative echocardiographic predictor of persistent left ventricular enlargement after valve replacement is the end-diastolic diameter (Fig. 3), although its predictive accuracy is not optimal. Using 75 mm as a cutoff point for end-diastolic diameter, the sensitivity was 61% and the specificity was 75%. A high level of sensitivity (92%) was achieved if the end-diastolic diameter of 75 mm or greater was used in combination with an end-systolic diameter of 50 mm or greater, but this was associated with a 50% false positive prediction. Therefore, the preoperative M-mode echocardiogram is a good predictor of patients whose left ventricular dimension will return to normal, but not of those who will have persistent left ventricular enlargement. The postoperative functional class is not related to postoperative ventricular dimensions.

Conclusions. The long-term prognosis is favorable for patients with symptomatic aortic insufficiency without associated other valvular or coronary artery disease who undergo uncomplicated valve replacement. Preoperative echocardiographic results do not affect the postoperative clinical course. Left ventricular dimensions may regress after the first postoperative year, and are normalized in the majority of patients 3 years after valve replacement. The preoperative M-mode echocardiogram is not a good predictor of late postoperative left ventricular enlargement. These results suggest that early surgery in patients with initial echocardiographic signs of left ventricular dysfunction is not mandatory if it is not indicated by symptoms.

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