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Prediction of Surgical Strategy in Mitral Valve Regurgitation Based on Echocardiography

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The purpose of this prospective multicenter study of 350 consecutive patients who were accepted for mitral valve surgery because of severe regurgitation, was to assess the value of preoperative transthoracic and transesophageal echocardiography in predicting the surgical strategy in severe mitral regurgitation: repair or replacement. The cardiologist predicted the surgical strategy on the basis of the echocardiographic examination, according to predefined guidelines for repair and replacement. The predicted strategy and motivation thereof were compared with the surgical findings and procedure that was performed. Agreement on the basis of transthoracic echocardiography was reached in 86% of the repair patients and on the basis of transesophageal echocardiography in 89%. Agreement on the basis of transthoracic echocardiography was reached in 74% of the replacement patients and on the basis of transesophageal echocardiography in 75%. This study underlines the potential role of echocardiography in predicting the surgical procedure to be applied, provided that both surgeon and cardiologist use the same nomenclature and that the guidelines for replacement/repair are adhered to. Both transthoracic and transesophageal echocardiography appear to be equally accurate in predicting the optimal surgical procedure in this respect. *© 1997 by Excerpta Medica, Inc.*

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We conducted a prospective multicenter study comprising 350 consecutive patients who were accepted for mitral valve surgery because of predominant regurgitation. All patients were investigated preoperatively by means of transthoracic and transesophageal echocardiography before operation, on the basis of which the cardiologists predicted the surgical strategy, according to guidelines formulated by a panel of participating surgeons. This study examined the value of each echo technique (i.e., transthoracic and transesophageal echocardiography) in predicting the surgical strategy and the applicability of the guidelines with respect to repair and replacement.

METHODS

Nine cardiothoracic centers participated in the study. In each center the principal investigator, a senior cardiologist experienced in echocardiography, was responsible for the realization of the study. Data collection and processing took place at the Interuniversity Cardiology Institute of The Netherlands data network in Utrecht. Data analysis was performed at the Department of Clinical Epidemiology and Biostatistics of the Academic Medical Center in Amsterdam. The study group included adult patients accepted for mitral valve surgery; those excluded had predominant mitral valve stenosis and/or previous mitral valve surgery. In all participating centers a complex of symptoms and clinical signs as well as the results of cardiac catheterization and echocardiography determined acceptance for mitral valve surgery, such as functional classification, severity of valvular dysfunction, presence of left ventricular dysfunction, rhythm disturbances, or presence of pulmonary hypertension. Additional surgical procedures during the same operation were no reasons for exclusion. Patient intake took place within 15 months, and 350 patients were entered into the study. On admittance to the hospital their complete medical history was taken, a complete physical workup, and their electrocardiographic and angiographic data were obtained. All patients underwent both preoperative transthoracic and transesophageal echocardiographic examination. Surgery consisted of either valve replacement or valve repair, if necessary followed by secondary valve replacement.

Echocardiography: Both transthoracic and monoplane transesophageal 2 dimensional and Doppler echocardiographic studies were performed. Multiple acoustic windows and imaging planes were used including parasternal long-axis, short-axis, and apical 2- and 4-chamber views as suggested by the American Society of Echocardiography.[1] The protocol for

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transesophageal imaging of the mitral valve apparatus and the specific views obtained have previously been described.[2] The transesophageal studies were performed either under local oropharyngeal anesthesia (preoperatively) or under general anesthesia (intraoperatively). Blood pressure was measured and recorded during the observation. Transthoracic Doppler echocardiography was performed with a 2.5- or 3-MHz annular phased-array transducer, and transesophageal Doppler echocardiography with a 5-MHz imaging transducer. Doppler signals were analyzed on-line using 5 cardiac cycles. During color Doppler examination, gain setting was increased to just below the level of background noise. In the transthoracic examination, mitral regurgitation was semiquantatively graded by determining the maximum regurgitant jet area relative to the left atrial area in multiple orthogonal planes.[3] Transesophageal echocardiographic grading of regurgitation was made using the maximum regurgitant jet area as a mean of 5 measurements, in the 3-chamber long-axis view as well as in the 4-chamber view.[4] The etiology of valve regurgitation was determined by identification of the anatomic substrate and functional condition. Carpentier's classification[5] of the functional condition was used: type I, normal valve mobility; type II, increased leaflet mobility; and type III, restricted valve mobility. The following anatomic characteristics were defined by echocardiography: perforations, circumscript discontinuity or hole in the leaflet leading to a regurgitant jet; vegetations, abnormal intracardiac mass attached to mitral valve leaflets or chordae; calcium, bright echoes, anywhere in the mitral valve apparatus, which are usually circumscript; chordal rupture: M-mode, low frequent flutter of the mitral valve during diastole and a high frequent flutter during systole; 2 dimensional echocardiography: loose structure attached to the mitral valve leaflet and showing an erratic motion pattern; and chordal lengthening, inappropriate lengthening of chordae, leading to systolic bulging of a part of the mitral valve leaflet into the left atrium. Origin, direction, number, and extent of jets were also used to determine the mechanism of mitral dysfunction. Depending on the site of anatomic abnormalities, the lesions were assigned to left ventricular wall, papillary muscle, chordae, annulus, or leaflet. Furthermore, if the lesion was localized at the level of the leaflet, a subdivision into 6 segments was made.

Surgery: Patients underwent operation according to the local (standard) surgical conditions as reported earlier.[6] Surgical classification of the genesis of valve regurgitation was based on findings at inspection, analogous to the echocardiographic classification of the functional condition and anatomic abnormalities.[5] Observations at inspection of the valvular apparatus, motivation of the surgical procedure, and the type and method of reconstructive technique were registered immediately after operation or ultimately within 24 hours. If secondary valve replacement was performed during the same procedure, its motivation was reported as well.

Data collection and monitoring: To ensure uniform data recording, the study coordinators designed a tailor-made, self-explanatory case record form. It provided instructions on measurements and observations, and contained numbered series of questions with categorized answers that could be indicated by ticking the appropriate boxes. All echocardiographic studies were performed according to written instructions and recorded on videotapes, which were used for off-line analysis and quality control. Surgical data were coded by the surgeon similar to the echocardiographic coding in the case record form.

Prediction of the surgical strategy: The echocardiologists were asked to document their predictions regarding the surgical procedure on the basis of guidelines formulated before onset of the study. Replacement was indicated if the leaflet was either extensively calcified or degenerated, or showed a prolapse of more than $\frac{1}{3}$ of the leaflet tissue. Valve replacement was also indicated in case of active endocarditis and if the subvalvular apparatus showed either extensive chordal fusion, calcium or papillary muscle rupture. Repair was indicated if none of the replacement conditions were present, e.g., circumscript calcium of leaflet or annulus, a prolapse of less than one third of either leaflet, pure annular dilatation, valvular perforations, or incomplete papillary muscle rupture. Prediction of the surgical strategy (based on echocardiography) was allocated to 1 of 4 categories: "repair," "replacement," "mitral valve surgery not indicated" (no surgery), or "no prediction possible" (no prediction). The category "mitral valve surgery not indicated" was only assigned when the regurgitation was not severe enough or when the etiology necessitated another procedure. "No prediction possible" was assigned if the available echocardiographic data were not sufficient; these cases were usually due to a poor-quality study. The predictions based on either transthoracic echocardiography or transesophageal echocardiography were recorded separately in the case record form. Thus, a repair procedure was considered twice.

The following definitions were used: Extensive calcium was identified by bright echocardiographic reflections in >1 site/spot of the leaflet apparatus leading to restricted leaflet mobility. Fibrosis was identified with echo by a combination of intense echoes and impaired pliability of the leaflet tissue and associated by thickening of leaflets due to degeneration and/or myxoid degeneration, with excess leaflet tissue. Chordal fusion was identified by intense echoes from the subvalvular apparatus in conjunction with thickening originating from the chordal apparatus leading to restricted valve mobility. A prolapse of the leaflet of $>\frac{1}{3}$ was identified by measuring the width of the prolapse using several transverse views by echocardiography. Active endocarditis was defined as clinically proven endocarditis with echocardiographic evidence of destruction of tissue of the leaflet apparatus. Leaflet vegetation was defined as a tumor-like structure on the leaflet or subvalvular tissue. Papillary muscle rupture was defined as complete dehiscence of 1 of the papillary muscles,

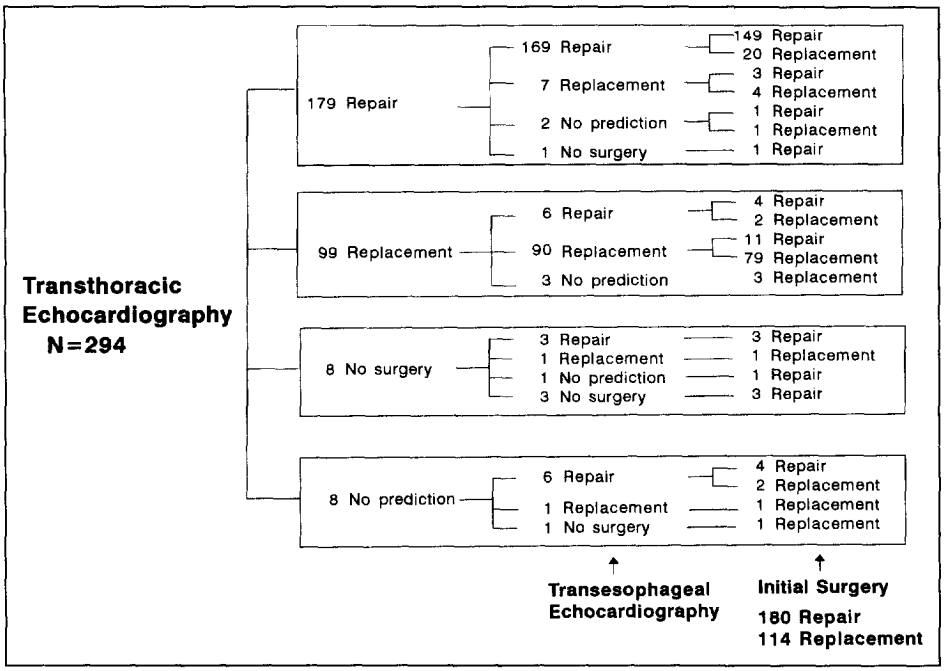

FIGURE 1. Prediction of surgical procedure by transthoracic and transesophageal echocardiography in relation to the actual initial procedure.

TABLE 1 Echocardiographic Prediction and Executed Initial Surgical Procedure

Predicted Surgical Strategy		Initial Surgical Strategy Repair Replacement	
TTE	TEE	(n = 180)	(n = 114)
Repair	Repair	149 (83%)	20 (18%)
Replacement	Replacement	11 (6%)	79 (69%)
Repair	Replacement	3 (2%)	4 (4%)
Replacement	Repair	4 (2%)	2 (2%)
No prediction/no surgery		13 (7%)	9 (8%)
Agreement			
TTE only		154 (86%)	84 (74%)
TEE only		160 (89%)	85 (75%)

TEE = Transesophageal echocardiography; TTE = transthoracic echocardiography.

echocardiographically identified by flail leaflet mobility in conjunction with overt regurgitation and with abnormal mass at the tips of the chordae. Surgical classification of the functional condition of the valvular apparatus as well as the anatomic abnormalities was made on the basis of findings at inspection. Motivation and description of the surgical procedure were registered in the case record form immediately after operation or ultimately within 24 hours. If the initial surgical procedure was valve repair, this was considered "initial surgery." However, if this was unsuccessful and necessitated a replacement, this was the outcome at "final surgery."

RESULTS

Data analysis: Data were analyzed with the SAS system.[7] Of the initial 350 patients enrolled in the central registry, 56 patients were excluded from the study for the following reasons: erroneous entry into the registry (n = 25), operation not within time window (n = 11), incomplete (echocardiographic) data (n = 6), or cancellation of mitral valve procedure (n = 14). Thus, the final study population consisted of 294 patients.

Clinical data: The mean age of the population was 62 years; there was an even distribution of men and women. The functional status was severely impaired in most patients: 80% were in New York Heart Association class III or IV before surgery. Duration of mitral regurgitation was >1 year in most patients (82%). A history of rheumatic heart disease was noted in 15% of the patients and a history of myocardial infarction in 22%. Forty percent of the patients had angiographically proven coronary artery disease. Sinus rhythm was present in 54% of the patients.

Surgery: A repair procedure was initiated in 61% of the patients, initially unsuccessful in 7% and completed in 54% of the patients. Replacement was initially performed in 39% of the patients. Concomitant cardiac surgery was performed in 63% of the initial repair group and in 55% of the ultimate replacement group. Annuloplasty was performed in 90% of the repair group and a quadrangular resection of the posterior leaflet in 39% of the patients.

Echocardiographic prediction of the initial surgical procedure (Figure 1, Table 1): Based on transthoracic echocardiography, repair was predicted in most patients. A small percentage showed no surgery or no prediction, the latter partially due to a poor quality echo. In the repair and replacement group, both echocardiographic modalities correctly predicted the initial surgical strategy in most patients. Disagreement between both echo techniques and the initial surgical procedure was noted in only 6% of the repair patients and in 18% of the replacement patients. In 8 patients, an incorrect prediction by transthoracic echocardiography was changed into a correct prediction after transesophageal echocardiography. In

another 5 patients, a correct prediction by transthoracic echocardiography was changed into an incorrect prediction by transesophageal echocardiography. In all 8 patients with no prediction by transthoracic echocardiography, prediction was feasible by transesophageal echocardiography, which was correct in most patients.

Motivation according to guidelines (Figure 2, Table II): Extensive fibrosis of the leaflet, extensive calcium, and fusion of the subvalvular apparatus were the most frequently noted motivations both by echocardiography and surgery to perform a valve replacement, although more often at surgery. In only 1 of the 114 replacement patients the surgeon provided no motivation. At surgery, the guidelines for replacement were followed for all but 6 patients; in 3 a papillary muscle rupture was repaired in contrast to the guidelines. Of the other 3 patients with restricted leaflet mobility and calcifications, repair was successful in just 1 patient. Motivation used by the surgeons in the 6 patients in which the guidelines for repair were not followed were: advanced age, concomitant procedures, or poor left ventricular function.

TABLE II Motivation for Replacement

	TTE (n = 99)	TEE (n = 99)	Surgery (n = 114)
Fibrosis of leaflet	50 (50%)	58 (58%)	56 (49%)
Extended calcification	40 (40%)	36 (36%)	54 (47%)
Fusion of subvalvular apparatus	42 (42%)	30 (30%)	32 (28%)
Prolaps of >1/3	13 (13%)	10 (10%)	8 (7%)
Papillary muscle rupture	2 (2%)	3 (3%)	4 (4%)
Fresh vegetation	2 (2%)	2 (2%)	—
"Other" motivation*	10 (10%)	5 (5%)	5 (4%)
No motivation	1 (1%)	3 (3%)	1 (1%)

* "Other" motivations than those formulated in the guidelines were: papillary muscle traction and large infarction area, annular calcifications, vegetations, and leaflet destruction.
Abbreviations as in Table I.

DISCUSSION

Because both timing and outcome of surgery are largely influenced by the type of surgery in patients with mitral valve regurgitation,[5,8–14] it is essential to know before surgery whether valve repair is feasible. Although both transthoracic and transesophageal echocardiography provide excellent information, particularly regarding the functional status of the mitral valve,[15] little is known of the relative value of the echocardiographic modalities in predicting the type of surgery in daily practice. Most studies on the subject are retrospective[16,17] and usually report the result of 1 center.[16–18]

Prediction of surgical strategy by echocardiography: The most important finding of this study is that both transthoracic and transesophageal echocardiography are equally accurate in predicting the surgical procedure to be performed. In an earlier publication,[15] we demonstrated that echocardiographic assessment of the underlying functional condition of the mitral valve yielded good results, although the specific anatomic features had been diagnosed "less than optimally." Notwithstanding the latter obstacle, surgical strategy appeared to be adequately predicted. This may be explained by the fact that the guidelines were very well adhered to. Compared with other studies,[16,17] the predictive value of the present study was similar for valve repair, but somewhat lower for valve replacement. However, these were retrospective studies from 1 center with a limited number of surgeons involved. Another important finding of the present study is that despite the better image quality of transesophageal echocardiography,[19] it nevertheless failed to show significant additional value in this respect. In only 8 patients the prediction by transthoracic echocardiography was correctly changed by transesophageal echocardiographic findings.

Disagreement in predicted and performed surgical strategy: limitations of echocardiography? Echocardiography predicted a different surgical strategy than actually performed in 31 patients. In the incorrectly predicted repair group (n = 11) (i.e., replacement predicted and repair performed), restricted leaflet mobility was the predominant feature (45%); also, increased leaflet mobility of >2 segments (27%) and leaflet calcium (27%) were other characteristics of this group. It is noteworthy that restricted leaflet mobility was found in approximately 5 of these 11 initial repair patients by both echo techniques and surgery. Of note in this respect was that repair was unsuccessful in 4 of these 11 patients. The discrepancies in predicted and performed surgical strategy may possibly be explained by underestimation of the degree of restriction/calcium by the surgeons and overestimation by the cardiologists.

Another group consisted of the 20 patients in whom repair had been predicted by both echo

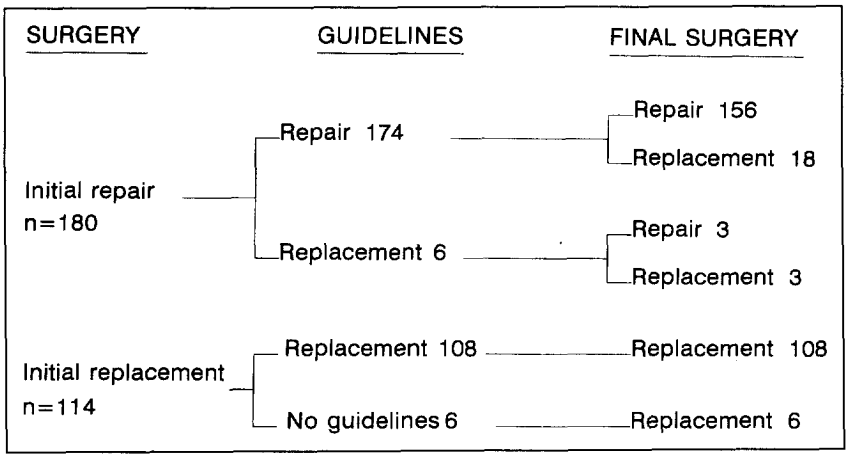

FIGURE 2. Motivation according to the guidelines in relation to the initial and ultimate surgical procedures.

modalities, but in whom nevertheless replacement was performed. Seventeen of these patients had increased leaflet mobility <2 segments of either leaflet. In addition, in 50% of these patients, a prolapse of the anterior leaflet was described by transesophageal echocardiography as motivation for repair. Although this condition usually allows for a repair procedure in most cases,[13,14,20] Barlow's disease, which is typified by a redundancy of leaflet tissue,[20,21] forms an exception. The extent of this condition, especially with involvement of the anterior leaflet, may necessitate replacement. Underestimation of the degree of increased leaflet mobility may be an explanation of this apparent disparity in prediction of the initially performed surgical strategy. In general, interpretation of the pathology of the mitral valve apparatus by echocardiography and at surgery in the incorrectly predicted group did not, however, reveal apparent differences. Of the 180 initial repair procedures, 12% were followed by replacement because of insufficient results. Remarkably, in 6 of these 21 patients replacement had been predicted.

Study limitations: One important limitation of this study is the fact that numerous surgeons are involved in this study with unequal skills in this respect. This may have influenced the results. Another limitation is the application of monoplane transesophageal echocardiography; however, at the time this study was conducted, this was the only tool available in the participating centers. It is conceivable that more advanced modalities such as multiplane transesophageal echocardiography[22] and, particularly, 3-dimensional reconstruction[23] do have a better yield.

Clinical implications: The results of this study underline the potential role of echocardiography in predicting the surgical procedure to be applied, provided that both surgeon and cardiologist use the same nomenclature and that the guidelines for replacement/repair are adhered to. Both monoplane transesophageal and transthoracic echocardiography appear to be equally accurate in predicting the optimal surgical procedure in patients undergoing mitral valve surgery for severe regurgitation. Hence, the implementation of echocardiography is mandatory to improve the management of these patients.

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APPENDIX

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