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Functional Assessment of Mitral Regurgitation by Transthoracic Echocardiography Using Standardized Imaging Planes

Diagnostic Accuracy and Outcome Implications

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OBJECTIVES We sought to assess the value of transthoracic echocardiography (TTE) using standardized imaging planes for the functional analysis of mitral regurgitation (MR) as well as for postoperative outcome implications.

BACKGROUND The feasibility of mitral valve repair is based on functional assessment of MR, mainly by transesophageal echocardiography (TEE). Considering the recent advances in TTE imaging, the incremental value of TEE in this setting needs to be re-examined.

METHODS Consecutive patients (n = 279; 181 men; median age 68 years [quartiles, 61 to 74]) who underwent surgery for MR were enrolled prospectively in two tertiary care centers. The accuracy of TTE (harmonic imaging) versus TEE for functional assessment of MR was evaluated against surgical findings.

RESULTS Valve repair (n = 237 patients, 85%) or replacement (n = 42) was predicted accurately by TTE in 97% of cases; TEE added significant information for only two patients. In the subgroup of degenerative MR (n = 190), agreement with surgical findings for the localization of prolapsed segments was 91% for TTE (kappa, 0.81) and 93% for TEE (kappa, 0.85) without incremental value of TEE ($p = 0.40$). Patients with single prolapse of the middle posterior scallop (P2) had a better postoperative outcome as compared with patients who had non-P2 lesions ($p = 0.008$). Furthermore, mitral replacement predicted by TTE was an independent predictor for postoperative long-term mortality (odds ratio 5.7, 95% confidence interval 1.97 to 16.4, $p = 0.001$).

CONCLUSIONS In experienced hands, functional assessment of MR by TTE can predict accurately valve repairability and has a strong influence on postoperative outcome. Thus, in most cases preoperative TEE is not mandatory, provided intraoperative TEE is performed. (J Am Coll Cardiol 2005;46:302–9) © 2005 by the American College of Cardiology Foundation

Valve repair is the optimal surgical treatment for patients with severe mitral regurgitation (MR) (1). As compared with valve replacement, it carries a lower perioperative mortality (1) and better postoperative outcome, explained by better preservation of left ventricular (LV) function and the avoidance of prosthetic valve-related events (2). Therefore, valve repair is a major incentive to early surgery in case of severe asymptomatic MR (3). Enriquez-Sarano et al. (4) have demonstrated that functional assessment of MR by transesophageal echocardiography (TEE) is a strong determinant of valve repairability and postoperative outcome with significant incremental value over transthoracic echocardiography (TTE).

However, the recent advent of new beam formers and harmonic imaging has improved dramatically the quality of transthoracic imaging; thus, the superiority of TEE over TTE in this setting needs to be re-examined. Furthermore, there are few data on the diagnostic accuracy of TTE for precise localization of prolapsed or flail segments in degenerative MR. Therefore, we sought to evaluate the current accuracy of TTE to predict the feasibility of valve repair as well as postoperative outcome implications in a series of consecutive patients who underwent surgery for severe MR at two tertiary care centers.

METHODS

Study population. Consecutive patients (n = 279) were prospectively enrolled at the Clinique Saint-Augustin, Bordeaux (n = 209), and the Henri Mondor University Hospital, Créteil (n = 70), between March 1998 and June 2003. Inclusion criteria were: 1) severe MR; 2) surgical correction with direct inspection of the valve by the surgeon (reference for comparisons); 3) preoperative TTE performed in routine clinical practice; and 4) TEE performed after TTE, mainly intraoperatively.

Patients with congenital heart disease, predominant mitral stenosis, papillary muscle rupture, previous mitral valve procedure, or those who required emergent surgery were

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Abbreviations and Acronyms

LV = left ventricular
MR = mitral regurgitation
NYHA = New York Heart Association
P2 = middle scallop of the posterior mitral leaflet
ROC = receiver-operating characteristic
TEE = transesophageal echocardiography
TTE = transthoracic echocardiography

excluded from analysis. No patient was excluded on the basis of age, LV dysfunction, aortic valve disease, or associated comorbidities, including previous cancer, provided that their long-term prognosis was favorable. This study was examined and approved by our local Advisory Board on Clinical Research, and informed consent was obtained from all patients before the investigations.

Echocardiographic analysis. Both centers used the same echocardiographic equipment (Acuson Sequoia, Siemens, Malvern, Pennsylvania) and same guidelines for functional analysis of MR by TTE and TEE. A comprehensive TTE examination was performed in all patients by senior echocardiographers, who had extensive experience in MR assessment, optimized by frequent confrontation with surgical findings.

Mitral regurgitation was quantified mainly by the proximal flow convergence method (5) or other validated Doppler methods (6,7). Valve prolapse or flail leaflets were assessed according to standard criteria (8). Functional anatomy of MR was assessed by: 1) Carpentier's functional classification (9); 2) suspected etiology according to functional analysis, anatomy of the valve, and patient history; and 3) precise localization of the involved scallops in case of degenerative MR, according to four standardized imaging planes (Fig. 1) (10).

Typical examples of posterior middle scallop (P2) prolapse and posterior commissural prolapse are shown in Figures 2 and 3. Echocardiographic analysis was directly transcripted from the echocardiographic reports that were typed online after each examination. The echocardiographic examinations were not reinterpreted. Valve replacement was predicted by echocardiography if at least one of the following criteria was present: extensive annular calcification, severe thickening or calcification of the mitral leaflets or subvalvular apparatus (rheumatic disease), multiple vegetations, or extensive ruptured chordae involving both leaflets (11). Otherwise, the prediction of surgical strategy was considered to be valve repair, including for patients with commissural prolapse.

Surgical findings, directly transcripted from the surgical reports, were the references to evaluate the diagnostic accuracy of TTE and TEE. The surgeons were aware of functional analysis by TTE and TEE but were not informed of the study. Thus, echocardiographic findings were independent from surgical assessment.

Postoperative outcome. Operative mortality was defined as death within 30 days after the operation. Clinical data at follow-up were obtained in all but four patients (follow-up 99% complete) at a median interval of 27 months (range, 21 to 35 months) by direct patient examination or telephone interview. Evaluated end points at follow-up were death, reoperation, and New York Heart Association (NYHA) functional class.

Statistical analysis. Continuous variables were described as medians and interquartile ranges and categorical variables as counts and percentages. Differences between groups at baseline were analyzed using the Kruskal-Wallis test, the Mann-Whitney *U* test, or chi-square test as appropriate. The sensitivity, specificity, and accuracy of TTE and TEE

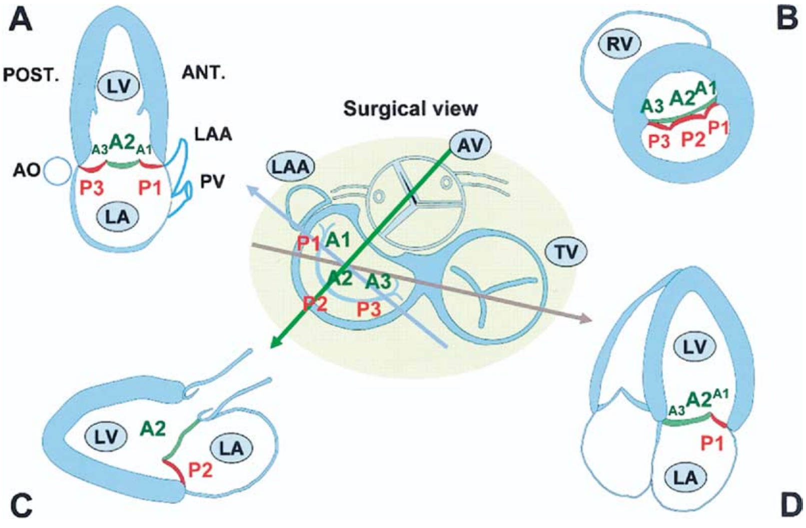

Figure 1. Four imaging planes to assess the precise localization of prolapsed or flail segments. **(A)** Intercommissural plane assessing the continuity of the commissural areas. **(B)** Parasternal short-axis view showing the anterior leaflet (A1, A2, and A3) and the three scallops of the posterior leaflet (P1, P2, and P3). **(C)** Parasternal long-axis view showing the middle segments of anterior (A2) and posterior (P2) leaflets. **(D)** Apical four-chamber view showing the anterior para commissural zone (between P1 and P2). ANT. = anterior; AO = descending aorta; AV = aortic valve; LA = left atrium; LAA = left atrial appendage; LV = left ventricle; POST. = posterior; PV = pulmonary vein; RV = right ventricle; TV = tricuspid valve.

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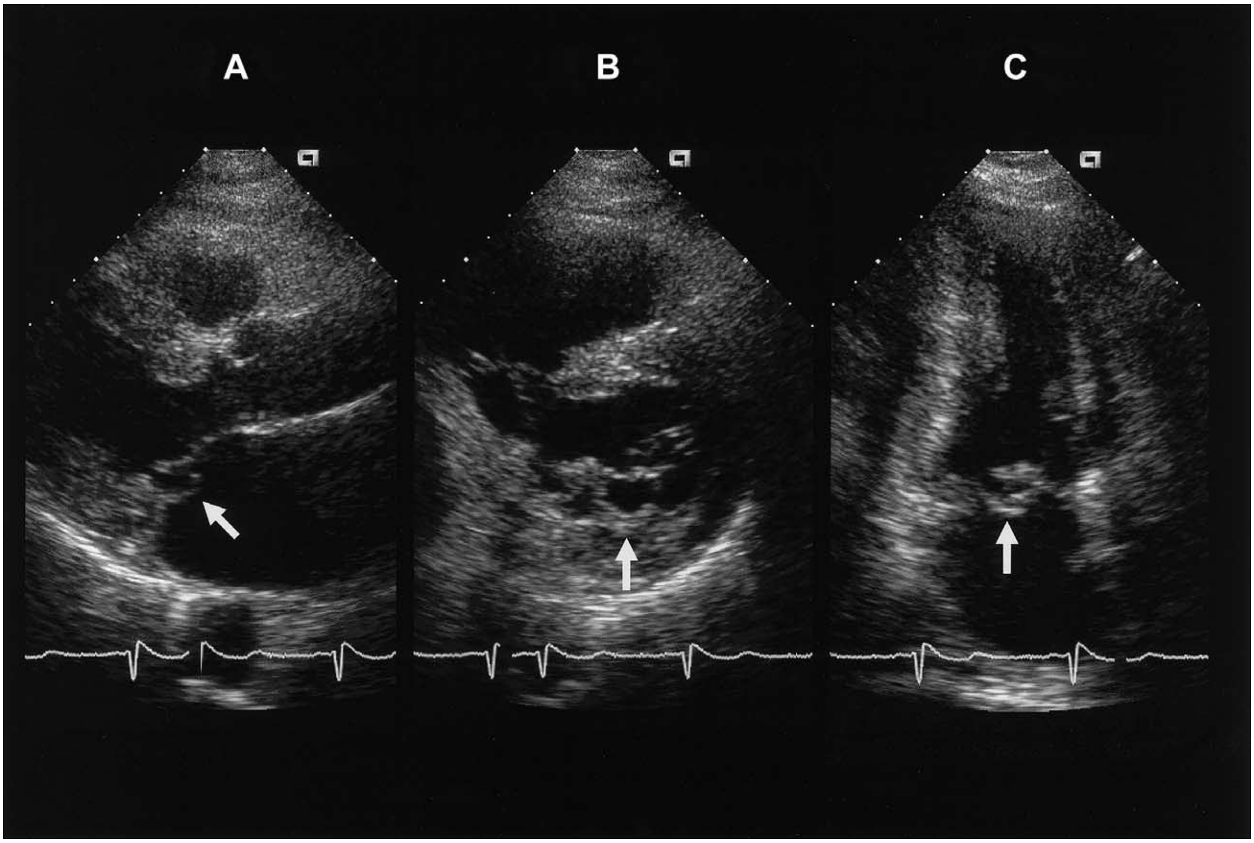

Figure 2. Flail posterior middle scallop (P2). **A** Parasternal long-axis view showing the flail P2 segment **(arrow)**; **(B)** and **(C)** Parasternal short-axis and inter-commissural views, respectively, showing medial doming of flail P2 scallop **(arrows)** without lateral discontinuity in the commissural areas (P1 and P3).

for the detection of vegetations, ruptured chordae, and annular calcification were calculated according to standard formulae. Sensitivity was plotted against 1 − specificity to produce a receiver-operating characteristic (ROC) curve. The area under the ROC curve is the predictive accuracy: a value of 0.5 indicating chance discrimination and a value of 1 indicating perfect discrimination. The area under the ROC curves of TTE and TEE were then compared.

In the subgroup of degenerative MR, the agreement between surgical findings and TTE or TEE for the localization of flailed segments was assessed by calculating the kappa coefficient (a value >0.75 indicating excellent agreement), and kappa statistics were compared using the Z test. The frequency of valve replacement versus repair according to etiology and involved scallops (for degenerative MR) was assessed by chi-square analysis.

The Kaplan-Meier method was used to establish the survival plot, and probability values for survival curve comparisons were calculated using the log-rank statistic. Variables significantly associated with perioperative mortality in univariate analysis were entered into a multiple logistic regression model to determine independent parameters. Variables significantly associated with postoperative long-term survival were included in a Cox proportional hazards survival model to assess their independent association with survival. Two-tailed p values <0.05 were considered statistically significant. Analyses were conducted using Stata software (version 7.0, Stata Corp., College Station, Texas).

RESULTS

Baseline characteristics. Among the 279 patients, 181 were men, and the median age was 68 years (range, 60 to 74); the etiology of MR assessed by TTE was degenerative (valve prolapse or flail leaflets) in 190 patients, cardiomyopathy in 49 (including 29 of ischemic origin), rheumatic disease in 24, and endocarditis in 16 patients. Baseline clinical and hemodynamic data for the whole group and according to etiology are presented in Table 1. Transesophageal echocardiography was performed intraoperatively in 210 patients; in the remaining 69 patients, it was performed after TTE in an outpatient setting and repeated intraoperatively.

Diagnostic accuracy of TTE versus TEE. Functional analysis of MR by TTE, including localization of prolapsed or flail segments, was complete in 276 patients (99%) and incomplete in 3 patients because of poor image quality. Agreement with surgical findings concerning Carpentier's classification was found in 98% of patients for both TTE and TEE (kappa coefficient, 0.94). TEE was significantly more accurate than TTE in visualizing ruptured chordae tendinae; the difference between the two techniques to

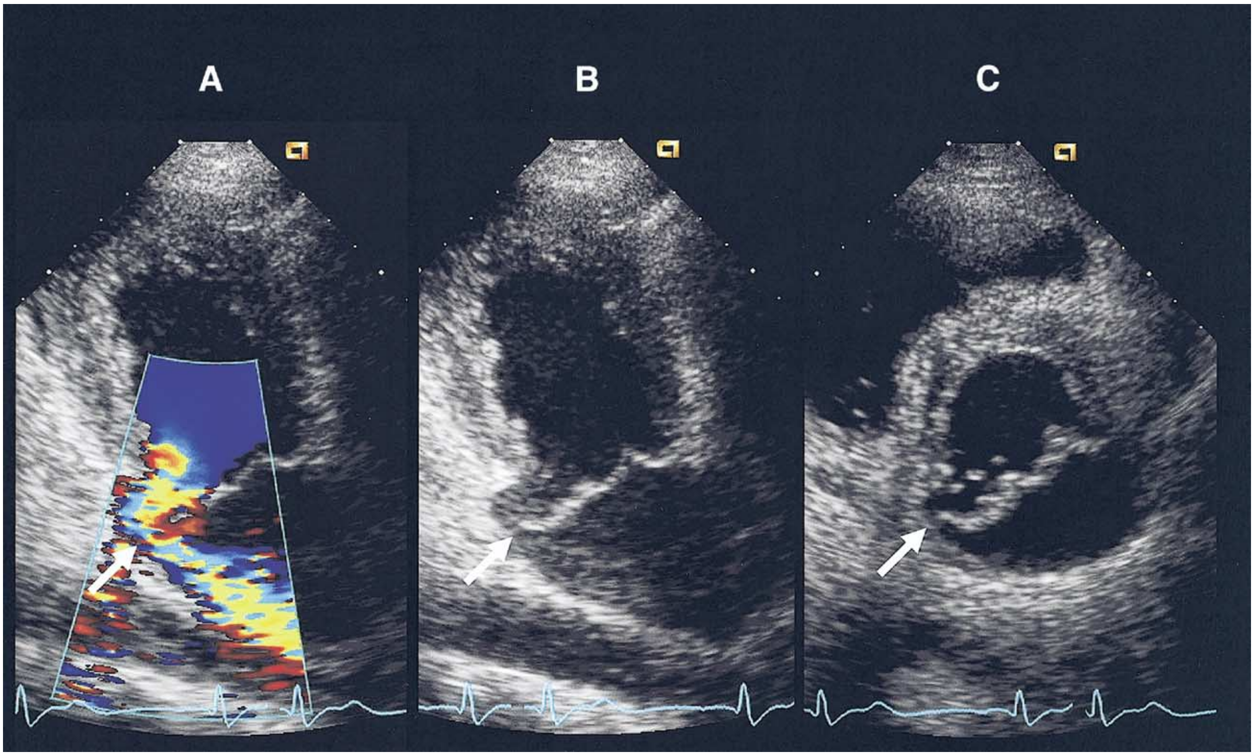

Figure 3. Posterior commissural prolapse. Eccentric regurgitant jet **(A)** resulting from a commissural discontinuity **(arrows)** seen in the intercommissural plane **(B)** and parasternal short-axis view **(C)**.

detect vegetations or annular calcium was not significant (Table 2).

Localization of prolapsed or flail segments. Among the 190 patients with degenerative MR, the concordance with surgical findings concerning the localization of prolapsed or flail segments was 91% for TTE (kappa, 0.81) and 93% for TEE (kappa, 0.85); incremental value of TEE over TTE was not significant (p = 0.40). Single P2 prolapse or flail (n = 147) was identified correctly by TTE and TEE in 140 (95%) and 142 patients (98%), respectively. Two patients with single P2 prolapse underwent valve replacement because of severe annular calcification. Commissural prolapse (n = 15, posterior localization in 13 cases) was correctly identified by TTE and TEE in 14 (93%) and 13 patients (87%) respectively; valve replacement was performed in 3 cases. Anterior prolapse (n = 13) was identified in 12 patients (92%) by both techniques, resulting in 3 valve replacements. Finally, bileaflet prolapse (n = 15) was

Table 1. Baseline Characteristics of the Whole Population and According to Etiology of MR Assessed by TTE

Variable	Overall (n = 279)	Degenerative (n = 190)	Cardiomyopathy (n = 49)	Rheumatic (n = 24)	Endocarditis (n = 16)	p Value
Age, yrs	68 (60–74)	68 (59–74)	70 (65–75)	71 (62–75)	64 (55–68)	0.06
Male gender, n (%)	181 (65)	134 (71)*	26 (53)	5 (21)†	16 (100)‡	0.001
NYHA functional class III–IV, n (%)	151 (54)	92 (48)	34 (69)§	14 (58)	11 (69)	0.035
Effective regurgitant orifice, mm^2	47 (34–70)	60 (39–78)	34 (16–47)§	24 (18–38)§	43 (38–57)	0.0001
LV ejection fraction, %	68 (57–75)	70 (60–75)	49 (38–56)‖	65 (60–70)	69 (63–70)	0.0001
Coronary artery disease, n (%)	72 (26)	33 (17)	36 (74)‖	2 (8)	1 (6)	0.0001
LV end-diastolic diameter, mm	60 (54–64)	60 (55–64)	60 (56–69)	50 (48–59)¶	58 (55–63)	0.0001
Left atrium diameter, mm	51 (45–58)	52 (46–49)	50 (43–55)	53 (42–58)	46 (40–53)	0.14
Atrial fibrillation, n (%)	55 (20)	33 (17)	12 (25)	8 (33)	2 (13)	0.19
Aortic valve replacement, n (%)	21 (8)	7 (4)	7 (14)#	2 (8)	5 (31)#	0.001
Chronic pulmonary disease, n (%)	22 (8)	14 (7)	5 (10)	2 (8)	1 (6)	0.91
Previous cancer, n (%)	11 (4)	7 (4)	3 (6)	1 (4)	0	0.72
Diabetes, n (%)	14 (5)	5 (3)	8 (16)§	1 (4)	0	0.001
Renal failure, n (%)	13 (5)	6 (3)	6 (12)	1 (4)	0	0.07

*p = 0.02 and †p = 0.008, respectively, vs. cardiomyopathy; ‡p = 0.001 vs. any other cause; §p < 0.01 vs. degenerative MR; ‖p = 0.001 for cardiomyopathy vs. any other cause; ¶p < 0.01 vs. any other cause; #p = 0.01 vs. cardiomyopathy.

LV = left ventricular; MR = mitral regurgitation; NYHA = New York Heart Association; TEE = transesophaseal echocardiography; TTE = transthoracic echocardiography.

Table 2. Respective Diagnostic Values for TTE and TEE Compared With Surgical Findings (n = Specified in Echocardiographic Report)

	Sensitivity (%)	Specificity (%)	Accuracy (%)
Vegetations			
TTE (n = 279)	79	98	97
TEE (n = 267)	83	99	99
Ruptured chordae			
TTE (n = 275)	90	89	89
TEE (n = 266)	97*	91*	95*
Calcified annulus			
TTE (n = 270)	72	97	92
TEE (n = 265)	64	96	91

*p = 0.001 vs. TTE.
TEE = transesophageal echocardiography; TTE = transthoracic echocardiography.

identified by TTE and TEE in 9 (60%) and 10 cases (67%), respectively, resulting in six valve replacements. Thus, the feasibility of repair was significantly influenced by the localization of prolapse; rates of successful repair for isolated P2 lesion, commissural, anterior, or bileaflet prolapse were 99%, 80%, 77%, and 60%, respectively (p = 0.001).

Prediction of valve repair. For the whole group, valve repair was performed in 237 patients (85%) and replacement in 42 (bioprosthesis, n = 22; mechanical, n = 20). Associated surgical procedures were coronary bypass surgery in 53 patients (19%), aortic valve replacement in 21 (8%, including three Bentall procedures), and tricuspid annulus in 2 patients. The feasibility of repair was strongly influenced by the etiology of MR; it was significantly higher for degenerative MR and lower for rheumatic disease and endocarditis (Table 3).

Valve replacement was correctly predicted by TTE in 33 of 42 patients for the following reasons (potentially in combination): extensive annular calcium (n = 18), severe thickening or calcification of mitral leaflets and/or subvalvular apparatus in the setting of rheumatic disease (n = 17), multiple vegetations (n = 4) or extensive bi-leaflet chordal rupture (n=7). Unpredicted valve replacement was performed in only nine patients (3%) for the following reasons: severe annular calcification (n = 2), extensive bileaflet chordal rupture (n = 2), commissural prolapse (n = 3), or severe endocarditis (n = 2).

Thus, the feasibility of valve repair was well predicted by TTE in 97% of cases. TEE added significant information to TTE for the prediction of valve replacement in only two cases: one patient with bileaflet prolapse and one patient with extensive endocarditis and incomplete TTE because of poor image quality.

Table 4. Multivariate Predictors of Perioperative Mortality

Variable	Odds Ratio	95% Confidence Interval	p Value
Aortic valve replacement	7.7	2.2 to 26.9	0.001
NYHA functional class (for each class > class I)	3.56	1.78 to 7.13	0.001
LV ejection fraction (for each 0.01-U < 0.50)	1.1	1.02 to 1.18	0.009

LV = left ventricular; NYHA = New York Heart Association.

Operative mortality. Nineteen patients died perioperatively, all from cardiac causes; among these 19 patients, 12 had severe comorbidities (including 5 patients with chronic pulmonary disease and 3 with renal failure) and 7 underwent associated aortic valve replacement. Thus, global operative mortality was 7%, which was significantly lower for degenerative MR as compared with any other etiology (Table 3).

Operative mortality in case of valve repair was 6% (15 of 237 patients), including five patients with associated aortic valve replacement. Among the 142 patients younger than 75 years with degenerative MR without aortic surgery or severe comorbidities, operative mortality was 2% (3 patients).

Univariate predictors for operative mortality were NYHA functional class (p = 0.001), chronic pulmonary disease (p = 0.008), renal failure (p = 0.03), LV end-diastolic diameter (p = 0.006), LV ejection fraction (p = 0.001), left atrium diameter (p = 0.023), and aortic valve replacement (p = 0.001). Multivariate analysis identified three independent predictors of operative mortality: concomitant aortic valve replacement, functional class NYHA, and LV ejection fraction (Table 4).

Long-term survival. Thirty patients who survived the perioperative period died during follow-up from cardiac causes (n = 16), cancer (n = 7, including two patients with known previous cancer), or miscellaneous noncardiac causes (n = 7). Long-term survival was significantly better for degenerative MR compared with the other groups (Table 3). Furthermore, in the subgroup of degenerative MR, patients with isolated P2 prolapse had a significantly better outcome as compared with patients with non-P2 lesions (Fig. 4).

Univariate predictors of long-term mortality were: LV ejection fraction (p < 0.001), previous cancer (p < 0.001), mitral valve replacement with a mechanical prosthesis (p =

Table 3. Perioperative Mortality, Frequency of Valve Repair, and Long-Term Survival in the Group as a Whole and According to Etiology of MR

Variable	Overall (n = 279)	Degenerative (n = 190)	Cardiomyopathy (n = 49)	Rheumatic (n = 24)	Endocarditis (n = 16)	p Value
Perioperative mortality, n (%)	19 (7)	7 (4)*	6 (12)	3 (13)	3 (19)	0.02
Valve repair, n (%)	237 (85)	176 (93)	44 (90)	7 (29)†	10 (63)†	0.0001
Three year survival, % (range)	83 (78–87)	88 (82–92)	66 (51–78)§‡	83 (61–93)	75 (46–90)	0.0025

Perioperative mortality: *p < 0.05 for degenerative MR vs. any other cause; frequency of valve repair: †p < 0.05 for rheumatic disease or endocarditis vs. other groups. Three year survival: ‡p < 0.01 vs. degenerative MR.
MR = mitral regurgitation.

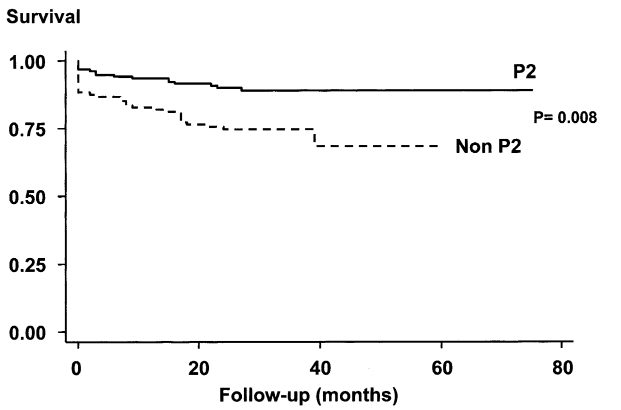

Figure 4. Kaplan-Meier survival curves according to the localization of prolapsed or flail segments in patients with degenerative mitral regurgitation.

0.001), peripheral vascular disease (p = 0.006), coronary artery disease (p = 0.01), and etiology of MR (p = 0.02). Multivariate analysis identified four independent predictors of long-term mortality: mitral valve replacement (mechanical prosthesis), previous cancer, peripheral vascular disease, and LV ejection fraction (Table 5). Reoperation was performed in only four patients, including mitral valve replacement after initial repair in three cases and surgery for endocarditis on a mechanical prosthesis in one. The small number of reoperated patients precluded any further analysis on this subgroup.

DISCUSSION

Mitral regurgitation is the second frequently encountered valve disease in western countries, representing nearly one third of acquired left-sided valve disease in a recent European survey (12). Valve repair is now widely accepted as the optimal surgical treatment for severe MR and is an incentive to early surgery in asymptomatic patients (3,13). Thus, valve repairability is the centerpiece of therapeutic strategy, and the prediction of successful valve repair is of crucial importance in these patients (3,13). Previous studies have demonstrated the outcome implications of the assessment of MR lesions using TEE (4), but few data are available on the diagnostic accuracy and outcome implications of TTE since the advent of harmonic imaging.

The main results of this study are: 1) TTE in experienced hands reliably can predict valve repairability without significant incremental value of TEE; 2) in degenerative MR, the precise localization of the involved segments by TTE has a strong influence on surgical results and postoperative outcome; and 3) valve replacement predicted by TTE is an independent predictor of long-term postoperative mortality.

Diagnostic accuracy of TTE. Previous studies have demonstrated the superiority of TEE over TTE to assess functional anatomy of MR (4,14,15). Enriquez-Sarano et al. (4) found a notable incremental value of TEE in flail leaflets, for which the issue of valve repairability is of paramount importance, despite a correct diagnostic accuracy of TTE in this study. In all previous studies, the available technology for TTE was fundamental imaging, yielding suboptimal image quality in a substantial proportion of patients: in the Mayo Clinic study, the anatomic assessment of MR by TTE was incomplete in 39 of 219 patients (18%), probably as the result of insufficient image quality (4).

In contrast, in our study, an incomplete TTE as the result of poor image quality was reported in only three patients; this rate may be explained in part by improved image quality because of current transducers and harmonic imaging technology (16). Hence, our results show a comparable agreement with surgical findings for TTE and TEE concerning Carpentier's classification; the incremental diagnostic accuracy of TEE being only significant for visualization of chordal rupture, but not for functional analysis of MR, in contrast to the latter study (4).

In our study, TEE was not superior to TTE to detect vegetations; this may be attributable to the small number of patients with endocarditis (n = 16) or to the presence of large vegetations in most cases. The superiority of TEE over TTE to detect small vegetations (<5 mm) has been well demonstrated (17); thus, despite our results, patients with a clinical suspicion of endocarditis should obviously undergo TEE. Finally, there was a trend toward a more reliable assessment of annular calcification by TTE in our study, this parameter being the main motivation for valve replacement in this series.

Localization of prolapsed or flailed segments. Another possible reason for improved accuracy of TTE is the use of four standardized imaging planes for precise localization of prolapsed or flailed segments. The four imaging planes used in the present study were previously validated for TEE (10). The precise localization of prolapsed or flail segments in degenerative MR is a major issue of concern, given its strong influence on the rate of successful repair (18). The most prevalent lesion in degenerative MR is a single prolapse of P2 (18,19), for which the rate of successful repair is highest. In our study, TTE accurately identified single P2 lesions as well as commissural or anterior lesions (respective accuracy of 95%, 93%, and 92%).

In contrast, the diagnostic accuracy of TTE for bileaflet prolapse was less satisfying (60%), mainly because of the underestimation of the extent of chordal rupture. Of note, the diagnostic accuracy of TEE in this setting also was disappointing (67%); this issue may be overcome by future improvements in real-time, three-dimensional echocardiog-

Table 5. Multivariate Predictors of Long-Term Mortality

Variable	Odds Ratio	95% Confidence Interval	p Value
Previous cancer	12.2	3.5 to 43.3	0.001
Mitral valve replacement (mechanical) vs. repair	5.7	1.97 to 16.4	0.001
Peripheral vascular disease	4.9	1.5 to 16.3	0.01
LV ejection fraction (for each 0.01-U < 0.50)	1.1	1.03 to 1.16	0.002

LV = left ventricular.

raphy (20). Nevertheless, the overall accuracy for localization of prolapsed or flail segments in our study was similar for TTE and TEE (91% and 93%, respectively) without incremental value for TEE.

Operative mortality. The relatively high operative mortality rate of 7% in the present study has to be compared with other cohorts of unselected patients. Among the 5,001 patients from Euro Heart Survey on valvular disease, operative mortality was 4% in case of isolated MR and 6.5% in case of multiple valve disease. Of note, 7 of the 19 patients who died perioperatively underwent concomitant aortic valve replacement; this rate may explain the relatively high operative mortality in the present series of consecutive patients who were not excluded on the basis of age, left ventricular dysfunction, associated aortic surgery or extra cardiac comorbidities.

If one considers the subgroup of younger patients (≤75 years old) with degenerative MR, operative mortality for isolated valve repair was 2%; this rate is comparable with other series that included the same kind of patients (4,21). Multivariate analysis identified three independent predictors of operative mortality: associated aortic replacement, NYHA functional class, and low LV ejection fraction. These predictors of operative risk are universally recognized (12,22,23), and this result is explained mainly by the relatively high prevalence of concomitant aortic valve surgery in our series, reflecting daily practice in two tertiary care centers.

Long-term outcome implications of TTE findings. Enriquez-Sarano et al. (4) found that functional anatomy of MR assessed by TEE has a significant influence on long-term survival; they also noted that this may rely in part on the interaction between MR etiology and LV systolic function. Of note, in the latter study potential predictors of postoperative outcome were adjusted for a limited number of variables, including age, gender, coronary artery disease, and LV ejection fraction and excluding extracardiac comorbidities (4).

In the present study, it is not surprising to find that cancer is a strong predictor of long-term mortality, as it is the case among the general population from western countries (24). Of note, among the seven patients who died from cancer during follow-up, only two were known to have previous cancer at preoperative evaluation, with a reasonable life expectancy in both cases. The second independent predictor of long-term mortality in our study was mitral valve replacement by a mechanical prosthesis. This result underlines the crucial impact of valve repairability assessed by TTE on postoperative outcome.

Furthermore, in the subgroup of patients with degenerative MR, we found a significant difference in postoperative outcome according to the localization of prolapse (P2 vs. non-P2 lesions), stressing the importance of precise localization of the involved scallops in degenerative MR. Finally, to the best of our knowledge, the precise localization of prolapsed segments by TTE according to four standardized imaging planes and its relationship with postoperative outcome were not reported previously.

Study limitations. The diagnostic accuracy of TTE reported in this study was obtained from senior cardiologists with much experience in MR assessment as well as the current opportunity to compare echocardiographic findings with direct inspection of anatomic lesions during surgery. Thus, our results may not be generalized to less experienced observers. The feasibility of valve repair may be influenced by the surgeon's skill, which may represent a limitation of the study. However, most (85%) of the patients from this series were operated on by four surgeons who were highly experienced in mitral valve repair. Furthermore, the rate of successful valve repair in our series was comparable with the most recent studies (4).

Conclusions. Our results demonstrate the high accuracy of TTE in experienced hands, with harmonic imaging technology, to predict valve repairability in patients with MR. Transthoracic echocardiography is also highly accurate for a precise localization of the involved scallops in case of degenerative MR. The strong influence of TTE findings on postoperative outcome also is supported by our data. Thus, clinical decision-making in patients with MR can rely mainly on TTE findings; a systematic preoperative TEE to predict the feasibility of valve repair is not mandatory in most cases. Nevertheless, intraoperative TEE performed just before surgery is still mandatory. Finally, the avoidance of systematic preoperative TEE in an outpatient setting may have a favorable impact on patient's comfort and medical costs.

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