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Global longitudinal strain predicts left ventricular dysfunction after mitral valve repair

Tomasz G. Witkowski[1,2], James D. Thomas[3], Philippe J.M.R. Debonnaire[1], Victoria Delgado[1], Ulas Hoke[1], See H. Ewe[1], Michel I.M. Versteegh[4], Eduard R. Holman[1], Martin J. Schalij[1], Jeroen J. Bax[1], Robert J.M. Klautz[4], and Nina Ajmone Marsan[1]*

[1]Department of Cardiology, Leiden University Medical Center, Albinusdreef 2, 2333 ZA Leiden, The Netherlands; [2]Department of Cardiology, 4th Military Hospital, Wroclaw, Poland; [3]Department of Cardiovascular Medicine, Heart and Vascular Institute, Cleveland Clinic, Cleveland, OH, USA; and [4]Department of Cardiothoracic Surgery, Leiden University Medical Center, Leiden, The Netherlands

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Aims Despite a successful surgical procedure and adherence to current recommendations, postoperative left ventricular (LV) dysfunction after mitral valve repair (MVr) for organic mitral regurgitation (MR) may still occur. New approaches are therefore needed to detect subclinical preoperative LV dysfunction. LV global longitudinal strain (GLS), assessed with speckle-tracking echocardiographic analysis, has been proposed as a novel measure to better depict latent LV dysfunction. The aim of this study was to investigate the value of GLS to predict long-term LV dysfunction after MVr.

Methods and results A total of 233 patients (61% men, 61 ± 12 years) with moderate–severe organic MR who underwent successful MVr between 2000 and 2009 were included. Echocardiography was performed at baseline and long-term follow-up (34 ± 20 months) after MVr. LV dysfunction at follow-up was defined as LV ejection fraction (EF) $<$50% and was present in 29 (12%) patients. A cut-off value of -19.9% of GLS showed a sensitivity and specificity of 90 and 79% to predict long-term LV dysfunction. By univariate logistic regression analysis, baseline LVEF $\leq$60%, LV end-systolic diameter (ESD) $\geq$40 mm, atrial fibrillation, presence of symptoms, and GLS $> -19.9\%$ were predictors of long-term LV dysfunction. By multivariate analysis, GLS remained an independent predictor of LV dysfunction (odds ratio 23.16, 95% confidence interval: 6.53–82.10, $P < 0.001$), together with LVESD.

Conclusion In a large series of patients operated within the last decade, MVr resulted in a low incidence of long-term LV dysfunction. A GLS of $> -19.9\%$ demonstrated to be a major independent predictor of long-term LV dysfunction after adjustment for parameters currently implemented into guidelines.

Keywords Organic mitral regurgitation • Mitral valve repair • Left ventricular function • Global longitudinal strain

Introduction

Severe organic mitral regurgitation (MR) is associated with increased risk of morbidity and mortality, but it can be successfully treated with surgery. Current guidelines recommend mitral valve surgery in symptomatic patients or in asymptomatic patients with signs of left ventricular (LV) dysfunction [end-systolic diameter (LVESD) >40 mm and LV ejection fraction (LVEF) ≤60%].[1,2] However, there is increasing evidence showing that mitral valve surgery performed in a timely manner, before LV damage occurs, confers superior outcomes.[3–5] In particular, LV function after surgery remains difficult to predict in the individual patient and postoperative LV dysfunction may still occur, yielding to a poor short- and long-term outcome.[1,2] The main challenge lies in accurately assessing LV function at baseline, since the abovementioned parameters commonly applied in the therapeutic decision-making process are significantly dependent on haemodynamic conditions and therefore not completely reliable in a volume overload condition such as MR. Furthermore, LVEF is not sensitive enough to detect subtle myocardial dysfunction, which might

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* Corresponding author. Tel: +31 71 5262020; fax: +31 71 5266809, Email: n.ajmone@lumc.nl

result in postoperative long-term LV failure.[6] Additional parameters are therefore needed to better identify patients at risk of LV dysfunction after mitral valve repair (MVr).

Speckle-tracking strain analysis has been recently introduced as a novel echocardiographic technique for an accurate and angle-independent assessment of myocardial deformation (strain), and showed to accurately reflect LV contractility in different cardiac diseases.[7] The aim of the present study was therefore to evaluate the value of LV global longitudinal strain (GLS) to predict long-term post-operative LV dysfunction, in comparison with established predictive factors such as LVEF and LVESD. In particular, the analysis was focused on a large series of patients with organic MR undergoing MVr within the last decade.

Methods

Patient population and data collection

The population consisted of 233 patients with severe organic MR, who were referred to our institution for MVr between 2000 and 2009 and had an echocardiographic follow-up at least 1 year after the operation. Patients' data were prospectively collected in the departmental Cardiology Information System (EPD-Vision®, Leiden University Medical Center, Leiden, The Netherlands) and included demographics, medications, identification of co-morbidities, and symptoms [New York Heart Association (NYHA) functional class]. Echocardiographic data were also prospectively digitally stored for off-line analysis of conventional parameters and were retrospectively assessed for speckle-tracking strain analysis. Institution's Ethics Committee approved this retrospective analysis of clinically obtained data and waived the need for patient written informed consent.

According to the current guidelines, most of these patients were referred for MVr in an early stage of the disease, before significant LV dilatation or dysfunction occurred.[1,2] All patients underwent successful MVr, defined as the absence of any significant residual regurgitation, stenosis, or systolic anterior motion of the mitral valve anterior leaflet. Exclusion criteria comprised: (i) associated congenital or acquired significant valvular disease; (ii) prior myocardial infarction, coronary revascularization, or cardiac surgery; and (iii) unsuccessful (at short- and long-term follow-up) MVr.

All patients underwent baseline clinical and echocardiographic evaluation. The same echocardiographic evaluation was repeated in all patients at long-term follow-up (>12 months; median 31 months) after corrective MVr in order to assess the incidence of LV dysfunction.

Echocardiographic evaluation

Transthoracic echocardiography was performed with commercially available systems (System 5, Vivid 7 and E9, GE-Vingmed, Horten, Norway). The images were obtained with a 3.5 MHz transducer and digitally stored for off-line analysis (EchoPAC 108.1.5, GE-Vingmed). According to the current recommendations, severity of MR was assessed using a multi-parametric approach based on colour-flow and continuous wave (CW) Doppler images, including proximal regurgitant jet width (vena contracta), effective regurgitant orifice area (using the proximal isovelocity surface area method), and regurgitant volume.[1,8]

LV diameters were measured from the parasternal long-axis view. LV end-diastolic and end-systolic volumes were calculated from the two- and four-chamber apical views, by using Simpson's biplane method and were indexed for body surface area;[9] LVEF was subsequently calculated. At long-term follow-up after MVr, LV dysfunction was defined as LVEF <50%.[10–12] In addition to LVEF, forward EF was calculated by dividing stroke volume through the LV outflow tract by LV end-diastolic volume. Right ventricular systolic pressure (RVSP) was estimated from the systolic right ventricular–right atrial gradient calculated from the peak velocity of systolic trans-tricuspid regurgitant CW Doppler flow signal by the simplified Bernoulli equation and the right atrial pressure derived by means of the inferior vena cava collapsibility index measured in the subcostal view.[13]

Speckle-tracking strain analysis

Speckle-tracking analysis (EchoPAC 108.1.5, GE-Vingmed) was performed to assess LV GLS. This novel technique allows the quantification of LV myocardial deformation by tracking on standard greyscale two-dimensional (2D) images, frame-to-frame, natural acoustic markers that interference patterns from subwavelength structures throughout the myocardium.[14] Longitudinal strain, evaluating the shortening (negative strain) and lengthening (positive strain) of the myocardial wall, was measured from the three apical views (long-axis and two- and four-chamber views): GLS was calculated by averaging the peak strain values of 18 segments (*Figure 1*). The mean frame rate of 2D images was 74 ± 8 frames/s. Inter- and intra-observer variability for LV GLS in our Center have been previously reported.[15]

Surgical procedure

Surgery was performed through a midline sternotomy on cardiopulmonary bypass with bicaval cannulation and with intermittent antegrade warm blood cardioplegia. All surgical procedures were performed by experienced mitral repair surgeons using standardized Carpentier techniques. In all cases, a ring annuloplasty (Carpentier Edwards Physio ring, Edwards Lifesciences, USA) was performed to stabilize the mitral annulus and the applied other techniques. In 109 (47%) patients, characterized by severe tricuspid annular dilatation (>4.0 cm) or regurgitation (grade ≥3), a concomitant tricuspid annuloplasty was performed. The majority of patients with pre-operative atrial fibrillation underwent concomitant atrial fibrillation ablation surgery by various techniques.

Statistical analysis

Distribution of the continuous data was tested with the Komolgorov–Smirnov one-sample test and the Shapiro–Wilk test. Normally distributed variables were presented as mean ± standard deviation, whereas non-normally distributed variables were presented as median and inter-quartile range. Categorical variables were presented as numbers and percentages. Comparisons of measurements were performed with Student's *t*-test or the Mann–Whitney test where appropriate. The relationship between long-term follow-up LVEF and baseline clinical and echocardiographic characteristics was tested with linear regression analysis (enter method). The study population was divided according to postoperative LVEF at long-term follow-up (<50 vs. ≥50%). To test the value of LV GLS to predict LV dysfunction after MVr, uni- and multivariate logistic regression analysis were performed, introducing other well-established independent predictors (LVEF, LVESD, atrial fibrillation, and symptoms). According to the guidelines, baseline LVEF and baseline LVESD were dichotomized with cut-off values of ≤60% and ≥40 mm, respectively.[1] The cut-off value of baseline LV GLS to predict postoperative LV dysfunction at long-term follow-up was determined by receiver operating characteristics curve analysis with the highest sum of sensitivity and specificity.

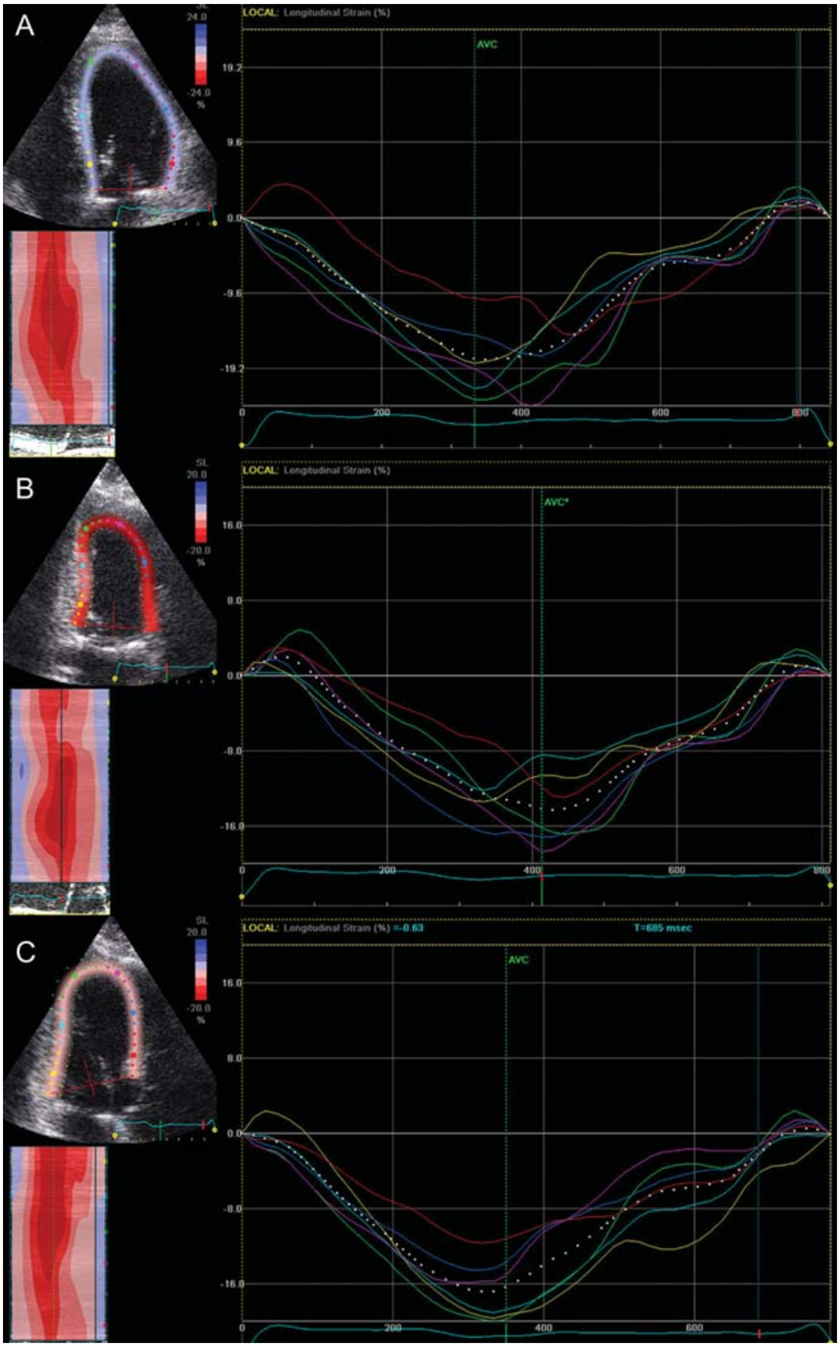

Figure 1 Example of LV GLS assessment by 2D speckle-tracking analysis in a patient with severe MR. The myocardium is divided into six segments in the apical four-chamber view (*A*), apical two-chamber (*B*), and three-chamber view (*C*). Longitudinal shortening (negative strain) is calculated for each segment over the cardiac cycle and LV GLS is calculated as the average of peak longitudinal strain of all segments, which in this example was −16.1%.

All variables significant in the univariate analysis were introduced in the multivariate model in an enter manner. The multivariate models' fit was assessed by the Hosmer–Lemeshow test and model's predictive accuracy by the Harrell's *c*-index.[16] For all statistical tests, a *P*-value of <0.05 was considered significant. All statistical analyses were performed with SPSS version 17.0 (SPSS, Inc., Chicago, IL, USA).

Results

Baseline characteristics

Baseline clinical and echocardiographic characteristics of the patient population are summarized in *Table 1*. Most patients

Table 1 Baseline clinical and echocardiographic characteristics of the patient population (n = 233)

Age (years)	61 ± 12
Men [*n* (%)]	143 (61)
NYHA class I/II/III/IV [*n* (%)]	82/113/31/7 (35/49/13/3)
Atrial fibrillation [*n* (%)]	73 (31)
Hypertension [*n* (%)]	75 (32)
Diabetes [*n* (%)]	19 (8)
Medical therapy	
ACEI/ARB [*n* (%)]	112 (48)
β-Blockers [*n* (%)]	98 (42)
Diuretics [*n* (%)]	70 (30)
Digoxin [*n* (%)]	19 (8)
Echocardiography	
LV ejection fraction (%)	66 ± 9
LV end-diastolic diameter (mm)	52 ± 6
LV end-systolic diameter (mm)	31 ± 6
LV end-systolic diameter index (mm/m^2)	16 ± 3
LV end-diastolic volume index (mL/m^2)	70 ± 18
LV end-systolic volume index (mL/m^2)	23 ± 8
LV forward ejection fraction (%)	34 ± 8
Right ventricular systolic pressure (mmHg)	44 ± 15
LV global longitudinal strain (%)	−21.8 ± 4.1

ACEI, angiotensin-converting enzyme inhibitor; ARB, angiotensin receptor blocker; LV, left ventricular; NYHA, New York Hear Association.

were mildly symptomatic (49% of patients in NYHA class II) and with a limited number of co-morbidities. All patients had moderate-to-severe MR before MVr (effective regurgitant orifice area: 0.46 ± 0.10 cm^2, vena contracta: 8 ± 1 mm, regurgitant volume: 65 ± 10 mL) due to: prolapse or flail in 200 (86%) patients, endocarditis in 11 (5%) patients, and rheumatic fever in 22 (9%) patients. LV systolic function was relatively preserved, with LVEF ≤60 only in 48 (21%) patients and an LVESD ≥40 mm only in 26 (11%) patients.

Changes in echocardiographic parameters after MVr

As showed in *Figure 2*, LV size significantly decreased at long-term follow-up, as expressed by LV end-diastolic volume index (70 ± 18 vs. 55 ± 17 mL/m^2, $P < 0.001$) and LV end-systolic volume index (23 ± 8 vs. 22 ± 10 mL/m^2, $P = 0.02$). Similarly, LV end-diastolic (52 ± 6 vs. 46 ± 5 mm) and ESDs (31 ± 6 vs. 28 ± 6 mm) showed a significant reduction after MVr (both $P < 0.001$). Additionally, when compared with baseline, LVEF decreased significantly at long-term follow-up after MVr (66 ± 9 vs. 61 ± 8%, $P < 0.001$). Of note, forward EF increased when compared with baseline (34 ± 8 vs. 57 ± 13%, $P < 0.001$), indicating that much of the decreased EF simply reflected removal of the regurgitation. Similarly, GLS significantly decreased from −21.8 ± 4.1% at baseline to −18.2 ± 3.8% at long-term follow-up ($P < 0.001$). RVSP significantly decreased from 44 ± 15 mmHg at baseline to 35 ± 9 mmHg at long-term follow-up ($P < 0.001$).

At long-term follow-up (34 ± 20 months) after MVr, LV dysfunction (defined as LVEF <50%) occurred in 29 patients (12%). There were no differences in age, sex, and incidence of hypertension between patients with LV dysfunction and preserved LVEF at follow-up (*Table 2*). However, preoperative atrial fibrillation was more frequent in patients with long-term LV dysfunction ($P = 0.023$). In addition, patients with preserved LVEF at long-term follow-up had higher LVEF before surgery, with smaller LV size. Importantly, baseline LV GLS was significantly lower in patients with preserved LVEF when compared with those with LV dysfunction at follow-up (*Table 2*).

Predictors of LV dysfunction at long-term follow-up after MVr

By univariate linear regression analysis (*Table 3*), baseline LVEF, LVESD, GLS, and presence of atrial fibrillation showed a significant association with LVEF at long-term follow-up, with GLS having the strongest correlation. By multivariate logistic analysis, sequential inclusion of baseline LVEF, baseline LVESD, atrial fibrillation, and baseline LV GLS to the model resulted in incremental improvement of its predictive value. The final model could explain up to 35% (adjusted $R^2 = 0.355$) of the variance of postoperative LVEF at long-term follow-up (*Table 3*).

In order to indentify the best cut-off value of baseline LV GLS to predict long-term LV dysfunction after MVr, receiver operating characteristic curve analysis was performed (*Figure 3*). The area under the curve for LV GLS was 0.88 (95% confidence interval 0.83–0.93) and a cut-off value of >−19.9% could predict LV dysfunction with a sensitivity and specificity of 90% and 79%, respectively.

Using the univariate logistic regression analysis (*Table 4*), GLS was the strongest predictor of long-term LV dysfunction. Atrial fibrillation at baseline, preoperative presence of symptoms, LVESD ≥40 mm, and LVEF ≤60% were also significant predictors of LV dysfunction. When LV GLS was adjusted for other significant predictors in the multivariate model, it remained the strongest and independent predictor of LV dysfunction together with LVESD ≥40 mm. Atrial fibrillation at baseline, preoperative symptoms, and LVEF ≤60% were not significant predictors of LV dysfunction (*Table 4*). The Hosmer–Lemeshow test and Harrell's statistic showed a very good calibration and discrimination of the multivariate model ($P = 0.568$ and *c*-index = 0.92, respectively).

Discussion

The main findings of the present study can be summarized as follows: (i) the incidence of long-term post-operative LV dysfunction is relatively low in patients with organic MR undergoing MVr during the last decade and according to current guidelines; (ii) in these patients, LV GLS, and not LVEF, is an independent predictor of long-term postoperative LV dysfunction, together with LV dimension.

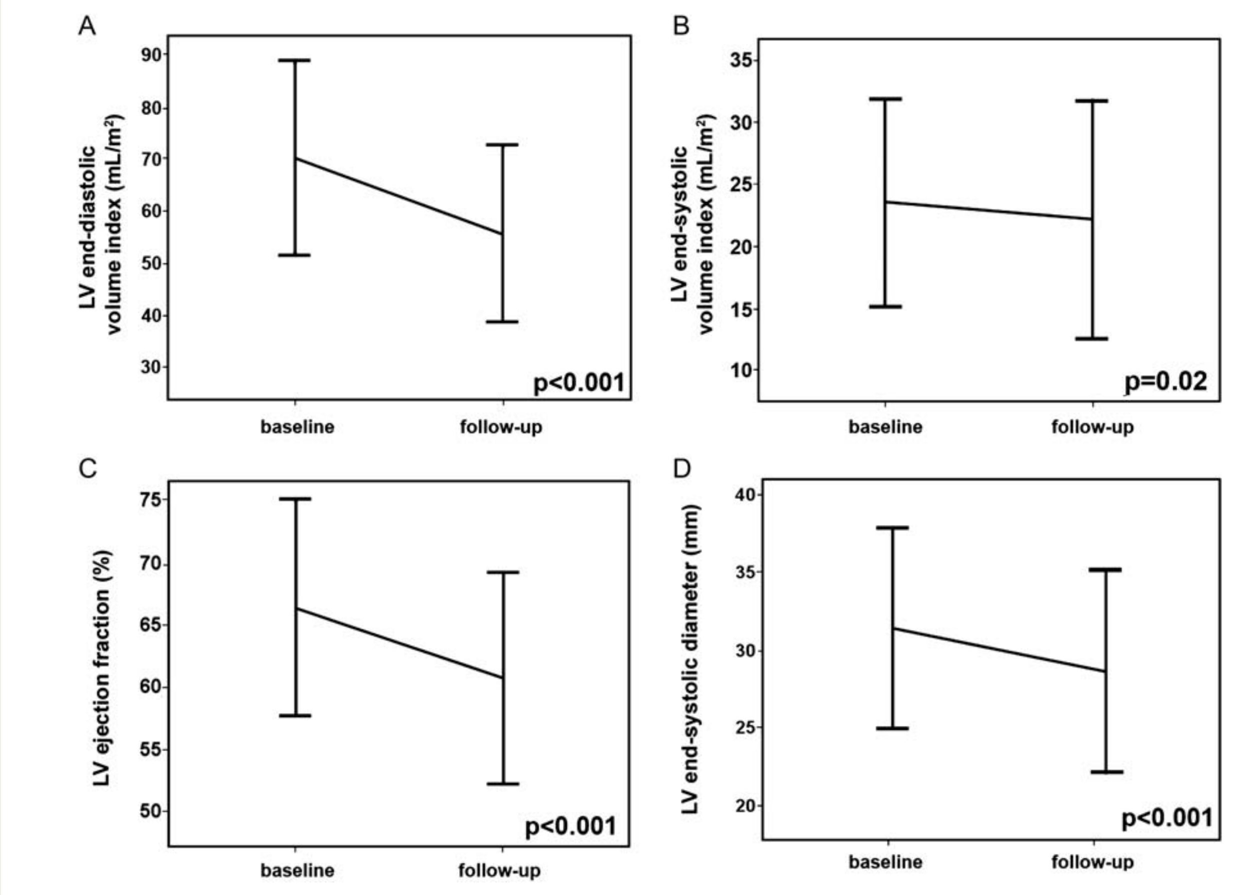

Figure 2 Changes from baseline to long-term follow-up (>12 months) of main echocardiographic parameters in patients with moderate-to-severe MR who underwent mitral valve corrective surgery. (*A*) LV end-diastolic volume index; (*B*) LV end-systolic volume index; (*C*) LVEF; (*D*) LVESD.

Table 2 **Comparison of baseline clinical and echocardiographic parameters in patients with LVEF ≥50% and <50% at long-term follow-up (>12 months) after mitral valve corrective surgery**

Variable	LVEF ≥50% (*n* = 204)	LVEF <50% (*n* = 29)	*P*-value
Age (years)	63 (IQR: 54, 70)	65 (IQR: 54, 72)	0.71
Men [*n* (%)]	122 (60)	21 (72)	0.12
Atrial fibrillation [*n* (%)]	59 (29)	14 (48)	0.023
Hypertension [*n* (%)]	63 (31)	12 (41)	0.39
LV ejection fraction (%)	68 (IQR: 63, 73)	60 (IQR: 53, 65)	<0.001
LV end-diastolic diameter (mm)	52 (IQR: 47, 56)	55 (IQR: 51, 59)	0.016
LV end-systolic diameter (mm)	30 (IQR: 26, 34)	37 (IQR: 33, 42)	<0.001
LV end-systolic diameter index (mm/m^2)	16 (IQR: 14, 18)	19 (IQR: 17, 21)	<0.001
LV end-diastolic volume index (mL/m^2)	68 (IQR: 55, 82)	72 (IQR: 58, 83)	0.189
LV end-systolic volume index (mL/m^2)	21 (IQR: 17, 27)	31 (IQR: 21, 39)	<0.001
LV forward ejection fraction (%)	36 (IQR: 28, 40)	33 (IQR: 28, 39)	0.418
Right ventricular systolic pressure (mmHg)	40 (IQR: 35, 51)	43 (IQR: 36, 51)	0.88
LV global longitudinal strain (%)	−22.4 (IQR: −24.9, −20.2)	−18.6 (IQR: −19.3, −14.7)	<0.001

IQR, inter-quartile range; LV, left ventricular.

Changes in LV size and function after MVr

The favourable effect of successful mitral valve corrective surgery on LV performance is mainly represented by a significant decrease in LV size, immediately after the operation and over time during long-term follow-up.[10,17,18] In the current evaluation, long-term follow-up revealed a substantial LV reverse remodelling after MVr, involving both LV end-systolic volume and LV end-diastolic volume, but more pronounced for LV end-diastolic volume, probably due to a significant reduction in LV preload. These significant changes in LV volumes result in a reduction in LVEF, which in these patients is therefore usually lower at follow-up when compared with baseline. In the current study, LVEF decreased in average from 66 ± 9% at baseline to 61 ± 8% ($P < 0.001$) at long-term follow-up. However, when a significant myocardial damage has already occurred before the procedure, despite a normal LVEF, these changes will unmask the latent LV dysfunction, resulting in an LVEF significantly below the normal range and in poor long-term outcome. The reported incidence of long-term postoperative LV dysfunction (LVEF <50%) varies from 41% in patients operated

Table 3 **Predictors of LVEF at long-term follow-up after mitral valve corrective surgery: uni- and multivariate linear regression analysis**

Univariate models	*R*	Adjusted R^2	*P*-value
LV ejection fraction	0.386	0.145	<0.001
LV end-systolic diameter	0.320	0.099	<0.001
Right ventricular systolic pressure	0.052	0.003	0.433
Atrial fibrillation	0.210	0.040	0.001
LV global longitudinal strain	0.583	0.337	<0.001
Multivariate model			
LV ejection fraction	0.416	0.166	<0.001
LV end-systolic diameter			
Multivariate model			
LV ejection fraction	0.434	0.178	<0.001
LV end-systolic diameter			
Atrial fibrillation			
Multivariate model			
LV ejection fraction	0.605	0.355	<0.001
LV end-systolic diameter			
Atrial fibrillation			
LV global longitudinal strain			

Parameters that were statistically significant at the univariate analysis were sequentially included in the multivariate analysis in order to test the gain in predictive accuracy of the model.
LV, left ventricular.

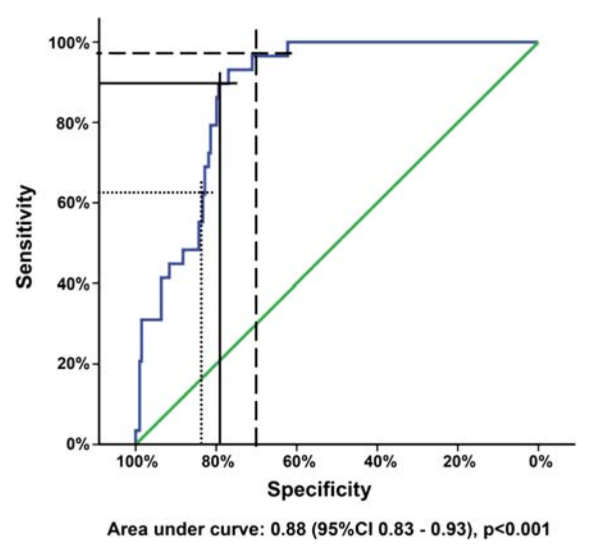

Figure 3 Receiver operating characteristic analysis of pre-operative LV GLS for LV dysfunction at long-term follow-up (>12 months). The optimal cut-off value of LV GLS to predict long-term postoperative LV dysfunction was determined by the highest sum of sensitivity (90%) and specificity (79%), which in this case was −19.9% (crosshair solid lines). The alternative cut-off value of −18.9% with a sensitivity and specificity of 62% and 83%, respectively, is indicated by dotted lines. Dashed lines indicate a cut-off value of −20.9% with 97% sensitivity and 68% specificity.

Table 4 **Predictors of LV dysfunction (LVEF <50%) at long-term follow-up after mitral valve corrective surgery: uni- and multi-variate logistic regression analysis**

	Univariate analysis				Multivariate analysis		
	χ^2	Odds ratio	95% CI	*P*-value	Odds ratio	95% CI	*P*-value
Atrial fibrillation	4.2	2.29	1.04–5.05	0.039	2.00	0.68–5.95	0.210
Presence of symptoms	5.18	2.91	1.07–7.94	0.037	2.38	0.70–8.14	0.165
LV ejection fraction ≤60%	19.9	6.61	2.90–15.07	<0.001	2.64	0.93–7.48	0.069
LV end-systolic diameter ≥40 mm	21.6	9.58	3.83–23.96	<0.001	6.71	1.91–23.52	0.003
LV global longitudinal strain > −19.9 %	48.9	24.11	7.95–73.05	<0.001	23.16	6.53–82.10	<0.001
						$\chi^2 = 69.1$, $P < 0.001$	

LV, left ventricular.

in early 1980s (including mitral valve replacement) to 15% in patients operated with MVr in the late 1990s.[10,19] In the present study, a large series of patients undergoing MVr within the last decade was included and a long-term postoperative LV dysfunction was observed in only 12% of patients, confirming the benefits of implementing advanced surgical repair techniques. However, the application of current guidelines resulted still in a suboptimal outcome in some patients[1,2] and additional parameters to predict long-term postoperative LV dysfunction are needed.

Echocardiographic determinants of long-term postoperative LV dysfunction in patients with severe MR

To ensure relief of symptoms, prevent heart failure and poor outcome, current guidelines recommend surgery in patients with severe MR and clinical symptoms.[1,2] In addition, in asymptomatic patients, MVr must be considered in cases of LV dysfunction (EF $<60\%$, recognizing the 'wasted' blood ejected into the atrium) and systolic dilation, presence of atrial fibrillation, or elevated RVSP.[1,2] In uncorrected severe MR, most of patients may remain asymptomatic because cardiac output is maintained by progressive LV eccentric hypertrophy (due to volume overload).[1,2] However, the increase in LV wall stress leads to progressive myocardial damage, which ultimately results in myocardial dysfunction. Consequently, optimal timing for surgery is extremely challenging, balancing between preventing overt LV dysfunction, and therefore poor long-term outcome,[20] and avoiding unnecessary perioperative risk in asymptomatic patients. Despite successful surgical procedure and careful adherence to current recommendations, postoperative LV dysfunction and clinically evident heart failure may still occur. Identification of patients with subtle myocardial dysfunction is crucial. Conventional echocardiographic parameters fail to detect potential subclinical myocardial damage due to the low sensitivity and to the volume-dependency.[6] However, Ahmed *et al.*[6] showed that significant histological alterations of myocardial structure and functions are present in patients with severe MR and LVEF $>60\%$.

The attention has therefore shifted towards identifying new parameters that would be able to detect subclinical changes in LV myocardial function. Elevated plasma levels of neurohormones were recently proposed as potential markers of subtle LV dysfunction or predictors of the occurrence of symptom in asymptomatic patients with MR.[21,22] Routine assessment of these parameters might help in the optimal timing of surgery. However, this approach needs to be validated in bigger cohorts of patients. Lee *et al.* proposed evaluation of LV contractile reserve defined as LVEF increase during exercise. Particularly, 4% increase in LVEF at peak exercise was a sensitive marker of LV dysfunction after mitral valve surgery.[11] In addition, Haluska *et al.*[23] showed correlation between contractile reserve on exercise echocardiography and LV function, which potentially could be used as prognosticators of postoperative LV dysfunction. Although promising, the implementation of this approach in clinical practice has been limited by the need for an additional echocardiographic examination and with high level of expertise. More recently, LV deformation (strain) parameters as assessed with different imaging techniques have been proposed to predict LV dysfunction after mitral valve surgery.[24–26] Magnetic resonance imaging with tissue tagging, considered as the gold standard for deformation measurements, was able to identify patients with LV dysfunction after MVr, despite good preoperative LVEF.[6] Additionally, echocardiographic analysis of myocardial velocity with tissue Doppler imaging at the level of the lateral mitral annulus showed promising results in predicting abnormal LV performance early after surgical correction of MR.[24] However, when compared with tissue Doppler imaging, novel speckle-tracking analysis allows an angle-independent assessment of myocardial strain, with the advantages of a comprehensive evaluation of all LV segments and the possibility of distinguishing between active contraction and passive motion of the myocardium within the predefined region. An initial study by de Isla *et al.*[25] observed in a small group of patients with MR that speckle-tracking-derived strain of the interventricular septum was a sensitive tool to predict subtle abnormalities of LV contractile function. In a previous study, we also showed that patients with severe MR but without significant LV dilatation and dysfunction exhibit increased LV GLS when compared with control subjects, due to the hyperdynamic function of the LV.[27] However, with further disease progression and LV dilatation, LV GLS showed a significant reduction, even in the presence of normal LVEF, suggesting a promising role of this parameter for the detection of LV dysfunction at an early stage before major and irreversible damage of the myocardium occurs. The aim of the present study was therefore to evaluate in large group of patients the value of a global measure of LV deformation (GLS) to predict long-term LV dysfunction in patients undergoing MVr. The linear regression analysis confirmed the value of the variables already implemented into current guidelines, namely preoperative LVEF, LVESD, presence of symptoms, and atrial fibrillation, to predict long-term LVEF. However, the predictive value of linear regression model increased significantly when preoperative GLS was also taken into consideration. Additionally, a GLS of $>-19.9\%$ was a powerful predictor of long-term LV dysfunction after MVr even when adjusted for other well-established prognosticators. This finding may have important clinical implications, since LV GLS might be used to identify (asymptomatic) patients at risk of developing long-term postoperative LV dysfunction, despite preserved LVEF before MVr, and therefore, it might provide an important additional tool for the monitoring and management of patients with severe organic MR. However, specific studies addressing ultimately the value of LV GLS to predict long-term outcome after MVr should be performed.

Conclusions

In a large series of patients operated within the last decade, MVr resulted in a low incidence of long-term LV dysfunction. Importantly, an LV GLS of $>-19.9\%$ was demonstrated to be a major independent predictor of long-term postoperative LV dysfunction after adjustment for the parameters currently implemented into guidelines.

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