Left ventricular contractile reserve in asymptomatic primary mitral regurgitation

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Aims
There are very few data regarding the assessment and prognostic value of left ventricular contractile reserve (LVCR) in asymptomatic patients with primary mitral regurgitation (MR). We aimed to quantify LVCR and to evaluate its usefulness for risk stratification in asymptomatic patients with primary MR.

Methods and results
Comprehensive resting and exercise (EX) transthoracic echocardiography, including two-dimensional speckle tracking quantification, were performed in 115 consecutive asymptomatic patients with ≥ moderate degenerative MR and no LV dysfunction/dilatation. Left ventricular contractile reserve was defined as an EX-induced increase in LV ejection fraction (LVCRLVEF) ≥ 4% or in LV global longitudinal strain (LVCRGLS) ≥ 2%. LVCRLVEF was present in 54 patients (47%) and LVCRGLS in 58 (50%). The brain natriuretic peptide (BNP) level was significantly correlated with EX-induced changes in GLS (r = 0.45, P < 0.0001), but not in LVEF (r = 0.09, P = 0.31). Patients with no LVCRGLS had significant lower 3-year cardiac event-free survival (42 ± 8 vs. 69 ± 7%, P = 0.0008). In contrast, there was no significant difference in outcome regarding to the presence or absence of LVCRLVEF (60 ± 7 vs. 51 ± 8%, P = 0.40). The multivariable Cox proportional hazard model showed that the absence of LVCRGLS was a strong independent predictor of cardiac events (HR = 2.27, 95% CI: 1.05–4.76, P = 0.037), even after adjustment for Ex-echo variables and BNP level. The association between LVCRGLS and outcome remained significant (HR = 1.6, 95% CI: 1.1–2.3, P = 0.01) after further adjustment for the resting echocardiographic parameters included in the ESC Guidelines.

Conclusion
In asymptomatic primary MR, LVCR seems to be better assessed using EX-induced changes in LV myocardial longitudinal function rather than in LVEF. In patients with preserved LV function, the absence of LVCR is independently associated with a two-fold increase in risk of cardiac events. Left ventricular contractile reserve may be useful to improve risk stratification and clinical decision-making in these patients.

Keywords
Valve • Exercise echocardiography • Mitral regurgitation • LV function • Contractile reserve • Surgery

Introduction
The management of asymptomatic patients with primary mitral regurgitation (MR) remains controversial.1,2 In these patients, mitral valve surgery is recommended (class I indication, level of evidence B) in both European Society of Cardiology (ESC) and American College of Cardiology and American Heart Association (ACC/AHA) guidelines when left ventricular (LV) function is impaired [LV ejection fraction (EF) < 60%] or in case of LV dilatation (LV end-systolic diameter > 40 mm in ACC/AHA and > 45 mm in ESC guidelines).3,4 However, symptoms commonly occur well before LV dysfunction or dilatation.5 Indeed, LVEF remains for long-time normal or supranormal5,6 and only one-third of patients with flail leaflet were reported as asymptomatic in the presence of LV dilatation.6,8 Hence, LV end-systolic diameter, the recommended measurement by current guidelines, may remain within the normal range despite overt LV dilatation; the LV volume appears to be more reliable to predict post-operative LV dysfunction than diameter.9 These

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observations underscore that the evaluation of LV function and the detection of early LV subclinical impairment in primary MR still remain challenging.

When evaluated during exercise (EX) or even immediately after EX, EX-induced changes in LVEF have been shown to better predict post-operative LV dysfunction than LVEF at rest. In addition, the presence of LV contractile reserve (LVCR) (i.e. the ability of the LV to recruit function during EX) is associated with post-operative preserved LV systolic function, improvement in EX capacity and better outcome. Ventricular contractile reserve was defined as an EX-induced increase in LVEF ≥ 4%. However, the superiority of the indices of LV longitudinal myocardial deformation [i.e. as measured by two-dimensional (2D) speckle tracking echocardiography] over LVEF in the assessment of LV subclinical dysfunction has been widely suggested. Our group has recently reported that brain natriuretic peptide (BNP) level is mainly related to the LV performance as assessed by LV global longitudinal strain (GLS) both at rest and during EX.

The purpose of the present study was to evaluate the LVCR and its impact on outcome in asymptomatic patients with primary MR. We hypothesized that the assessment of LVCR by LV GLS using 2D speckle tracking is more powerful to predict the outcome than when defined by changes in LVEF.

**Methods**

**Study population**

Since January 2008 to June 2011, we prospectively included 135 consecutive asymptomatic patients with moderate to severe degenerative MR [defined as an effective regurgitant orifice (ERO) area ≥ 20 mm² and/or a regurgitant volume (RV) ≥ 30 mL], preserved LVEF (>60%) and normal LV end-systolic diameter (<45 mm) referred to our outpatient valvular heart disease clinic for EX Doppler echocardiography. A total of 115 patients met the inclusion criteria and had LVCR assessment available with both GLS and LVEF. Patients were enrolled in two centres (University of Liège, CHU Sart Tilman, Liège, Belgium and Quebec Heart and Lung Institute, Quebec, Canada). All the patients included were in sinus rhythm and none of them had concomitant > mild valvular stenosis or regurgitation or renal failure (serum creatinine > 160 mmol/L). Patients with suspected coronary arterial disease (CAD), with electrical changes during EX or EX-induced wall motion abnormalities were excluded.

The present protocol was approved by the relevant institutional review boards and all the patients gave written informed consent.

**Demographic and clinical data**

Demographic and clinical data included age, gender, height, weight, history of smoking, documented diagnosis of hypertension, hypercholesterolaemia, overweight, and diabetes.

**Exercise echocardiography**

Following comprehensive resting Doppler echocardiogram, all the patients performed a symptom-limited graded bicycle EX test, in a semi-supine position on a dedicated tilting EX table (Ecogito, Easystress Liege, Belgium and Ergoline, 800 ER, Cosmed). The initial workload of 25 W was maintained for 2 min; the workload was increased every 2 min by 25 W. Blood pressure and a 12-lead ECG were recorded every 2 min. Two-dimensional and Doppler echocardiographic imaging was available throughout the test.

**Echocardiographic measurements**

Echocardiographic examinations were performed with a Vivid 7 or 9 imaging device (GE Healthcare, Little Chalfont, UK). All Doppler echocardiographic data were obtained in digital format and stored on a workstation for off-line analysis (EchoPAC, GE Vingmed Ultrasound AS, Horten, Norway). All the measurements were averaged over three cardiac cycles. Mitral regurgitation was quantified as previously described and recommended. Both the regurgitant volume (RV) and the effective regurgitant orifice (ERO) area were obtained. The LV diameters were obtained from the parasternal long-axis view by the 2D-guided M-mode using the leading edge methodology at end-diastole and end-systole. The LV end-systolic and end-diastolic volumes as well as the LV EF were obtained using the modified biplane Simpson’s method. The LV forward stroke volume was calculated by multiplying the LV outflow tract area by the LV outflow tract velocity–time integral measured by pulsed-wave Doppler. The left atrial (LA) volume was obtained using the biplane area–length method. Mitral E- and A-wave velocities were measured with pulsed-wave Doppler, and e’-wave velocity by tissue Doppler imaging in the septal position of the mitral annulus. Systolic pulmonary arterial pressure was derived from the regurgitant jet of tricuspid regurgitation using systolic transtricuspid pressure gradient calculated by the modified Bernoulli equation and the addition of 10 mmHg for right atrial pressure as previously performed and validated. The right atrial pressure was assumed to be constant from rest to EX.

Left ventricular longitudinal myocardial function was evaluated with the quantification of both resting and EX GLS using 2D speckle tracking analysis, as previously described. Exercise echocardiographic acquisitions for the measurement of both GLS and LVEF were performed before the end of EX, at a heart rate between 90 and 110 b.p.m.

The echocardiographic parameters were independently acquired and measured (P.L., L.P., J.M., H.M.) in the centre where the patient was enrolled. The data were then merged in a computerized database and analysed in University of Liège, CHU Sart Tilman, Liège, Belgium. The methods for the measurements of Doppler-echocardiographic variables were established a priori before initiation of this prospective study and H.M. and J.M. travelled to each centre to ensure optimal standardization of the measurements.

**Evaluation of the presence of left ventricular contractile reserve**

The LVCR was evaluated using the two most recently validated and published methods in patients with primary MR. The presence of LVCR was independently defined as (i) exercise-induced improvement in LVEF ≥ 4% (LVCR_{LVEF}) or (ii) exercise-induced improvement in GLS ≥ 2% (LVCR_{GLS}).

**Plasma brain natriuretic peptide level measurement**

Venous blood samples for BNP measurement were drawn before echocardiography (after 20 min of the supine rest). Chilled ethylene-diamine-tetra-acetic acid tubes were centrifuged immediately at 2667 g (4 °C) for 15 min. Separated plasma samples were processed by the immunofluorescence assay (Biosite, Beckman Coulter, San Diego, California). The inter- and intra-assay variations were 5 and 4%, respectively. The assay detection limit was 1 pg/mL.

**Cardiac event-free survival**

Patient follow-up was performed according to current guidelines. Follow-up information was obtained from interviews with the patients, physicians, or eventually next of kin, every 6–12 months. Cardiac
event was defined as the occurrence of cardiovascular death, mitral valve surgery (only indicated by the development of symptoms or LV dysfunction, according to current guidelines), and hospitalization for acute pulmonary oedema or congestive heart failure. Surgery performed only on the basis of the presence of pulmonary hypertension was not considered as an event. At the end of this study, patients with a last follow-up > 6 months were re-evaluated by telephone calls from physicians or next of kin. The follow-up collection was complete in the 115 patients (100%).

Statistical analysis
Results are expressed as means ± SD or number (percentage) unless otherwise specified. Before analysis, normality distribution was tested with the Kolmogorov–Smirnov test. Differences between groups (i.e. according to the presence or absence of LVCR) were analysed for statistical significance with Student’s t-test, χ² test, or Fisher exact test, as appropriate. Since the distribution of the BNP level was not normal, the differences between groups were assessed using the Mann–Whitney U test. Correlations between EX-induced changes in LVEF or LV GLS and log BNP levels were assessed with Pearson’s correlation test. Probabilities of cardiac event-free survival were obtained by Kaplan–Meier estimation and then compared by the use of a two-sided log-rank test. Cox proportional-hazards models were used both in univariable and multivariable analyses to identify the independent predictors of cardiac event-free survival.

Inter-observer and intra-observer variabilities for the measurement of EX-induced changes in LVEF and GLS was determined from the analysis of the Doppler echocardiographic images of 38 randomly selected patients by two independent observers (J.M. and P.L.). Pearson correlation coefficient, Bland–Altman method, and inter-rater agreement Kappa statistic were used to assess the reproducibility of these parameters. The percentage of correct classification (i.e. when compared with the presence or absence of LVCRGLS and LVCR LVEF established by the observer 1) was calculated with the measurement of each parameter by observer 2 (inter-observer) and by the repeated measurements of observer 1 (intra-observer).

Values of P < 0.05 were considered significant and all statistical tests were two-sided. All statistical analyses were performed with STATISTICA version 7 (StatSoft, Inc., Tulsa, Okla).

Results
Among the 115 patients included in the study (mean age = 61 ± 14 years, 56% of male), 63% had severe MR, defined as a RV > 60 mL. The presence of hypertension was found in 47% of patients, overweight in 46%, hypercholesterolaemia in 22% and diabetes in 8%. A history of smoking was reported in 35% of patients.

Presence of left ventricular contractile reserve and characteristics of patients
Resting LVEF and LV GLS were 69 ± 6% and −20 ± 4%, respectively. During EX, LVEF did not significantly increase (+2.3 ± 9.1, P = 0.21). There was an increase significant in LV GLS during EX (+2.02 ± 4.3, < 0.0001). Exercise-induced changes in LVEF were not correlated with changes in LV GLS (r = 0.03, P = 0.76, Figure 1). There was an agreement between the two methods to identify LVCR in 67 (58%) patients. The concomitant presence of LVCRLVEF and absence of LVCRGLS was found in 22 (19%) patients, and the absence of LVCRLVEF but the presence of LVCRGLS in 26 (23%) patients.

There was no significant difference in baseline characteristics between patients with LVCRLVEF and those without LVCRLVEF regarding demographic and clinical data, risk factors, and medications (Table 1). In contrast, patients without LVCRGLS were significantly older (P < 0.0001, Table 1) than those with LVCRGLS. There was no other significant difference between these two groups. Comparisons of echocardiographic data according to the presence or the absence of LVCR are reported in Table 2. Left ventricular end-systolic and end-diastolic diameters were not statistically different between patients with vs. those without LVCR, assessed using GLS. According to LVCR assessed using LV EF (LVCR LVEF), patients without LVCR LVEF had significantly larger LV end-systolic diameter than those with LVCR LVEF but statistically similar LV end-diastolic diameters and indexed LV diameters. Indexed LV end-systolic diameter > 22 mm m⁻² was found in 12 patients (10%), without significant difference between those with or without LVCR and regardless the modality used to assess LVCR: LVCRGLS: 10 vs. 11%, P = 0.97; LVCR LVEF: 1 vs. 11%, P = 0.82. Similar results were found with indexed LV end-diastolic diameter > 38 mm m⁻²: LVCRGLS: 3.5 vs. 7%, P = 0.40; LVCR LVEF: 7 vs. 3%, P = 0.33.

Patients without LVCR LVEF had significant higher EX indexed LA volume (P = 0.01), and the prevalence of severe MR was close to be significantly higher (P = 0.05) as well as EX E/e' ratio (P = 0.07), than those with LVCR LVEF. Conversely, the absence of LVCRGLS was associated with significantly more frequent severe MR at rest, more severe MR at EX, higher resting and EX E/e' ratio, resting indexed LA volume and EX systolic pulmonary arterial pressure (Table 2). Of note, there was no significant difference between the absence and the presence of LVCRGLS in respect to EX indexed LA volume, and there was only a tendency for significant difference between the two groups in resting systolic pulmonary arterial pressure (P = 0.05).

Left ventricular contractile reserve and brain natriuretic peptide level
The BNP levels were similar in patients with LVCR LVEF and those without LVCR LVEF (P = 0.90, Table 1) and there was no linear
The absence of LVCRGLS was not associated with reduced cardiac event-free survival (2-year: 61 ± 7 vs. 60 ± 7%, 3-year: 51 ± 8 vs. 60 ± 7%, P = 0.40; Figure 3A). Using GLS, there was a significant relationship between the presence of LVCRGLS and higher cardiac event-free survival (2-year: 74 ± 6 vs. 46 ± 8%, 3-year: 69 ± 7 vs. 42 ± 8%, P < 0.001, Figure 3B).

Using the Cox proportional hazard model, LVCR_LVEF was not a predictor of cardiac event-free survival [hazard ratio (HR): 0.78, 95% confidence interval (CI): 0.43–1.4, P = 0.41]. In contrast, univariable analysis showed that the presence of LVCR_GLS was associated with significant better event-free survival (HR = 0.41, 95% CI: 0.22–0.75, P = 0.001, Table 3). In multivariable analysis, after adjustment for age and sex, LVCRGLS was independently associated with better outcome (HR = 0.43, 95% CI: 0.23–0.81, P = 0.008).

With further adjustment for EX RV, EX systolic pulmonary arterial pressure, and EX E/e’ ratio, the presence of LVCRGLS remained an independent predictor of better cardiac event-free survival (HR = 0.40, 95% CI: 0.17–0.94, P = 0.035). Lastly, even after adjustment for the BNP level, LVCRGLS was an independent predictor of event-free survival (HR = 0.44, 95% CI: 0.21–0.95, P = 0.037). In patients with severe MR, the absence of LVCRGLS was associated with reduced cardiac event-free survival (P = 0.019). In contrast, LVCR_LVEF was not a predictor of cardiac event (P = 0.14).

### Incremental prognostic value of LVCRGLS

In a multivariate model including echocardiographic parameters (i.e. LVEF, LV end-systolic diameter, indexed LA volume, and pulmonary hypertension) that are proposed in the most recent ESC guidelines to determine the indication for surgery, the absence of LVCRGLS was...
independently associated with worse outcome (HR = 1.6, 95% CI: 1.1–2.3, P = 0.01). Of interest, only indexed LA volume remained an independent predictor of cardiac event in this model (HR = 1.02, 95% CI: 1.1–2.3, P = 0.04). In addition, patients with LVCRGLS had significantly better prognosis than those without LVCRGLS, regardless of the level of indexed LA volume (Figure 4: <40 mL m⁻²: P = 0.043; >40 mL m⁻²: P = 0.017).

Reproducibility of exercise-induced changes in left ventricle ejection fraction and global longitudinal strain

Intra- and inter-observer reproducibility were good for both EX-induced changes in GLS and in LVEF (Intra: 1.4 ± 0.9 and 3.7 ± 2%; Inter: 1.4 ± 0.9 and 4.7 ± 3%; respectively) (Supplementary material online). The Kappa statistics revealed good agreement in both inter- and intra-observer measurements (EX-induced changes in GLS: k = 0.74 and k = 0.796, respectively; EX-induced changes in LVEF: k = 0.72 and k = 0.788, respectively). The interclass correlation coefficients for the absolute agreement (ICCa) were also good in both inter- and intra-observer measurements [EX-induced changes in GLS: ICCa = 0.889, 95% confidence interval (CI): 0.799–0.941 and ICCa = 0.894, 95% CI: 0.806–0.943, respectively; EX-induced changes in LVEF: ICCa = 0.814, 95% CI: 0.672–0.899 and ICCa = 0.874, 95% CI: 0.772–0.932, respectively].

The intra- and inter-observer percentages of correct classification for LVCRGLS and LVCRLVEF were high (intra: 100 and 97.4%; inter: 97.4 and 97.4%, respectively).

Discussion

The results of the present study show that in asymptomatic patients with moderate to severe chronic primary MR and no LV dysfunction/dilatation, the absence of LVCR is frequent as it occurs in about half of the patients. Given the lack of relationship between LVCRGLS and BNP level and the outcome in these patients, the LVCR seems to be more accurately assessed using 2D speckle tracking analysis and GLS quantification than with the standard LVEF. The absence of LVCRGLS is a powerful independent predictor of outcome and multiples by more than two the risk of cardiac event during the follow-up, even when compared with echocardiographic criteria considered as trigger for surgery in current guidelines.

Exercise left ventricular function in mitral regurgitation

During EX, recruitment in LV function allows to adequately adapt LV forward stroke volume and cardiac output to central and peripheral demands. In addition to chronotropic adaptation, LV improves contractility with an increase in longitudinal shortening, circumferential,
and radial thickening. Because the orientation of myocardial fibres is mainly longitudinal, this function is crucial to provide good ejection during systole. Moreover, the first consequences of LV myocardial damage primarily occur on longitudinal function, before impairment of circumferential or radial function. In this regard, the quantification of GLS by 2D speckle tracking echocardiography allows identifying subtle and early LV myocardial longitudinal dysfunction. Recent studies have shown that GLS is better correlated with the BNP level than LVEF both at rest and during EX.15,16 These recent findings suggest that LV GLS is superior to conventional echocardiographic parameters to unmask subclinical LV dysfunction. During EX, the absence of improvement in longitudinal function is thus a sign of latent LV myocardial dysfunction.

The lack of myocardial longitudinal recruitment during EX seems to be related to the increase in volume overload. Patients without LVCRGLS more often have an increase in MR severity during EX. Two mechanisms may support such a relationship. First, in the presence of acute increase in LV volume overload, the LV may be unable to improve contractility and filling. Secondly, patients with dynamic primary MR may have intermittent increase in MR. Hence, MR severity evaluated at rest does not correspond to MR severity experienced in daily life activities. In this regard, early and latent LV myocardial dysfunction revealed by the absence of LVCRGLS could represent the real MR consequences on LV, especially in patients with dynamic MR.

Concomitantly to the frequent increase in LV volume overload during EX, patients without LVCRGLS may also have a significant increase in estimated LV filling pressure. This haemodynamic phenomenon may be related to the absence of recruitment in LA function and volume and to impaired atrio-ventricular compliance. As a
result, the LV cannot provide adequate response to this additional burden and is not able to improve its longitudinal function. The correlation reported in our study between EX-induced changes in LV GLS and the BNP level supports this hypothesis.

Conversely, we did not find any relationship between the absence of LVCRLVEF and elevated BNP level or reduced cardiac event-free survival. This could, thus, explain at least in part, the lack of relationship between LVCRLVEF and outcome.

**Comparison with previous studies**

Exercise LV volumes and LVEF have been shown to be more accurate than their values at rest to predict post-operative LV dysfunction in patients with severe primary MR. More recently, it was emphasized that 2D speckle tracking-derived parameters, such as LV GLS or GLS indexed for LV volumes, are probably better than LV volumes or LVEF to predict post-operative LV dysfunction. Nevertheless, the vast majority of patients included in these studies had a class I indication for surgery (including LV dilatation/dysfunction) limiting the usefulness of these parameters for the risk stratification and management of asymptomatic patients with primary MR.

Lee et al. were the first to report that preoperative LVCRLVEF was an independent predictor of both post-operative LV dysfunction and outcome. In contrast, the present study does not report a significant association between LVCRLVEF and outcome. Both baseline differences in the two studied population and end-point selection for outcome analysis may explain this discrepancy. Indeed, our population was asymptomatic, without LV dysfunction/dilatation (i.e. no class I indication for surgery) or atrial fibrillation, and also included some patients with moderate MR. Our primary end-point was the combined occurrence of cardiovascular event and/or mitral valve surgery only motivated by a class I indication, whereas Lee et al. analysed post-operative outcome, including cardiac death, occurrence of heart failure or atrial fibrillation. Furthermore, they assessed the presence or absence of LVCR using parameters not obtained during EX but during the early post-EX recovery, a stage where the influence of MR changes on LVEF, related to loading conditions, might be attenuated.

**Usefulness of left ventricular contractile reserve for the management of asymptomatic mitral regurgitation**

In recent studies, LV GLS was identified as an independent predictor of resting BNP level, but also of reduced cardiac event-free survival. Furthermore, LV longitudinal function assessment seems to better predict post-operative LV dysfunction than LVEF. In this regard, LV GLS and LVCRLVEF emerged as useful in the risk stratification of asymptomatic patients with primary MR.

Indeed, the lack of LVCRLVEF is independently associated with a more than two-fold increase in the risk of cardiac event during the follow-up. Nevertheless, it should be emphasized that the vast majority of events occurring in our series are not ‘hard’, which is consistent with the baseline characteristics of this population. Furthermore, patients with no LVCRLVEF are frequently those with a marked increase in MR severity during EX and with EX pulmonary hypertension. These two concomitant haemodynamic features were also associated with reduced symptom-free survival. In the light of these findings, it seems that EX stress echocardiography may help to identify a subset of asymptomatic patients with primary MR who can be considered at higher risk of event. Interestingly, when adjusting for echocardiographic parameters included in the most recent guidelines and considered as trigger for surgery (i.e. LVEF, LV end-systolic diameter, indexed LA volume, and pulmonary hypertension) LVCRLVEF remained a significant predictor of outcome, suggesting its valuable incremental prognostic value. Hence, these findings suggest that patients with asymptomatic MR and without overt LV

![Figure 4](image-url)
dysfunction/dilatation but with no LVCRGLS could benefit from early surgery in order to avoid early occurrence of symptoms and to preserve post-operative LV function. Conversely, watchful waiting strategy may be advised for patients with LVCRGLS because, as shown by our data, BNP remains low and event-free survival is satisfactory in these patients. Nonetheless, further data are needed to support this proposed strategy.

Limitations
The lack of relationship between EX-induced changes in LVEF and BNP level or outcome could be related to the relative small sample size of the study. However, significant associations were found with EX-induced changes in GLS. By design, we have only included patients with both resting and EX quantification of LVEF and GLS available, thereby avoiding difference in statistical power between the two methods tested.

As reported in this study, the measurement of LV GLS may be subject to some degree of both inter- and intra-observer variability. Clinical experience shows that reliance on a single quantitative echocardiographic parameter for clinical decision-making often entails potential pitfalls and limitations. Hence, we caution that the measurement of LVCRGLS requires good-quality tracings and requires a learning curve. The consideration of other indices included in the current guidelines may be useful to obtain a more comprehensive evaluation of patients. Nevertheless, the fact that LVCRGLS defined on the basis of EX-induced changes in GLS was associated with higher BNP level and markedly worse clinical outcome further supports the clinical usefulness of this method.

Although patients with suspected CAD or with EX-induced changes in wall motion were excluded, we did not systematically performed angiography in all patients. This underlines that some patients with CAD may be included in the present study. However, the population is relatively young, with low rate of comorbidities and with pure degenerative MR. Coronaro-angiography is not commonly indicated in this population and the prevalence of significant obstructive CAD is likely very low.

Conclusion
In asymptomatic primary MR, despite preserved resting LV function and no LV dilatation, LVCR may be absent in about half of the patients. LVCR seems to be better assessed using EX-induced changes in LV myocardial longitudinal function rather than by changes in the standard LVEF. The absence of LVCR on EX is independently associated with more than two-fold increase in risk of cardiac events, even after adjustment for echocardiographic parameters considered as trigger for surgery in the most recent ESC Guidelines. Hence, LVCR may be useful to improve risk stratification and clinical decision-making in asymptomatic patients with chronic primary MR.

Supplementary material
Supplementary material is available at European Heart Journal online.

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Conflict of interest: none declared.

References


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**CARDIOVASCULAR FLASHLIGHT**

**Post-implantation transcatheter aortic valve migration in a left ventricular assist device patient with severe aortic insufficiency**

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A 49-year-old man with dilated cardiomyopathy who underwent HeartMate II (Thoratec) left ventricular assist device (LVAD) implantation 1 year prior presented with cardiac failure secondary to severe aortic regurgitation (AR) requiring inotropic support. He previously developed acute pump thrombosis requiring emergency pump exchange complicated by right heart failure requiring temporary right VAD support. Because of his extreme surgical risk (EuroSCORE-II 48.15%), transcatheter aortic valve implantation (TAVI) was offered on humanitarian grounds. Computed tomography showed an aortic annulus diameter of 27 mm based on its perimeter (86 mm). A 31 mm self-expanding CoreValve (Medtronic) was deployed via the transfemoral approach. Post-deployment, it was satisfactorily positioned with acceptable mild–moderate paravalvular leak (Panels A and B). However, he became haemodynamically unstable 2 h post-procedure. Investigations confirmed that the CoreValve migrated into the LV outflow tract, causing severe AR (Panels C and D). Emergency surgery was performed to remove the prosthesis and close the aortic valve. After a complicated post-operative recovery, he was discharged well. We postulate that the early CoreValve migration was contributed by the lack of calcium on the native aortic valve to provide fixation, and the absence of pulsatile flow resulting in the CoreValve leaflets being constantly in a ‘closed’ state, allowing the LVAD to act as a suction to pull it towards the apex. Thus, the application of TAVI in LVAD patients with AR must be viewed cautiously. A possible alternative would be transcatheter aortic valve closure with an Amplatzer Septal Occluder. (Black arrow, intersection of CoreValve with Swan-Ganz catheter on fluoroscopy; white arrow, aortic annulus on echocardiography)

P.T.L.C. is a proctor for Edwards Lifesciences and Medtronic CoreValve.

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