Chapter Ten

Left Ventricular Twist during Dobutamine Stress Echocardiography after Acute Myocardial Infarction: Association with Reverse Remodeling

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ABSTRACT

Objectives

Left ventricular (LV) twist is emerging as a marker of global LV contractility after acute myocardial infarction (AMI). This study aimed to describe stress-induced changes in LV twist during dobutamine stress echocardiography (DSE) after AMI and investigate their association with LV reverse remodeling at 6 months follow-up.

Methods and Results

In 82 consecutive first AMI patients (61±12 years, 85% male) treated with primary percutaneous coronary intervention, DSE was performed at 3 months follow-up. Two-dimensional speckle-tracking-derived apical and basal rotation and LV twist were calculated at rest, low- and peak-dose stages. LV reverse remodeling was defined as ≥10% decrease in LV end-systolic volume between baseline and 6 months follow-up. Patterns of LV twist response on DSE consisted of either a progressive increase throughout each stage (n=18), an increase at either low- or peak-dose (n=53) or no significant increase (n=11). LV reverse remodeling occurred in 28 (34%) patients, who showed significantly higher peak-dose LV twist (8.51 vs. 6.69°, p=0.03) and more frequently progressive LV twist increase from rest to peak-dose (39% vs. 13%, p<0.01) compared to patients without reverse remodeling. Furthermore, increase in LV twist from rest to peak-dose was the only independent predictor of LV reverse remodeling at 6 months follow-up (OR 1.3, 95% CI 1.1-1.5, p=0.005).

Conclusions

Both the pattern of progressive increase in LV twist and the stress-induced increment in LV twist on DSE are significantly associated with LV reverse remodeling at 6 month follow-up after AMI, suggesting its potential use as a novel marker of contractile reserve.

INTRODUCTION

Contraction of the spirally oriented myofibers of the left ventricle (LV) results in a 'wringing' motion about its long-axis, referred to as 'LV twist', which plays a crucial role in optimizing LV performance through the equal distribution of fiber stress across the LV wall. Given that any cardiac pathology causing fiber disarray may result in abnormal torsional mechanics, LV twist has emerged as an important and sensitive parameter of LV systolic function in different patient populations.[1] Furthermore, the development of two-dimensional (2D) speckle-tracking echocardiography, validated against sonomicrometry and cardiac magnetic resonance imaging (CMR),[2, 3] has provided a relatively simple and widely available method to measure LV apical and basal rotation and LV twist.

Several studies evaluating LV twist in patients after acute myocardial infarction (AMI) have shown that the degree of impairment in LV twist after AMI is related to the extent of LV systolic dysfunction, infarct size and/or transmurality of infarction.[4-7] LV twist has therefore emerged as a new parameter to define the extent of myocardial dysfunction and its impact on global LV performance in these patients. Of similar importance in patients with myocardial infarction is the identification of viable myocardium and inotropic contractile reserve, well-known to have significant prognostic implications.[8] Dobutamine stress echocardiography (DSE) is therefore performed after AMI to evaluate LV inotropic response in addition to detecting potential residual ischemia, for both prognosis and risk stratification purposes.[9] Despite rotational mechanics being shown to reflect overall global myocardial function post-AMI, the role of measuring LV twist during DSE in these patients has not been evaluated.

Accordingly, the aim of the present study was twofold. Firstly, we sought to describe the patterns of response of LV twist on DSE in post-AMI patients and secondly, given the emergence of LV twist as a marker of global LV contractility, we aimed to explore the relationship between stress-induced changes in LV twist and the development of LV reverse remodeling at 6 months follow-up, a known predictor of favorable long-term outcome after AMI.

METHODS

Patient population and protocol

The population consisted of consecutive patients admitted with a first ST-segment elevation AMI treated with primary percutaneous coronary intervention (PCI) who underwent DSE at 3 months follow-up as part of the institutional MISSION!

Protocol.[10] This protocol, based on the most recent American College of Cardiology Foundation/American Heart Association and European Society of Cardiology guidelines, provides a clinical framework including immediate coronary angiography and primary PCI, 2D echocardiography performed within 48 hours of admission and at systematic outpatient follow-up at 3 and 6 months, and structurized medical therapy. Diagnosis of AMI was made on the basis of typical electrocardiographic changes and/or ischemic chest pain associated with elevation of cardiac enzymes.[11]

DSE was performed 3 months after AMI in all patients to optimize management and risk stratification through detection of residual ischemia and/or myocardial viability.[9] Patients were excluded from the study if DSE was positive for ischemia (defined as a new or worsening regional wall motion abnormality[12]), given the likelihood that this would necessitate further therapeutic options which could in turn affect follow-up LV volumes. Patients were also excluded if the DSE protocol was not completed due to significant arrhythmias, hypotension, severe hypertension (systolic blood pressure >240mmHg) or intolerable symptoms.[12]

Speckle tracking analysis was performed to assess rotational mechanics at rest, low-dose and peak-dose. In particular, the relationship between stress-induced changes in LV twist and the occurrence of LV reverse remodeling at 6 months follow-up, defined as ≥10% reduction in LV end-systolic volume (LVESV) between baseline and 6 month 2D echocardiography studies, was evaluated.[13]

Clinical data was prospectively collected in the departmental Cardiology Information System (EPD-Vision®, Leiden University Medical Center) and retrospectively analysed. The study protocol was approved by the Institutional Review Board of the Leiden University Medical Center.

2-dimensional echocardiography

All patients were imaged in the left lateral decubitus position using a commercially available system (iE33, Philips Medical Systems, Bothell, Washington, USA) equipped with a broadband S5-1 transducer. Standard 2D images and Doppler data were acquired from parasternal and apical (4-, 2- and 3-chamber) views and saved in cine-loop format from 3 consecutive beats. Analysis was subsequently performed offline using Q-Lab Version 8.0, (Philips Medical Systems). LVESV, LV end diastolic volume (LVEDV) and LV ejection fraction (LVEF) were assessed using the Simpson's biplane technique.[14] Qualitative assessment of regional wall motion was performed by calculating the global wall motion score index (WMSI) according to current recommendations.[14]

Dobutamine stress echocardiography

DSE was performed according to standard protocols.[12] Dobutamine was administered beginning at a dose of 5 or 10ug/kg/min and increased at 5 minute intervals up to 40ug/kg/min. If target heart rate (defined as 85% of age-predicted maximal heart rate) was not achieved, intravenous atropine (up to 1mg) was given. Low-dose echocardiographic images were acquired at 20ug/kg/min and peak-dose images were acquired upon achievement of target heart rate.

Speckle-tracking analysis

At each stage of DSE (rest, low-dose and peak-dose) parasternal short-axis images were acquired at the LV basal and apical levels. To obtain the most accurate apical rotation value, the transducer was positioned 1 or 2 intercostal spaces more

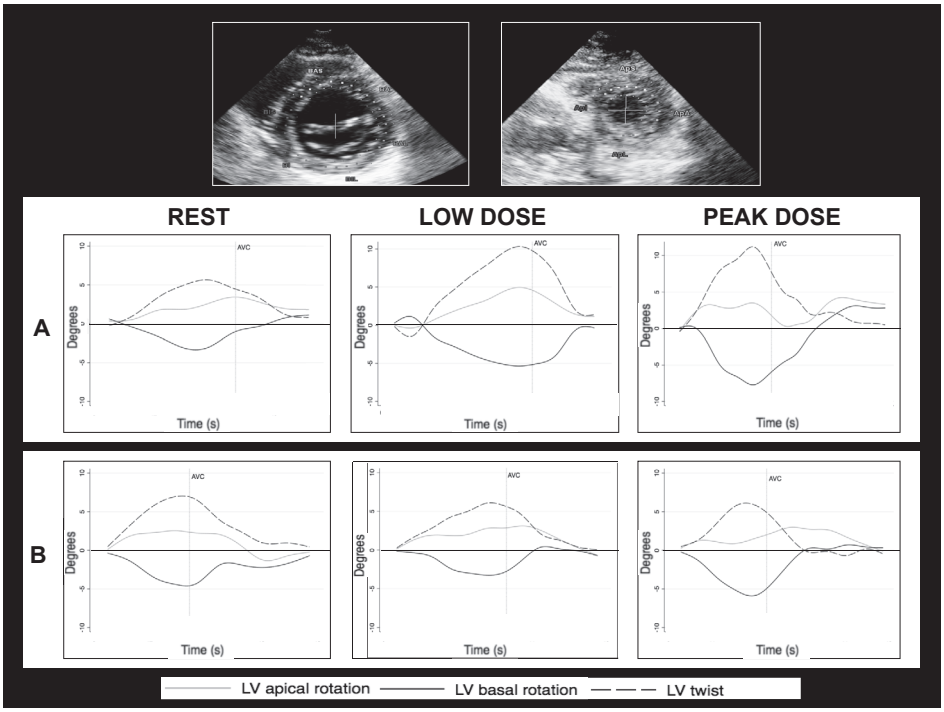

Figure 1. LV Apical and basal rotation and LV twist curves at each stage of DSE. (A) A patient with progressive increase in LV twist throughout DSE (pattern 1), who showed LV reverse remodeling at 6 month follow-up; and (B) a patient with no significant increment in LV twist (pattern 3), who did not show LV reverse remodeling at follow-up. At the top, basal (left) and apical (right) short axis images are shown to which two-dimensional speckle-tracking analysis was applied. LV twist values at rest, low-dose and peak-dose were 6.4°, 10.4° and 11.3° respectively for patient (A) and 7.1°, 6.1° and 7.4° respectively for patient (B). AVC, aortic valve closure; Dobutamine stress echocardiography; LV, left ventricular

caudally than the standard parasternal position.[15] Patients without true apical images (defined as the smallest cavity achievable distal to the papillary muscles) were excluded. The frame rate ranged from 60 to 100 frames per second, and 3 cardiac cycles for each short axis level at each stage were stored in cine-loop format for offline analysis (Q-Lab Version 8.0, Philips Medical Systems). For speckle-tracking analysis, the circular region of interest was placed within the 2 thin muscular bands corresponding to the subepi- and subendocardial layers (using the optimal frame for endocardial identification). The software then tracks the two borders frame by frame, allowing the operator to check the tracking quality and subsequently to adjust both borders manually if necessary (Figure 1). LV rotation for each short-axis image was calculated as the average angular displacement of the 6 standard segments referring to the ventricular centroid, frame by frame. To calculate LV twist, defined as the net difference (in degrees) of the apical + basal rotation at isochronal time points, global apical and basal rotation data for each stage was exported to an Excel spreadsheet file. The curves of LV apical and basal rotation and LV twist were then derived for each stage of DSE (rest, low-dose and peak-dose) (Figure 1). LV torsion was calculated as the ratio between LV twist and the LV diastolic longitudinal length (in cm) between the LV apex and the mitral valve plane.[16]

Statistical methods and analyses

Continuous variables are expressed as mean ± standard deviation (SD) if normally distributed and as median and interquartile range when not. Categorical data is presented as absolute numbers and percentages. Differences in continuous variables between 2 groups were assessed with Student *t* test or Mann-Whitney *U* test for continuous data or chi-square $(X)^2$ or Fisher's exact test for categorical data as appropriate. A linear mixed-effects modeling approach was used to evaluate differences in DSE characteristics (general and rotational deformation parameters) across groups (LV reverse remodeling or not) and stages (rest, low-dose and peak-dose).

The relationship between LV reverse remodeling as a binary outcome variable and a range of putative predictor variables was evaluated using multiple logistic regression. Candidate predictor variables associated with a p-value <0.1 on univariate analysis were included in the multivariate analysis. For the purposes of investigating the relationship between stress-induced changes in LV rotational parameters and reverse remodeling, LV twist rather than LV torsion was chosen as the predictor variable - principally for general reproducibility, as it is the less complex of the 2 measurements. Receiver operating characteristics (ROC) curve analysis was undertaken to evaluate the predictive capacity of the change in LV

twist from rest to peak-dose - "Δ twist"- for the occurrence of LV reverse remodeling at 6 months. Finally subgroup analysis was performed in patients with baseline LVEF <50%, who constitute a group of particular clinical interest.

The statistical software program STATA version 11 (STATA Corp., College Station, Texas) was used for statistical analysis.

Reproducibility

Bland-Altman analysis was performed to evaluate the reproducibility of global LV twist measurement in 14 randomly selected patients. LV twist was calculated from repeated apical and basal rotation measurements performed at both rest and peak-dose stages by the same observer and by another independent observer 4 weeks later. According to Bland-Altman analysis, the mean intra-observer difference ± 2SD was 0.11±0.77° and the mean inter-observer difference ± 2SD was 0.10±0.91°.

RESULTS

Patient population

A total of 129 patients had uncomplicated complete DSE studies at 3 months follow-up after first ST-segment AMI. Among these, 8 patients had studies positive for ischemia and were therefore excluded. Inadequate rest and/or stress image quality and/or unreliable speckle tracking curves were observed in 39 (30%) patients who were also subsequently excluded. Baseline clinical and conventional echocardiographic characteristics of the remaining 82 patients are summarized in Table 1.

The majority were male, with either left anterior descending (LAD) (42%) or right coronary artery (RCA) (40%) AMI. Multivessel disease (defined as angiographic stenosis ≥50% in ≥2 vessels, including the culprit vessel) was present in 50% of the population. Optimized medical therapy as outlined in the MISSION! protocol was present in all patients as tolerated (100% ≥1 antiplatelet agent; 95% angiotensin converting enzyme inhibitor or angiotensin receptor blocker; 89% beta-blockers; 100% statins). Exactly half of the patients exhibited an LVEF <50%.

LV reverse remodeling at 6 months occurred in 34% (n=28) of patients. Baseline characteristics of patients who showed LV reverse remodeling compared to those without remodeling are summarized in Table 1. Patients with LV reverse remodeling at follow-up had a lower LVEF at baseline (45±10 vs. 51±8%, p=0.01) and were also more likely to have a family history of coronary artery disease (CAD). No other significant differences in clinical or echocardiographic characteristics were observed between the 2 groups at the time of AMI.

Table 1. Baseline clinical and echocardiographic characteristics in the total population and according to LV reverse remodelling or not subgroups

	Total Population (n=82)	LV Reverse Remodeling (n=28)	No LV Reverse Remodeling (n=54)	P value*
Clinical				
Age, years	61±12	63±14	60±12	0.29
Male, n (%)	70 (85)	21 (75)	49 (92)	0.10
Diabetes, n (%)	6 (7)	2 (7)	4 (8)	1.0
Family History of CAD, n (%)	32 (39)	16 (57)	16 (30)	**0.04**
Hypercholestrolemia, n (%)	17 (21)	7 (25)	10 (19)	0.68
Hypertension, n (%)	31 (38)	12 (43)	19 (36)	0.68
Current or previous smoking, n (%)	48 (59)	17 (61)	31 (59)	0.65
Infarct-related artery, n (%)				
Left Anterior Descending	34 (42)	14 (50)	20 (38)	0.52
Left Circumflex	14 (17)	3 (11)	11 (21)	
Right Coronary	33 (40)	11 (39)	22 (42)	
Left main	1 (1)	0 (0)	1 (2)	
Multivessel disease, n (%)	41 (50)	13 (46)	28 (53)	0.80
Peak Troponin T, ug/L	3.0 (0.98-7.3)	2.7 (1.3-8.4)	3.2 (0.82-7.3)	0.70
Echocardiographic				
LVEDV, ml	98 (83-114)	102 (89-121)	94 (83-113)	0.6
LVESV, ml	47 (40-60)	55 (45-66)	45 (38-56)	0.7
LVEF (%)	49±9	45±10	51±8	**0.01**
>50%, n (%)	41 (50)	10 (36)	31 (57)	**0.06**
<50%, n (%)	41 (50)	18 (64)	23 (43)	
WMSI	1.38±0.32	1.45±0.39	1.35±0.27	0.29
LV diastolic longitudinal length, cm	8.2±0.6	8.1±0.6	8.2±0.6	0.72

*P values are given for the difference in baseline characteristics between patients with LV reverse remodeling compared to no reverse remodeling.
CAD, coronary artery disease; LV, left ventricular; LVEDV, left ventricular end diastolic volume; LVEF, left ventricular ejection fraction; LVESV, left ventricular end systolic volume; WMSI, wall motion score index.

DSE parameters and LV reverse remodeling at 6 months follow-up

The main DSE findings are summarized in Figure 2. Mean heart rates at rest, low-dose and peak-dose were 63±12, 77±16 and 138±13 beats per minute (bpm) respectively. Baseline regional wall motion abnormalities were present in 84% (n=69) of patients. Mean values of WMSI at rest and at peak-dose for the total population were 1.22±0.21 and 1.17±0.20 respectively (p<0.001). Overall mean LV twist increased by an absolute value of 1 degree from rest to peak-dose (6.31±2.71° up to 7.31±3.53°, p=0.009). LV torsion (LV twist indexed to diastolic

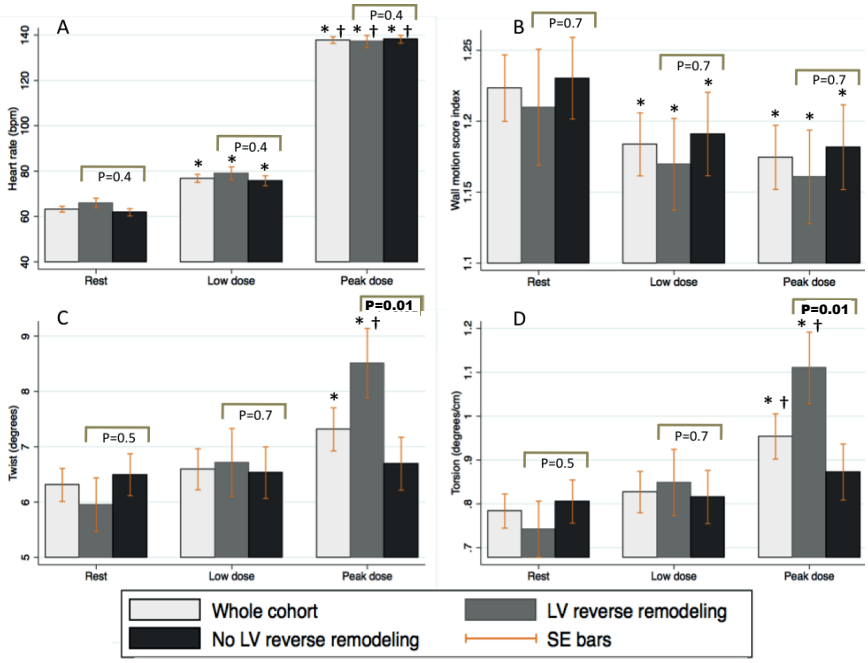

Figure 2. DSE parameters in the total population and according to LV reverse remodeling or not subgroups. Mean values of heart rate (A), wall motion score index (B), LV twist (C) and LV torsion (D) at each stage (rest, low-dose and peak-dose) of DSE in the total population and divided into subgroups according to LV reverse remodeling (n=28) or not (n=53). P values shown represent the differences in DSE characteristics between the 2 groups.* represents P value <0.05 between low and/or peak-dose compared to rest stage.† represents P value <0.05 between peak-dose compared to low-dose stage. Dobutamine stress echocardiography; LV, left ventricular; SE. standard error.

length at each stage) increased by 18% from rest to peak-dose (0.78±0.35°/cm to 0.95±0.47°/cm, p=0.001).

Overall, a significant increment in LV twist at ≥1 stage of DSE occurred in the majority of patients (n=71, 87%). Particularly, 3 distinct patterns of response of LV twist to pharmacological stress were observed. A total of 18 patients (22%) showed a progressive increase in LV twist through each stage of DSE (pattern 1). In contrast, 53 patients (65%) did not display a progressive increase but had an increase in LV twist at either low- or peak-dose (pattern 2). Finally, 11 patients (13%) did not show a significant increase in LV twist at any stage of DSE (pattern 3). The mean values for heart rate increase ± SD for pattern 1, 2, and 3 respectively were 12.9±9.6, 13.3±14.4 and 15.2±10.9bpm for rest to low-dose (p=0.9); and 72.3±17.2, 76.8±17.5 and 68.1±18.6bpm for rest to peak-dose (p=0.3).

As detailed in Figure 2, no significant differences were observed between patients with or without LV reverse remodeling at 6 months in peak-dose heart

rate (137±14 vs. 138±13bpm, p=0.74) or in WMSI either at rest (1.21±0.22 vs. 1.23±0.21, p=0.68) or at peak-dose (1.16±0.17 vs. 1.18±0.22, p=0.66). In addition, the change in WMSI from rest to peak-dose did not differ between the 2 groups (p=0.98). Regarding rotation parameters, there was no difference between the 2 groups at rest or at low-dose DSE. However, at peak-dose, LV twist (8.51 vs. 6.69°, p=0.01) and LV torsion (1.11 vs. 0.87°/cm, p=0.01) were significantly higher in patients who showed LV reverse remodeling as compared to those without reverse remodeling. Furthermore as shown in Figure 3, the group of patients showing LV reverse remodeling more frequently displayed the pattern of progressive increase in LV twist (pattern 1) at each stage of the test (39% vs. 13%, p<0.01). Conversely, none of the patients with pattern 3 showed LV reverse remodeling at follow-up (p=0.01 vs. those who had an increase at ≥1 stage).

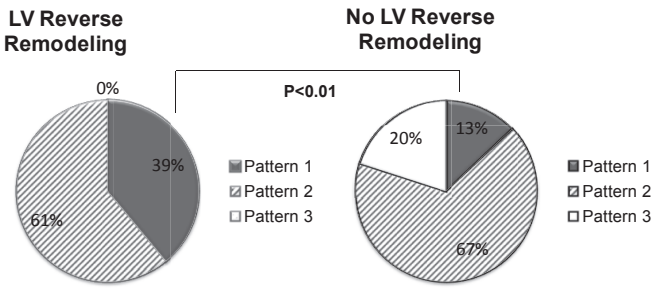

Figure 3. Pattern of LV twist response on DSE and LV reverse remodeling. Percentage of patients exhibiting each pattern of LV twist response on DSE according to LV reverse remodeling (left) (n=28) or no LV reverse remodeling (right (n=53) at follow-up. Pattern 1 indicates a progressive increase in LV twist throughout each stage of DSE; pattern 2 indicates an increase in LV twist at either low- or peak-dose and pattern 3 indicates no significant increase in LV twist at any stage of DSE. Dobutamine stress echocardiography; LV, left ventricular.

Univariate and multivariate predictors of LV reverse remodeling at 6 months

Table 2 shows the results of univariate and multivariate logistic regression analyses investigating the determinants of LV reverse remodeling at 6 months follow-up. At univariate analysis, baseline LVEF (p=0.03), family history of CAD (p=0.05) and Δ twist (p=0.005) were significantly related to LV remodeling. The area under the ROC curve for Δ twist for prediction of LV reverse remodeling at 6 months was 0.75 (95% CI 0.67-0.83). Furthermore on multivariate analysis only Δ twist was independently related to follow-up LV reverse remodeling (OR 1.3, 95% CI 1.1-1.5, p=0.005) (Table 2).

Table 2. Univariate and multivariate logistic regression analyses to determine the independent predictors of LV reverse remodeling at 6 months

	Univariate		Multivariate	
	OR (95% CI)	**P value**	**OR (95% CI)**	**P value**
Age (years)	1.0 (0.98-1.1)	0.3		
Female gender	2.5 (0.71-8.7)	0.1		
Family History CAD	2.7 (1.0-7.4)	0.05	2.8 (0.97-7.9)	0.06
Multivessel disease	0.81 (0.42-1.5)	0.5		
Infarct-related artery (vs. LAD)				
RCA	0.73 (0.27-2.0)	0.6		
LCx	0.44 (0.10-1.9)	0.3		
Killip class	0.76 (0.16-3.6)	0.7		
Peak troponin T (ug/L)	1.0 (0.92-1.1)	0.9		
Baseline LVEF (%)	0.94 (0.89-0.99)	0.03	0.96 (0.91-1.0)	0.2
WMSI baseline	1.9 (0.45-8.0)	0.4		
Time from symptom onset to balloon inflation (hours)	0.94 (0.85-1.0)	0.3		
Rest stage LV twist (°)	0.91 (0.76-1.1)	0.3		
Δ twist (°)	1.3 (1.1-1.5)	0.005	1.3 (1.1-1.5)	**0.005**

CAD, coronary artery disease; LAD, left anterior descending; LCx, left circumflex artery; LV, left ventricular; LVEF, left ventricular ejection fraction; RCA, right coronary artery; WMSI, wall motion score index.

Finally, subgroup analysis was performed in patients with baseline LVEF <50% (n=41). Overall 18 (44%) patients in this group ultimately showed LV reverse remodeling. At multivariate analysis, the ability of Δ twist to predict LV reverse remodeling remained significant for this clinically important subgroup (OR 1.6, 95% CI 1.1-2.3, p=0.01).

DISCUSSION

The current study describes for the first time stress-induced changes in LV rotational deformation parameters during DSE in contemporary post-AMI patients. Overall significant increment in LV twist at ≥1 stages of DSE occurred in the majority of patients. The increase in LV twist from rest to peak-dose on DSE was found to be the only independent predictor of LV reverse remodeling at 6 months follow-up.

LV twist is emerging as a thorough index of LV systolic myocardial performance, directly related to fiber architecture, ventricular geometry, oxygen demand and the compressibility and contractility of the myocardium.[17-19] Its role as marker of LV contractility has been supported by studies showing its increase during physiological exercise[20] and during positive inotropic interventions.[19, 21] Furthermore, it has been shown to be a global rather than a regional or site-specific measure

of LV function after myocardial ischemia and/or infarction.[5-7, 4] Although DSE has been widely applied in the post-AMI and other settings to quantify global LV functional capacity, few studies to date have incorporated LV twist measurement on DSE. An initial study in non-AMI patients previously showed a trend towards reduced increase in LV twist during peak-dose in patients with myocardial ischemia.[6] However, no data are available in patients after AMI for whom an accurate identification of LV inotropic contractile reserve by DSE has well-known prognostic value.[8] Meanwhile, it is accepted that standard wall motion analysis during DSE is highly subjective, and an expert observer is required to achieve published levels of accuracy.[22] Thus, the implementation during DSE of LV twist, as a thorough and quantitative index of global rather than regional LV systolic myocardial performance, may have an added benefit in post-AMI risk stratification.

In our large unselected group of contemporary-treated stable post-AMI patients with a high proportion of baseline regional dysfunction but without evidence of demonstrable ischemia, we observed 3 main patterns of LV twist response on DSE based on progressive increase or not through each stage of the test. In the post-AMI setting, loss of myocardial contractile function may occur due to myocardial necrosis, stunning or hibernation; the latter two reflecting reversible and the former reflecting irreversible myocardial dysfunction. DSE is frequently used in these patients to quantify the amount of reversible myocardial dysfunction (viable myocardium) and therefore identify patients with higher likelihood of LV function improvement at follow-up.[12,9] It can be hypothesized that the patterns of LV twist response found in the current study reflect reversibly (stunning) and irreversibly (necrosis) impaired myocardial contraction, respectively. We therefore explored the correlation between the overall increase and patterns of increase in LV twist during DSE and the occurrence of LV reverse remodeling during follow-up after AMI.

LV reverse remodeling after AMI is of well-known prognostic value; in a recent multicenter study, LV reverse remodeling at 6 months was the only independent predictor of 2-year event free survival and occurred in 39% of patients.[13] The rate of LV reverse remodeling in the current study was similar at 34%. Importantly, LV reverse remodeling at follow-up was significantly associated with a higher absolute value of LV twist and LV torsion at peak-dose of DSE and was more likely to occur in those patients who demonstrated the pattern of progressive increase in LV twist throughout each stage of DSE. Furthermore, the increase in LV twist was independently related to the subsequent development of LV reverse remodeling at 6 months follow-up. In contrast, none of the patients without a significant increase in LV twist on DSE showed LV reverse remodeling. Given that the extent of viable myocardium is an important determinant of LV reverse remodeling,[23] the finding

that LV twist response on DSE is predictive of later LV reverse remodeling (and ultimately favorable long-term outcome) supports the hypothesis that LV twist may represent a novel marker of inotropic contractile reserve in this patient group.

The association of stress-induced changes in LV twist on DSE with 6 month LV reverse remodeling underscores a potentially highly relevant clinical role for DSE-based LV twist evaluation in post-AMI risk stratification. Of particular clinical relevance is the finding that stress-induced changes in LV twist remained predictive of LV reverse remodeling in a subgroup of patients with baseline LV systolic dysfunction. Although improvement in LV function is expected in many AMI patients post revascularisation,[24] not all patients improve without further therapies or intervention and a further subset of patients may even go on to undergo adverse remodeling. These patients are widely accepted to have increased risk of worse outcome.[25-27] In the current study, only 44% of patients with LVEF <50% showed significant reverse remodeling at follow-up. Therefore it is important to identify patients with persistent increased risk at an earlier stage so that appropriate pharmacological, interventional and/or device strategies can be instigated in a targeted effort to reduce this risk.

Limitations

Inadequate image quality and/or associated unreliable speckle tracking curves led to the exclusion of 30% of otherwise eligible patients. Thus, the current consensus that additional data from multicenter settings is required before LV twist and other deformation parameters are ready for routine clinical use is also true for this potential novel application.[16] However, we find it reassuring at this current stage in the evolution of 2D speckle-tracking-derived rotational mechanics that our numbers for DSE-based LV twist measurements (representing a requirement for 3-stage optimal images per patient) are within published limits of the feasibility of one-stage LV twist measurements.[28] High frame rates required for accurate speckle tracking on DSE may have influenced accuracy of the current study by underestimating peak-dose LV twist values. However, the current study frame rates allowed reconstruction of obtained LV rotation data at low- and peak-dose stress into twist waveforms highly similar to published 'rest' standards.[29] Furthermore, by focusing on the pattern of individual response of LV twist to pharmacological stress and/or the increment in LV twist between stages, the impact of potential subtle inaccuracies by underestimating peak stress LV twist values was expected to be minimal. Additionally, definitive conclusions about baseline differences between the LV remodeling or no LV remodeling subgroups could not be drawn due to the limited number of patients in this study; this is particularly relevant for age and gender variables which are known to influence LV twist. However, on multivariate

analysis, whether in the overall population or according to LVEF < or ≥50%, Δ twist was independently related to follow-up LV reverse remodeling. Larger patient studies including a broader group of patients (including more females and those with positive DSE studies with or without previous AMI) are needed to confirm our findings. Finally, longer-term follow-up including harder clinical endpoints would also be desirable to strengthen our study.

Conclusion

LV twist measurement on full-protocol DSE is feasible and displays a significant increase from rest to peak-dose in the majority of patients post-AMI. Both the pattern of progressive LV twist increase throughout DSE and the stress-induced increment in LV twist from rest to peak-dose were significantly associated with LV reverse remodeling at follow-up. Our findings suggest a novel, clinical use for LV twist as a marker of LV inotropic contractile reserve in post-AMI patients.

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