Myocardial Infarction

Association Between Left Ventricular Global Longitudinal Strain and Adverse Left Ventricular Dilatation After ST-Segment–Elevation Myocardial Infarction

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Background—Myocardial infarct size is a major determinant of left ventricular (LV) remodeling after ST-segment–elevation myocardial infarction. We evaluated whether LV global longitudinal strain (GLS), proposed as a novel marker of infarct size, is associated with 3- and 6-month LV dilatation after ST-segment–elevation myocardial infarction.

Methods and Results—In the first ST-segment–elevation myocardial infarction patients treated with primary percutaneous coronary intervention, baseline LVGLS was measured with 2-dimensional speckle-tracking echocardiography. Patients were dichotomized according to median value. The independent relationship between GLS groups and LV end-diastolic volume at 3 and 6 months (adjusted for clinical and echocardiographic variables) was assessed. The final study population comprised 1041 patients (60±12 years; 76% men). Median LVGLS was −15.0%. Patients with baseline LVGLS >−15.0% exhibited greater LV dilatation at 3 and 6 months compared with patients with GLS ≤−15.0% (LV end-diastolic volume 123±44 versus 106±36 mL and 121±43 versus 102±34 mL, respectively; global group–time interaction P<0.001). This association retained the same statistical significance after adjustment for various relevant demographic, clinical, and echocardiographic characteristics. Further, net reclassification improvement index demonstrated significant incremental value of LVGLS for prediction of LV end-diastolic volume increase (0.14 [95% confidence interval, 0.00034–0.29]; P=0.04).

Conclusions—LVGLS before discharge after ST-segment–elevation myocardial infarction is independently associated with LV dilatation at follow-up. (Circ Cardiovasc Imaging. 2014;7:74-81.)

Key Words: echocardiography ■ myocardial infarction ■ ventricular remodeling

Myocardial infarct size is a major determinant of subsequent left ventricular (LV) remodeling and dysfunction, both strong predictors of poor outcomes after ST-segment–elevation myocardial infarction (STEMI).1–3 Assessment of infarct size can be achieved by several methods, including quantification of cardiac biomarkers, 2-dimensional (2D) echocardiographic estimation of LV ejection fraction (EF) and wall motion score index (WMSI), and contrast-enhanced magnetic resonance imaging. Although measurement of creatinine kinase or troponin T levels is widely available, their accuracy to predict LV remodeling is modest.4,5 Alternatively, contrast-enhanced magnetic resonance imaging can accurately quantify the extent of myocardial scarring after myocardial infarction and has become the new gold standard for infarct size assessment in many randomized clinical trials. However, this imaging technique is not available at the bedside and may not be feasible in some patients. In contrast, echocardiography is widely available in the acute setting and thus has become the imaging technique of first choice for risk stratification after myocardial infarction. LVEF and WMSI measured early after STEMI are valid surrogates of infarct size and have become established predictors of LV remodeling and clinical outcome.6,7 However, several limitations exist in the quantification of these parameters by 2D echocardiography, including the assumption of symmetrical LV geometry, intraobserver and interobserver variability, and, in the case of WMSI, the requirement for expert observers.

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Novel echocardiographic imaging techniques such as speckle-tracking strain imaging provide information on myocardial tissue function, which is incremental to LVEF and WMSI to predict LV functional recovery and clinical outcome after STEMI.7,8 LV global longitudinal strain (GLS)
measurement after STEMI has also demonstrated specific benefit compared with LVEF in evaluation of the extent of post-STEMI LV myocardial injury. However, despite being proposed as a novel marker of infarct size, few studies have specifically investigated the relationship between baseline LVGLS and LV remodeling in the contemporary post-STEMI population. The aim of the current evaluation was to investigate whether LVGLS measurement before discharge predicts LV dilatation at 3 and 6 months after infarction in a large contemporary STEMI population.

**Methods**

**Patient Population**

Patients admitted with a first STEMI treated with primary percutaneous coronary intervention from February 2004 to December 2008 were included in this analysis. All patients were treated according to the institutional MISSION! protocol based on its motion and systolic thickening (1=normokinesis, 2=hyperkinesis, 3=akinesis, 4=dyskinesis), and WMSI was calculated as the sum of the segment scores divided by the number of segments scored. Severity of mitral regurgitation was graded according to current recommendations. Diastolic function was assessed according to standard recommendations. Left atrial volume was evaluated with the biplane Simpson technique and indexed to body surface area.

**GLS Analysis**

LVGLS was quantified from the apical 4-, 2-, and 3-chamber views stored as digital cine-loops and processed offline using commercially available speckle-tracking analysis software (EchoPac 112.0.1, GE Medical Systems; Horten, Norway). Images were recorded with frame rates of >40 frames per second to ensure reliable analysis by the software. The end-systolic frame was defined in the apical long-axis view by marking the closure of the aortic valve. After this, the LV endocardial border was traced at end systole in all 3 apical views, and the automatically created region of interest was manually adjusted to the thickness of the myocardium. Tracking quality was assessed in all segments, and if tracking was of poor quality, segments were discarded. LVGLS was provided by the software as the average value of the peak systolic longitudinal strain of the 3 apical views, using a 17-segment model, in a bull’s-eye plot (Figure 1). As previously reported, the intraobserver and interobserver variability for the measurement of LVGLS in our institution was 1.4±2.2% and 0.2±0.8%, respectively.

**Statistical Analysis**

Continuous, normally distributed variables are presented as mean and standard deviation or standard error, as appropriate. Non-normally distributed data are presented as median and interquartile range. Categorical variables are presented as frequencies and percentages. The total population was divided into 2 groups based on the median value of LVGLS. Continuous variables were compared between the 2 groups using the Student t test, Mann–Whitney U test, or χ2 test, as appropriate.

The primary modeling approach was linear mixed-effects model analysis, with LVEDV as the dependent variable and time (0, 3, and 6 months) as the principal fixed effect. The ability to predict change in LVEDV over time. The effect of baseline LVGLS on change in LVEDV was also adjusted for these parameters.

In addition, to evaluate the incremental value of LVGLS compared with clinical and conventional echocardiographic variables in predicting LVEF, reclassification improvement index were performed.41 Net reclassification improvement was used to evaluate the incremental value of baseline LVGLS in reclassifying the risk of individuals developing ≥20% increase in LVEDV 6-months after STEMI. To assess robustness of our initial model, sensitivity analysis was performed, excluding those patients who had died and those who did not have either 3- or 6-month or both echocardiographic data sets available for the initial analysis.

**Results**

**Baseline Characteristics**

Of the 1245 patients initially evaluated, 102 (8%) were excluded because of previous myocardial infarction. Twenty-two (2%) patients died during index hospitalization. An additional 30 patients were excluded because of cardiogenic shock (n=10; 1%) or atrial fibrillation at the time of baseline echocardiography. LVGLS measurement after STEMI was associated with subsequent change in LVEDV, it was modeled in an interaction term with time. If this group–time interaction term was significant, it indicated a time-dependent relationship between baseline LVGLS and LVEDV. Post hoc testing was then performed to determine the time points at which LVEDV differed between the LVGLS groups. Other important and potentially confounding baseline clinical and echocardiographic predictors known to influence outcome and LV systolic function after STEMI were similarly tested for their ability to predict change in LVEDV over time. The effect of baseline LVGLS on change in LVEDV was also adjusted for these parameters.

In addition, to evaluate the incremental value of LVGLS compared with clinical and conventional echocardiographic variables in predicting LVEF, reclassification improvement index were performed.41 Net reclassification improvement was used to evaluate the incremental value of baseline LVGLS in reclassifying the risk of individuals developing ≥20% increase in LVEDV 6-months after STEMI. All statistical tests were 2-sided, and a value of P <0.05 was considered statistically significant. Statistical analysis was performed using STATA version 11 (STATA Corp; College Station, TX). The authors had full access to the data and take responsibility for its integrity. All authors have read and agreed to the article as written.
summarizes the baseline characteristics of the patient population (mean age, 60±12 years; 76% men).

**Baseline LVGLS**

Median LVGLS was −15.0% (interquartile range, −12.1% to −18.0%) for the total population. Baseline characteristics according to LVGLS >−15.0% (n=520) and ≤−15.0% (n=521) are shown in Table 1. Patients with LVGLS >−15.0% more frequently had diabetes mellitus, the left anterior descending artery as the culprit vessel, multivessel disease, and higher cardiac biomarker concentrations compared with patients with LVGLS ≤−15.0%. On echocardiography, patients with LVGLS >−15.0% had significantly larger LV volumes and WMSI and lower LVEF compared with their counterparts. Regarding diastolic parameters, E/E′ ratio was significantly higher, and E/A ratio, deceleration time, and E′ were significantly lower in patients with LVGLS >−15.0%. Presence of grade ≥2 mitral regurgitation or left atrial volume index did not differ significantly between the 2 groups.

**Follow-Up**

Across the total patient population, LVEDV increased significantly between baseline and 3- and 6-month follow-up (from 103±34 to 115±41 and to 112±40 mL, respectively; P<0.001), whereas LV end-systolic volume did not change significantly overall (from 55±22 to 57±29 and to 54±29 mL, respectively; P=0.21). In addition, the number of patients showing grade ≥2 mitral regurgitation over length of follow-up also increased significantly (from 6.0% to 7.9% and to 7.7%, respectively; P=0.006).

**Predictors of Change in LVEDV From Baseline to Follow-Up**

Table 2 details the results of linear mixed model analyses. Higher WMSI was significantly associated with LV remodeling, as were male sex, left anterior descending artery infarct compared with non–left anterior descending artery, higher discharge heart rate and peak troponin concentration, and lower LAVI at baseline. Regarding LVGLS, although baseline LVEDV was
higher in patients with baseline LVGLS $\geq$−15.0% compared with $\leq$−15.0%, this difference was nonsignificant after adjustment for other relevant baseline clinical characteristics (P=0.1). In addition, patients with baseline LVGLS $\geq$−15.0% exhibited greater LV dilatation at 3 and 6 months (LVEDV 124±44 versus 106±36 mL; $P<0.001$ and 121±43 versus 102±34 mL; $P<0.001$, respectively; group–time interaction term P<0.001) compared with their counterparts. This association between LVGLS and increased LV dilatation retained the same statistical significance after adjustment for all parameters significantly different between GLS groups, in addition to other parameters considered clinically significant (Figure 2).

On likelihood ratio test, LVGLS (according to median) provided significant incremental value for the prediction of

<table>
<thead>
<tr>
<th>Table 1. Baseline Characteristics of the Patient Population</th>
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<tr>
<td></td>
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<tr>
<td>Total Patient Population (n=1041)</td>
</tr>
<tr>
<td>LVGLS $\geq$−15.0% (n=520)</td>
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<tr>
<td>LVGLS $\leq$−15.0% (n=521)</td>
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<tr>
<td>$P$ Value*</td>
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<td></td>
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<tr>
<td><strong>Clinical</strong></td>
</tr>
<tr>
<td>Age, y</td>
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<tr>
<td>Male sex, n (%)</td>
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<tr>
<td>Current or previous smoking, n (%)</td>
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<tr>
<td>Diabetes mellitus, n (%)</td>
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<tr>
<td>Family history of coronary artery disease, n (%)</td>
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<tr>
<td>Hyperlipidemia, n (%)</td>
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<tr>
<td>Hypertension, n (%)</td>
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<tr>
<td>Killip class ≥2, n (%)</td>
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<tr>
<td>Glucose level, mmol/L</td>
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<tr>
<td>Estimated glomerular filtration rate, mL/min per 1.73 m²</td>
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<tr>
<td>Left anterior descending coronary artery as culprit vessel</td>
</tr>
</tbody>
</table>

**Multivessel disease, n (%)** | 487 (47) | 259 (50) | 228 (44) | 0.04  |

**Peak creatinine phosphokinase, U/L** | 1612 (771–3164) | 2363 (1286–4080) | 1124 (536–2075) | <0.001 |

**Peak troponin T level, μg/L** | 4.3 (1.8–8.2) | 6.4 (2.1–11) | 2.9 (1.1–5.7) | <0.001 |

**Symptom-to-balloon onset, min** | 173 (126–259) | 181 (132–277) | 165 (120–244) | 0.06  |

**Time from reperfusion to echocardiography, h** | 24 (24–48) | 24 (24–48) | 24 (24–48) | ...   |

**Discharge heart rate, bpm** | 70±12 | 72±12 | 67±11 | <0.001 |

**Discharge systolic blood pressure, mmHg** | 114±17 | 114±16 | 115±17 | 0.39  |

**Discharge diastolic blood pressure, mmHg** | 69±11 | 70±11 | 69±11 | 0.50  |

**Antiplatelets (≥1)** | 1041 (100%) | 520 (100%) | 521 (100%) | ...   |

**Lipid-activating receptor blocker inhibitor** | 1016 (98%) | 504 (97%) | 512 (98%) | 0.21  |

**β-Blockers** | 984 (95%) | 491 (95%) | 493 (95%) | 0.99  |

**Statins** | 1033 (99%) | 516 (99%) | 517 (99%) | 0.61  |

**Echocardiography**

**LV end-systolic volume, mL** | 55±22 | 61±23 | 48±18 | <0.001 |

**LVEDV, mL** | 103±34 | 108±36 | 98±31 | <0.001 |

**LVEF, %** | 47±9 | 44±9 | 51±8 | <0.001 |

**WMSI** | 1.4 (1.3–1.7) | 1.6 (1.4–1.8) | 1.3 (1.2–1.5) | <0.001 |

**Mitral regurgitation grade ≥2** | 61 (6%) | 31 (6%) | 30 (6%) | 0.89  |

**Moderate–severe aortic valve disease** | 23 (2.2%) | 14 (2.7%) | 9 (1.7%) | 0.29  |

**Left atrial volume index, mL/m²** | 20±8 | 20±8 | 20±8 | 0.26  |

**E/A** | 0.90 (0.73–1.1) | 0.84 (0.66–1.1) | 0.97 (0.79–1.2) | <0.001 |

**Deceleration time, ms** | 212 (167–263) | 199 (159–246) | 221 (177–274) | 0.001 |

**E′, cm/s** | 5.4 (4.2–6.8) | 4.8 (3.5–6.2) | 6.1 (4.9–7.4) | <0.001 |

**E/E′ ratio** | 12 (10–15) | 13 (10–17) | 11 (9–14) | <0.001 |

**LVGLS, %** | −15±4.2 | −11.6±2.4 | −18±2.5 | <0.001 |

Continuous data are presented as mean±SD or median and interquartile range. GLS indicates global longitudinal strain; LV, left ventricular; LVEF, left ventricular ejection fraction; LVEDV, left ventricular end-diastolic volume; and WMSI, wall motion score index.

*P values are given for the difference in baseline characteristics between LVGLS $\geq$−15.0% and LVGLS $\leq$−15.0% groups.
follow-up LV dilatation to a model containing all other significant clinical and echocardiographic predictors of LV remodeling (male sex, left anterior descending artery infarct, peak troponin concentration, discharge heart rate, left atrial volume index, and WMSI; log-likelihood difference of 17.8, \( P < 0.001 \) for measuring LVGLS in addition to clinical predictors, left atrial volume index and WMSI compared with clinical predictors, left atrial volume index and WMSI alone). In addition, net reclassification improvement index demonstrated significant incremental value of LVGLS to predict ≥20% increase in LVEDV over and above multiple covariates, including age, sex, diabetes mellitus, infarct territory, multivessel disease, Killip class, peak creatinine kinase and troponin concentrations, glucose concentration, symptom-to-balloon time, mitral regurgitation severity, discharge heart rate, and neurohormonal therapy prescription at discharge (net reclassification improvement, 0.14 [95% confidence interval, 0.00034–0.29]; \( P = 0.04 \)).

Finally, the analysis was performed after excluding patients who did not have both echocardiographic data sets available for the initial analysis (n=144). In the remaining large subgroup (n=897), the adjusted group–time interaction term \( P \) value for this sensitivity analysis remained <0.001.

### Discussion

The present observational study shows that in the acute phase after STEMI, stratifying patients according to median LVGLS (−15.0%) delineates a group of patients more likely to show increased LV dilatation at follow-up. LVGLS >−15.0% was independently associated with significantly larger LV volumes during both 3- and 6-month follow-up. In addition, baseline LVGLS provided incremental value to a model containing peak troponin concentration and WMSI to predict LVEDV increase after STEMI.

### LVGLS as a Marker of Infarct Size

Speckle-tracking–derived LVGLS is a novel parameter of LV function, which more closely reflects intrinsic myocardial function than traditional parameters by evaluating the active component of deformation.22 Further, speckle-tracking–derived LVGLS is independent of geometric assumptions and insonation angle and has relatively low intraobserver and interobserver variability.22 Because of these inherent

### Table 2. Predictors of Change in LVEDV From Baseline to Follow-Up

<table>
<thead>
<tr>
<th>Covariate</th>
<th>Coefficient</th>
<th>(95% Confidence Interval)</th>
<th>( P ) Value*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age, y</td>
<td>0.03</td>
<td>(−0.14 to 0.20)</td>
<td>0.72</td>
</tr>
<tr>
<td>3-mo LVEDV</td>
<td>4.0</td>
<td>(0.17 to 7.9)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>6-mo LVEDV</td>
<td>9.0</td>
<td>(5.1 to 13)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Diabetes mellitus</td>
<td>3.8</td>
<td>(−2.8 to 10)</td>
<td>0.29</td>
</tr>
<tr>
<td>3-mo LVEDV</td>
<td>5.1</td>
<td>(−1.6 to 12)</td>
<td>0.05</td>
</tr>
<tr>
<td>6-mo LVEDV</td>
<td>5.4</td>
<td>(0.86 to 10)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Male sex</td>
<td>1.3</td>
<td>(−3.3 to 5.8)</td>
<td>&lt;0.001</td>
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<tr>
<td>3-mo LVEDV</td>
<td>1.3</td>
<td>(−3.3 to 5.8)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>6-mo LVEDV</td>
<td>5.4</td>
<td>(0.86 to 10)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Multivessel disease</td>
<td>1.9</td>
<td>(−2.0 to 5.8)</td>
<td>0.63</td>
</tr>
<tr>
<td>3-mo LVEDV</td>
<td>1.9</td>
<td>(−2.0 to 5.8)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>6-mo LVEDV</td>
<td>0.53</td>
<td>(−3.4 to 4.4)</td>
<td>&lt;0.001</td>
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<tr>
<td>Discharge heart rate, bpm</td>
<td>0.03</td>
<td>(−0.14 to 0.18)</td>
<td>&lt;0.001</td>
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<tr>
<td>3-mo LVEDV</td>
<td>0.02</td>
<td>(−0.14 to 0.18)</td>
<td>&lt;0.001</td>
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<tr>
<td>6-mo LVEDV</td>
<td>0.41</td>
<td>(0.25 to 0.57)</td>
<td>&lt;0.001</td>
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<td>Peak troponin T concentration, μg/L</td>
<td>1.6</td>
<td>(1.3 to 2.0)</td>
<td>&lt;0.001</td>
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<tr>
<td>3-mo LVEDV</td>
<td>1.6</td>
<td>(1.3 to 2.0)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>6-mo LVEDV</td>
<td>1.6</td>
<td>(1.3 to 1.9)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Killip class ≥2</td>
<td>0.34</td>
<td>(−10 to 9.8)</td>
<td>0.44</td>
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<tr>
<td>3-mo LVEDV</td>
<td>−0.34</td>
<td>(−10 to 9.8)</td>
<td>&lt;0.001</td>
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<tr>
<td>6-mo LVEDV</td>
<td>5.9</td>
<td>(−4.6 to 16)</td>
<td>&lt;0.001</td>
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<tr>
<td>Time from reperfusion to echocardiography, h</td>
<td>−0.8024</td>
<td>(−0.0035 to 0.0030)</td>
<td>&lt;0.001</td>
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<tr>
<td>3-mo LVEDV</td>
<td>−0.0024</td>
<td>(−0.0035 to 0.0030)</td>
<td>&lt;0.001</td>
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<tr>
<td>6-mo LVEDV</td>
<td>0.0019</td>
<td>(−0.0014 to 0.0052)</td>
<td>&lt;0.001</td>
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</table>

### Table 2. Continued

<table>
<thead>
<tr>
<th>Covariate</th>
<th>Coefficient</th>
<th>(95% Confidence Interval)</th>
<th>( P ) Value*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Left atrial volume index</td>
<td>−0.35</td>
<td>(−0.59 to −0.12)</td>
<td>&lt;0.001</td>
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<tr>
<td>3-mo LVEDV</td>
<td>−0.35</td>
<td>(−0.59 to −0.12)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>6-mo LVEDV</td>
<td>−0.43</td>
<td>(−0.66 to −0.19)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>LVGLS &gt;−15.0% vs ≤−15.0%</td>
<td>6.7</td>
<td>(2.8 to 11)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>3-mo LVEDV</td>
<td>6.7</td>
<td>(2.8 to 11)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>6-mo LVEDV</td>
<td>10.3</td>
<td>(6.3 to 14)</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>

GLS indicates global longitudinal strain; LV, left ventricular; LVEDV, left ventricular end-diastolic volume; and WMSI, wall motion score index.

*\( p \) values represent the covariate–time interaction term; if significant (\( P < 0.05 \)), it indicates a time-dependent relationship between LVEDV and the particular covariate.
advantages compared with other echocardiographic modalities, several recent studies have investigated the role of LVGLS measurement as a marker of infarct size, whether measured in the acute phase after revascularization or at follow-up. A cutoff for LVGLS of −15% measured after reperfusion served as a more precise predictor of large infarction than LVEF in 39 thrombolysis-treated patients with STEMI. In a larger group of primary percutaneous coronary intervention-treated patients, LVGLS measured at day 1 was also superior to LVEF in predicting 30-day infarct size. In our large population of contemporary STEMI patients treated with primary percutaneous coronary intervention, a postrevascularization LVGLS value >−15.0% was significantly associated with clinical characteristics traditionally indicative of larger infarct size (diabetes mellitus, multivessel disease, and higher biomarker levels). In addition, these patients had significantly more impaired global and regional systolic and diastolic function parameters (including LVEF, WMSI, and E') compared with the group of patients with more preserved myocardial shortening (LVGLS ≤−15.0%).

LVGLS and LV Remodeling

Despite the demonstrated role of LVGLS in accurately identifying the extent of global myocardial injury and dysfunction after infarction, few studies in the contemporary era have specifically related LVGLS measurement in the acute phase after STEMI to the risk of LV remodeling at follow-up. A substudy of the Valsartan in Acute Myocardial Infarction Trial (VALIANT) study, including 603 post-STEMI patients with LV dysfunction, demonstrated no significant association between myocardial longitudinal strain rate and LV remodeling. However, those patients were enrolled before the systematic use of primary percutaneous coronary intervention and other current guideline-based antiremodeling therapies. Studies involving modern era patients with STEMI, which have demonstrated an association between LVGLS and LV remodeling, are limited by small numbers, variable LV remodeling definitions, and shorter follow-up periods. The current evaluation considerably expands on previous studies by relating baseline LVGLS measurement in a large cohort of contemporary STEMI patients to accepted echocardiographic outcomes on systematic 3- and 6-month follow-up. Patients with LVGLS >−15% were significantly more likely to display pathological LV dilatation at both 3 and 6 months after STEMI. This relationship remained significant even after adjusting for multiple clinical parameters known to influence post-STEMI outcome. Importantly, repeating the analysis per quartile of GLS (Data Supplement) showed a stepwise relationship between less negative (more impaired) GLS and progressive LV dilatation, with the greatest and most significant increase in LVEDV at both 3 and 6 months occurring in those patients in the highest quartile of GLS (≥−12.1%). The finding that LVGLS measurement before discharge can identify patients at increased risk of LV dilatation is particularly relevant, given that it can be quantified at rest and without need for pharmacological stressors, expensive contrast media, or exposure to ionizing radiation.

LVGLS Versus WMSI in Risk Stratification After STEMI

Previous studies have consistently shown that WMSI evaluation is superior to LVEF for early risk assessment after STEMI. WMSI and LVGLS were recently shown to accurately identify substantial infarction in non-STEMI patients before revascularization. However, segmental motion, and thus WMSI, unlike LVGLS, may be influenced by tethering of scar tissue by adjacent viable myocardium. In the current study, we confirmed an advantage of LVGLS compared with WMSI for early risk stratification after STEMI. Although baseline WMSI was independently associated with LV remodeling at 3- and 6-month follow-up, the addition of LVGLS to a model containing WMSI provided incremental value for prediction of LVEDV increase. Although the absolute differences in LVEDV at follow-up seem small, LVGLS was both incremental to WMSI and significantly reclassified additional patients over and above traditional post-STEMI risk parameters. Given these findings and the fact that LVGLS provides a semiautomated, quantitative measure of LV systolic function, its future use for risk stratification in all patients with STEMI is highly foreseeable.

Limitations

This was a retrospective evaluation. However, it reports prospectively collected real-world data on a large cohort of modern-era patients with STEMI treated optimally according to a dedicated, guideline-based protocol. Patients in cardiogenic shock requiring supportive therapy were not included in this study; therefore, these findings may not apply to this important patient group. However, these patients represent a high-risk group, and additional strategies for risk stratification are less clinically relevant. In addition, echocardiography was performed within 48 hours after STEMI in all patients; the dynamic nature of LV function recovery after STEMI may lead to an underestimation of the systolic function during this time period. However, in the final adjusted model, time from reperfusion to baseline echocardiography did not have a significant effect on the

![Figure 2. Left ventricular (LV) global longitudinal strain (GLS) stratified according to median value (−15.0%) and related to the change in LV end-diastolic volume (EDV) during 3- and 6-month follow-up, adjusted for multiple other relevant post-STEMI parameters. Patients with LVGLS >−15.0% (represented by the green bars) showed a significantly higher increase in LVEDV at 3 and 6 months compared with those with LVGLS ≤−15.0% (represented by blue bars; P<0.001). ¶Adjusted P value. Data are presented as mean±standard error. CI indicates confidence interval; and STEMI, ST-segment-elevation myocardial infarction.](http://circimaging.ahajournals.org/doi/abs/10.1161/CIRCIMAGING.117.007281?journalCode=circi)
relationship between baseline LVGLS and follow-up LV dilatation. Two-dimensional Simpson biplane method to assess LVEDV may be less accurate in the presence of foreshortening or irregular LV geometry and is associated with a high variability. However, the prognostic value of LVEDV using this method of assessment has been proven, and it remains the currently recommended method to assess LV systolic function on 2D echocardiography. Changes in heart rate during follow-up and their association with LV dilatation were not assessed. However, the aim of the current study was to assess the effect of LVGLS measured in the acute phase after STEMI on follow-up LV dilatation compared with other baseline characteristics (including discharge heart rate) known to influence later risk of remodeling. In addition, changes in medication at follow-up were not systematically recorded. However, it is known from a systematic overview of angiotensin-converting enzyme inhibition in patients with STEMI that most of the survival benefit is observed in the first week. Intraobserver and interobserver variability measurements were not performed as part of the current study protocol. However, our laboratory performs LVGLS measurements in a standardized manner. The reproducibility measurements for GLS from our laboratory were recently reported in a similar patient cohort to the current study population. Finally, contrast-enhanced magnetic resonance imaging would have been desirable to strengthen our observations on LVGLS and its relation to infarct size and subsequent LV remodeling. However, LVGLS provided significant incremental value to other established parameters of infarct size, including peak troponin concentration and WMSI, for the prediction of LV dilatation at follow-up.

Conclusions
Stratifying patients with STEMI according to median value of LVGLS on baseline echocardiography may serve as an additional marker of infarct size. Further, LVGLS before discharge after STEMI was an independent predictor of LV dilatation at both 3- and 6-month follow-up. This large contemporary registry study confirms the benefit of this quick, inexpensive, and widely available tool for risk stratification after STEMI.

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Disclosures
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**CLINICAL PERSPECTIVE**

In this study, left ventricular (LV) global longitudinal strain (GLS) derived from 2-dimensional speckle-tracking echocardiography was measured in 1041 contemporary treated ST-segment–elevation myocardial infarction (STEMI) patients before discharge and related to the occurrence of LV dilatation at systematic 3- and 6-month follow-up. In the acute phase after STEMI, stratification of patients according to median LVGLS (−15.0%) delineated a group of patients more likely to show increased LV dilatation at follow-up. LVGLS >−15.0% was independently associated with significantly larger LV volumes during both 3- and 6-month follow-up compared with patients with LVGLS ≤−15.0%. Importantly, LVGLS also provided incremental value to traditional parameters for assessment of infarct size, including wall motion score index and peak troponin level, for prediction of LV enlargement after STEMI. Although the absolute differences in LV end-diastolic volume at follow-up seem small, LVGLS was both incremental to WMSI and significantly reclassified additional patients over and above known clinical and echocardiographic post-STEMI risk parameters. The finding that LVGLS measurement before discharge can identify patients at increased risk of LV dilatation is particularly relevant, given that it provides a semiautomated, quantitative measure of LV systolic function quantifiable at rest and without need for expert observers, pharmacological stressors, expensive contrast media, or exposure to ionizing radiation. This quick, inexpensive, and widely available tool may thus become a valuable tool for risk stratification after STEMI.
Association Between Left Ventricular Global Longitudinal Strain and Adverse Left Ventricular Dilatation After ST-Segment–Elevation Myocardial Infarction
Emer Joyce, Georgette E. Hoogslag, Darryl P. Leong, Philippe Debonnaire, Spyridon Katsanos, Helèn Boden, Martin J. Schalij, Nina Ajmone Marsan, Jeroen J. Bax and Victoria Delgado

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SUPPLEMENTAL MATERIAL
Supplemental Methods

Per Quartile Analysis

A per quartile analysis was performed which demonstrates similar findings to our previous analysis in which baseline GLS was dichotomized by its median. Patients were divided into 4 groups according to LV GLS quartile: quartile 1: LV GLS <-18%, quartile 2: LV GLS between -18% and -15%, quartile 3: LV GLS between -14.9% and -12.1% and quartile 4: LV GLS >-12.1%. The unadjusted association between baseline GLS by quartile and change in left ventricular end-diastolic volume (LVEDV) is illustrated in the figure below. A stepwise relationship between less negative GLS (more impaired) and greater LV dilatation is illustrated (ie for each quartile worsening in baseline LV GLS, there is progressive LV dilatation). The per quartile analysis was repeated with adjustment for all the covariates used in the dichotomized model - age, gender, diabetes, infarct location, multivessel disease, Killip class, discharge heart rate, beta-blocker or angiotensin converting enzyme-inhibitor/angiotensin receptor blocker use, mitral regurgitation severity, peak creatine kinase and troponin concentrations, symptom-to-balloon time, baseline blood glucose concentration, baseline LV end-systolic volume, LV ejection fraction, wall motion score index, E/A ratio and deceleration time, E/E’ ratio and baseline left atrial volume index. The results remained the same as for the analysis performed using median GLS to dichotomize patients. The specific adjusted coefficients and associated 95% confidence intervals per GLS quartile and p-values shown in the table below. Analysis of the quartile-time interaction demonstrates a particularly marked difference in LV remodeling between the highest and lowest quartiles of GLS (quartile 4 vs. 1: 8.5 ml increase in LVEDV, 95% CI 2.7 to 14mls; p=0.004 at 3 months and 15 ml increase in LVEDV, 95% CI 8.8 to 20mls, p<0.001 at 6 months).
<table>
<thead>
<tr>
<th>Time</th>
<th>Baseline GLS quartile*</th>
<th>Coefficient (95% CI)**</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>3 months</td>
<td>2</td>
<td>-3.2 (-8.9 to 2.5)</td>
<td>0.3</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>0.85 (-4.9 to 6.6)</td>
<td>0.8</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>8.5 (2.7 to 14)</td>
<td>0.004</td>
</tr>
<tr>
<td>6 months</td>
<td>2</td>
<td>0.93 (-4.8 to 6.6)</td>
<td>0.8</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>5.3 (-0.42 to 11)</td>
<td>0.07</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>15 (8.8 to 20)</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>

* the reference group is first quarter of GLS. ** adjusted by age, gender, diabetes, infarct location, multi-vessel disease, Killip class, discharge heart rate, beta-blocker or angiotensin converting enzyme-inhibitor/angiotensin receptor blocker use, mitral regurgitation severity, peak creatine kinase and troponin concentrations, symptom-to-balloon time, baseline blood glucose concentration, baseline LV end-systolic volume, LV ejection fraction, wall motion score index, E/A ratio and deceleration time, E/E’ ratio and baseline left atrial volume index.

Supplemental Figures
Figure 1. Patient population

- Total Number of Patients meeting initial inclusion criteria
  N=1091

- LV GLS measurement possible at baseline
  N=1008

- Inadequate image quality & too low frame rate
  N=23

- Reinfarction prior to 6 month follow-up
  N=27

- Final Population for Analysis
  N=1041

- 3 month TTE N=932
  Death prior to TTE: N=5
  No TTE: N=104

- Missing TTE data at 3 months: N=109 (10%)

- 6 month TTE N=932
  Death prior to TTE: N=6
  No TTE: N=101

- Missing TTE data at 6 months: N=109 (10%)