Global longitudinal strain in acute myocardial infarction and incidence of in-hospital heart failure.

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Global Longitudinal Strain in Acute Myocardial Infarction and Incidence of In-hospital Heart Failure

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Abstract

Background: Myocardial strain is a good prognostic factor independent of ejection fraction for outcomes in heart failure. We evaluated the prognostic role of global longitudinal strain in acute myocardial infarction to identify the likelihood of in-hospital heart failure.

Methods: Forty participants with acute myocardial infarction were included, ranked according to Killip class, and classified into 2 groups: patients complicated by in-hospital heart failure (Killip class II — IV) on admission or during hospital stay (n = 16) and patients with no clinical evidence of in-hospital heart failure (Killip class I) on admission or during hospital stay (n = 24). All participants underwent reperfusion by percutaneous intervention or fibrinolytic therapy followed by transthoracic echocardiography within 72 hours of admission.

Results: There were statistically significant differences between both groups regarding the global longitudinal strain, ejection fraction and the wall motion score index. In patients with mildly reduced ejection fraction, there was a statistically significant difference between both groups regarding the global longitudinal strain and statistically non-significant differences regarding the ejection fraction and wall motion score index. Global longitudinal strain was the only echocardiographic parameter with statistically significant difference between Killip class I and class II.

Conclusions: Global longitudinal strain was superior to ejection fraction and wall motion score index in detection of in-hospital heart failure in Killip class II and in evaluation of myocardial dysfunction in patients with mildly reduced ejection fraction. Global longitudinal strain could be considered as a part of the routine echocardiographic evaluation of acute myocardial infarction for detection of in-hospital heart failure and risk stratification of patients with acute myocardial infarction especially those with mildly reduced ejection fraction and those without overt heart failure (Killip class II).

Keywords: Acute myocardial infarction, Ejection fraction, Global longitudinal strain, In-hospital heart failure

Introduction

Patients with acute myocardial infarction (MI) complicated by in-hospital heart failure (HF) with significant myocardial injury have worse prognosis [1]. However, patients with minor myocardial injury complicated by in-hospital HF with mildly reduced and preserved ejection fraction (EF) have a significantly increased risk of adverse outcomes as well [2]. Longitudinal myocardial dysfunction has been reported in HF with preserved EF (HfPEF) [3]. The extent and magnitude of longitudinal myocardial dysfunction reflects the infarct size [4]. Global longitudinal strain (GLS) analysis by speckle tracking echocardiography is considered a sensitive parameter for assessment of left ventricular (LV) function and performance thus providing prognostic information on the likelihood...
of longitudinal myocardial dysfunction [5–7]. Antecedent research has shown that, compared to EF, GLS has better diagnostic accuracy of acute coronary syndrome [8–10], better inter- and intra-observer reproducibility [8,11,12], and equivalent feasibility [13] and processing time [8,13]. We wanted to evaluate the prognostic role of GLS in acute MI to identify the likelihood of in-hospital HF.

Methods

Study participants

Our cross-sectional study enrolled 40 patients, with acute MI from January 2015 to March 2016. The study protocol was approved by the ethics committee. Written informed consent was signed by each patient. We included patients above 18 years old with either ST-segment elevation MI (STEMI) or non-ST segment elevation MI (NSTEMI).

Exclusion criteria:

1. Refusal of participation in the study.
2. Patients with history or electrocardiographic (ECG) evidence of old MI.
3. Patients with previous coronary artery bypass graft surgery or percutaneous coronary intervention (PCI).
4. Patients with ventricular-paced rhythm or preexcitation syndrome.
5. Hemodynamically unstable patients.
6. Patients with poor echocardiographic acoustic window.
7. Patients with significant valvular, myocardial, or pericardial diseases not caused by MI.

Patients were classified into 2 groups, group 1; patients with in-hospital HF (Killip class > I) on admission or during hospital stay and group 2; patients with no in-hospital HF (Killip class I). On hospital admission, we subjected the patients to the following: complete history, full clinical examination with ranking by Killip class (from I–IV), 12 leads ECG, laboratory investigations including brain natriuretic peptide (BNP) and reperfusion by PCI or fibrinolytic therapy.

Successful reperfusion was confirmed in PCI by having TIMI (Thrombolysis in myocardial infarction) III flow score and in fibrinolytic therapy by resolution of chest pain and 50% or more decrease in ST segment elevation within 90 minutes from the beginning of the therapy.

Study procedures

Transcatheter echocardiography

Transcatheter echocardiography was performed within 72 hours of admission. Images were obtained using a commercially available system (GE vivid 7) with assessment of LV dimensions, diastolic function, and EF by modified Simpson’s method and M mode. According to the European Society of Cardiology guidelines on HF, patients are categorized into HF with reduced EF (HFrEF) with EF < 40%, HF with mildly reduced EF (HFmrEF) with EF between 40-49% and HF with preserved EF (HFpEF) with EF ≥ 50% [14]. Visual analysis of the contractile function of all the 17 segments was interpreted using a four-point wall motion score (WMS) as follows: (1) normal; (2) hypokinetic; (3) akinetic; or (4) dyskinetic. The Wall Motion Score Index (WMSI) was calculated by dividing the sum of the scores of the cardiac segments by the number of segments scored according to the American Society of Echocardiography [15].

Strain analysis

Assessment of longitudinal peak systolic strain (peak S) by speckle tracking in a 17 LV segment model, and global strain was obtained by averaging all 17 segments. The two-dimensional loops from the routine echocardiographic examination were processed offline. The software is dependent on high-resolution image quality and applied with harmonic imaging. The end-systolic frame was first defined in the apical long-axis (3-chamber) view, where the aortic valve is directly visible. Aortic valve closure time was marked. The R wave to aortic valve closure time was then measured by the software. Subsequently, the same R wave to aortic valve closure time distance was used as a reference on the other loops. The time distance was also checked against mitral valve opening, which is easily seen in any apical plane. This allowed accurate timing of systole, diastole and aortic valve closure on all views.

Within the end-systolic frames an estimation of the LV myocardium was traced in a click-to-point approach. Subsequently the software automatically defines an epicardial and midmyocardial line and processes all frames of the loop. Endocardial border was identified by edge detection, based on black-and-white transition recognition on a single frame. The myocardium was defined by empiric estimation of myocardial thickness and can then be further corrected by the operator. Motion was evaluated by
tracking speckles (natural acoustic markers) in the ultrasonic image in two dimensions. A bull’s eye diagram can then be created from the data obtained from all myocardial segments with interplanar values interpolated. The diagnostic information of each trace is contained in a parametric color, labeling qualitative and quantitative indices of myocardial wall motion. Global strain was achieved simply by measuring and averaging the strain in all segments of the ventricle.

**Statistical analysis**

Data were coded and entered using the statistical package for the social sciences (SPSS®) version 25. Data was summarized using mean and standard deviation for quantitative variables and frequencies (number of cases) and relative frequencies (percentages) for categorical variables. Comparisons between groups were done using unpaired t test for parametrically distributed continuous variables. For comparing non-parametrically distributed categorical data, Chi square ($\chi^2$) test was performed and Fisher’s Exact test was used instead when the expected frequency was low (more than 20% of the cells have expected count less than 5). Correlations between parametrically distributed quantitative variables were done using Pearson correlation coefficient. P-values less than 0.05 were considered as statistically significant.

**Results**

The study population was classified into 2 groups, group 1; patients with in-hospital HF (Killip class > I) on admission or during hospital stay and group 2; patients with no in-hospital HF (Killip class I). The mean age was 51.53 years, 85% of patients were males (34 patients) and 15% were females (6 patients). Diabetes was present in 52.5% (21 patients), 55% were hypertensives (22 patients), 62.5% (25 patients) were dyslipidemic, 75% (30 patients) were smokers and 45% (18 patients) had a positive family history. There were no statistically significant differences between the two groups regarding risk factors, sex, type of MI, diastolic dysfunction, and type of reperfusion.

**Killip Classification:** There were 24 patients with Killip class I (60%), 8 patients with Killip class II (20%), 3 patients with Killip class III (7.5%), and 5 patients with Killip class IV (12.5%). The number of patients with no in-hospital HF (Killip Class I) and EF$\geq$50%, EF between 40–49% and EF$<$40% were 7 (29.17%), 8 (33.33%) and 9 (37.5%) respectively. Level of BNP: BNP ranged from 214 to 1224 pg/ml with a mean value of 604.55 ± 285.8 pg/ml and showed a statistically significant difference between the two groups with a P value < 0.0001. ECG findings: The ECG of the studied patients showed STEMI in 75% of patients (24 anterior STEMI and 6 inferior STEMI) and NSTEMI in 25% of patients (10 patients). Reperfusion: 75% (30 patients) of patients underwent PCI including primary PCI for STEMI patients and early invasive strategy for NSTEMI patients, while only 25% (10 patients) had fibrinolytic therapy. Echocardiographic parameters: Mean LV end diastolic diameter (LVEDD) was 56.71 mm, mean LV end systolic diameter (LVESD) was 42.39 mm, mean EF by modified Simpson’s method was 39.71%. Mean WMSI was 1.41. There were statistically significant differences between group 1 (Killip class > I) vs group 2 (Killip class I) regarding GLS, LV dimensions, EF, and WMSI. Patients with in-hospital HF (group 1) had reduced (more positive in value) GLS ($-8.63% \pm 1.57%$ vs $-12.41% \pm 1.31%$, p < 0.001), higher LVEDD (59.72 ± 4.9 mm vs 54.71 ± 5.11 mm, p < 0.001), higher LVESD (46.94 ± 7.37 mm vs 39.36 ± 6.21 mm, p < 0.001), lower LVEF (34.17% ± 8.17% vs 42.92% ± 7.98%, p < 0.001) and higher WMSI (1.57 ± 0.32 vs 1.31 ± 0.24, p < 0.006). Two-dimensional strain: GLS was more reduced in group 1 (Killip class > I) than in group 2 (Killip class I) with statistically significant difference (p < 0.001) as shown in Table 1 and Figure 1.
The decrease in the EF was noted which means that the decrease in the EF was associated with more reduced (more positive in value) GLS. Another statistically significant moderate positive correlation was also observed between GLS and BNP level (p < 0.001, r = 0.643). GLS was more reduced, with the increase in the BNP level. There was a statistically significant weak positive correlation between GLS and WMSI (p = 0.022, r = 0.360). This showed that increase in the GLS was associated with increase in the WMSI.

In patients with mildly reduced EF (n = 11), there were statistically significant differences in the GLS and BNP, and non-significant differences in the EF and WMSI between patients with Killip class > I vs Killip class I, respectively. Patients with Killip class > I had more reduced (more positive in value) GLS (−9.27% ± 3.54% vs. −13% ± 2.7%, p = 0.034) and higher BNP (850.50 ± 280.69 pg/ml vs 403.07 ± 132.43 pg/ml, p < 0.001). There were no statistically significant differences in the EF (p = 0.068) or the WMSI (p = 0.082) as shown in Table 2.

GLS was also the only echocardiographic parameter that showed statistically significant difference between patients with Killip class I and patients with Killip class II (p = 0.003), while WMSI and EF showed no statistically significant difference as shown in Table 3. BNP also showed statistically significant difference between the two Killip classes (I and II) (p = 0.005).

### Discussion

Our study showed a statistically significant moderate positive correlation between GLS and BNP level, a statistically significant weak positive correlation between GLS and WMSI, and a statistically significant weak negative correlation between GLS and EF by modified Simpson’s method in patients with acute MI. These significant linear correlations were proven by other studies. In 2010, Mollema SA et al. reported a statistically significant moderate positive correlation between global LV strain and WMSI (P < 0.05, r = 0.52). A study by Shimon A et al., in 2004 also showed a statistically significant moderate positive correlation between WMSI and GLS (P < 0.0001, r = 0.68).

In our study, we found statistically significant differences between the Killip class II—IV group vs the Killip class I group regarding the GLS, the EF, and the WMSI. There was a statistically significant difference in the GLS, and non-significant differences in the EF and WMSI between patients with Killip class > I vs Killip class I, respectively. This means that GLS was superior to EF and WMSI in detecting in-hospital HF in patients with mildly reduced EF. BNP level was the only parameter superior to GLS in detecting in-hospital HF in patients with mildly reduced EF. However, the feasibility and availability of GLS, compared with BNP level, may add to its prognostic role in identifying adverse outcomes in this patient population. GLS was the only echocardiographic parameter with statistically significant difference between Killip class I vs Killip class II study participants. Being able to differentiate between Killip class I patients who have no clinical signs of heart failure and Killip class II patients who may develop rapid hemodynamic deterioration makes GLS a sensitive diagnostic adjunct in management of heart failure.

In 2012, Ersboll M et al. compared acute MI patients with in-hospital HF (Killip class II—IV) vs acute MI patients with no clinical evidence of in-hospital HF (Killip class I) and reported significantly lower GLS (−10.1 ± 3.5% vs. −14.6 ± 3.3%, p < 0.0001), significantly lower LVEF (43.2 ± 12.2% vs. 52.1 ± 9.8%, p < 0.0001), and significantly higher WMSI (1.75 ± 0.3 vs. 1.41 ± 0.27, p < 0.0001) in patients with in-hospital HF. These significant linear correlations were proven by other studies. In 2010, Mollema SA et al. reported a statistically significant moderate positive correlation between global LV strain and WMSI (P < 0.05, r = 0.52). A study by Shimon A et al., in 2004 also showed a statistically significant moderate positive correlation between WMSI and GLS (P < 0.0001, r = 0.68).

### Table 1. Two-dimensional strain in the two groups.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Killip class &gt; I</th>
<th>Killip class I</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>GLS</td>
<td>−8.63 ± 1.57</td>
<td>−12.41 ± 1.31</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>

GLS, global longitudinal strain.

### Table 2. Patients with mildly reduced EF in the two groups.

<table>
<thead>
<tr>
<th>Killip class &gt; I</th>
<th>Killip class I</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>GLS</td>
<td>−9.27%</td>
<td>3.54</td>
</tr>
<tr>
<td>EF</td>
<td>42.94%</td>
<td>7.98</td>
</tr>
<tr>
<td>WMSI</td>
<td>1.52</td>
<td>0.24</td>
</tr>
<tr>
<td>BNP (pg/mL)</td>
<td>850.50</td>
<td>280.69</td>
</tr>
</tbody>
</table>

### Table 3. Differentiation between Killip class I and II.

<table>
<thead>
<tr>
<th>Killip class I</th>
<th>Killip class II</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>GLS</td>
<td>−12.58%</td>
<td>2.79</td>
</tr>
<tr>
<td>EF</td>
<td>42.94%</td>
<td>7.98</td>
</tr>
<tr>
<td>WMSI</td>
<td>1.30</td>
<td>0.22</td>
</tr>
<tr>
<td>BNP (pg/mL)</td>
<td>461.04</td>
<td>181.87</td>
</tr>
</tbody>
</table>

GLS, global longitudinal strain; EF, ejection fraction; WMSI, wall motion score index; BNP, brain natriuretic peptide.

* EF was measured by modified Simpson’s method.
patients with in-hospital HF. In acute MI patients with LVEF of >40% (n = 464, 85% of total study population), 53 (11.2%) experienced in-hospital HF and exhibited significantly reduced GLS compared to 411 (88.8%) who did not experience in-hospital HF (−11.9 ± 2.9% vs. −15.1 ± 3.0%, p < 0.0001) [16]. Another study by Louisa Antoni M. et al., in 2010 showed that strain was significantly related with all-cause mortality, revascularization, re-infarction, and hospitalization for heart failure. After adjustment for covariates, strain was found to be independently associated with all the endpoints and potentially superior to LVEF and WMSI in risk stratification after MI [17]. The findings of our study are consistent with those of the above work.

Conclusions

GLS can offer accurate, feasible and non-invasive assessment of hemodynamic deterioration in patients with acute MI. It was shown to be superior to both EF and WMSI in the evaluation of myocardial dysfunction in patients with mildly reduced EF. It was also shown to be superior to both EF and WMSI in detection of Killip class II patients. More studies should be performed on the importance of GLS in risk stratification of acute MI and its prognostic role in identifying the likelihood of development of in-hospital heart failure.

Ethics information

The study was approved by the Ethics Committee of the corresponding author’s affiliated institution.

Acknowledgments and funding

None.

Conflict of interest

None declared.

References

[14] McDonagh TA, Metra M, Adamo M, Gardner RS, Baumbach A, Böhm M, et al. ESC Guidelines for the diagnosis and treatment of acute and chronic heart failure: developed by the task force for the diagnosis and treatment of acute and chronic heart failure of the ESC. With the special contribution of the Heart Failure Association (HFA) of the ESC. Eur Heart J 2021;42(36):3599–726.