Value of two-dimensional strain imaging in prediction of myocardial functional recovery after percutaneous revascularization of the infarct-related artery

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Abstract

Background: We performed this study to evaluate the role of speckle-tracking echocardiography (STE) with automated function imaging (AFI) in the prediction of left-ventricular function recovery after the percutaneous intervention to the left anterior descending (LAD) artery in patients with anterior ST-elevation myocardial infarction and impaired LV ejection fraction.

Methods: We enrolled 50 patients with first STEMI and 15 controls. All patients underwent percutaneous coronary intervention to LAD within one week after MI. Then, they were imaged by SPECT, conventional echocardiography, and STE at baseline and after 90 days of follow-up. Patients were classified into two groups with positive (Group A: N=24) and negative (Group B: N=26) functional recovery.

Results: We recorded significant differences between groups A and B in terms of LV ejection fraction, wall motion score index, number of affected LAD segments, and LAD and global longitudinal strain by STE (at baseline and 90-day follow-up, p<0.001). The mean territorial LAD strain was significantly different in groups A and B, compared to the control group (p<0.001). The ROC curves identified cut-off values for baseline territorial LAD strain and LV global longitudinal strain of -11.3% (sensitivity= 84% and specificity= 83.3%) and -11.8% (with sensitivity= 88%, specificity= 83%), respectively.

Conclusion: Assessment of global and territorial LV strains using STE at baseline (early after anterior STEMI) has a good predictive value for LV function recovery. Therefore, baseline global and territorial LV strains, measured using STE, may serve as markers of residual myocardial viability after infarction.

Keywords: Tissue Doppler Imaging; Myocardial imaging; Revascularization; Speckle-tracking Echocardiography; Strain imaging
INTRODUCTION

Because the presence of viable myocardial tissue is an important determinant of left-ventricular functional recovery after acute myocardial infarction (MI), quantitative assessment of LV myocardial viability may provide a valuable tool for prediction of functional recovery in MI patients. Currently, there are two ways to assess myocardial deformation by echocardiography: Tissue Doppler Imaging (TDI) and speckle-tracking echocardiography (STE). The latter is not based on Doppler analysis, but on the following of bright points via grayscale analysis (1).

Speckle-tracking echocardiography is a non-invasive ultrasound imaging technique that allows for an objective and quantitative evaluation of global and regional myocardial function, independent from the angle of insonation and cardiac translational movements (2). Therefore, echocardiographic analysis of myocardial deformation by STE has an additional value in the assessment of myocardial viability (3). Two-dimensional STE can also be used for the evaluation of coronary artery disease during dobutamine stress echo (4).

Automated function imaging (AFI) is an effective means of assessing LV function due to its short acquisition time, feasibility and accuracy, regardless of the experience of the operator. STE can calculate myocardial strain, using AFI, independent of the angle of incidence (5). By measuring deformation derived from tissue Doppler velocity, strain imaging had largely overcome TDI limitations (6). Angle dependency is not a problem with 2D STE, but this technique is dependent on the image quality and operates at limited frame rates (7).

We performed this study to evaluate the role of STE with AFI in the prediction of LV function recovery after PCI to the LAD artery in patients with anterior ST-segment elevation myocardial infarction (STEMI) and impaired LV ejection fraction (LVEF).

METHODS

2.1. Patients: This study included 50 patients and 15 healthy volunteers as controls. The patients had their first attack of anterior STEMI, were admitted to the CCU unit at Bakhsk Hospital Group (BHG), Saudi Arabia between September 2016 and September 2018, and were treated with thrombolytic therapy after exclusion of contraindications for its use. All participants signed an informed written consent after understanding the purpose and procedures of the study. The study protocol was approved by the Ethical Research Committee at the Faculty of Medicine, Al-Azhar University, Cairo, Egypt.

All patients met the following inclusion criteria: 1) anterior STEMI, treated with thrombolytic therapy, 2) impaired LVEF (45% or less), 3) single vessel disease, i.e., LAD artery; amenable for percutaneous coronary intervention (PCI), and 4) demonstrated myocardial viability using Myocardial perfusion scan and Gated-SPECT studies. Patients were excluded if they had significant arrhythmias interfering with STE analysis as atrial fibrillation, significant valvular disease, significant lesions in coronary vessels other than LAD, or developed acute coronary syndrome after PCI. To assess matching the eligibility criteria, all patients underwent comprehensive history taking, general and cardiac examination, laboratory investigations, and 12-lead ECG at the start of the study.

2.2. Procedures: All patients underwent PCI to LAD within one week after MI for patients with demonstrated myocardial viability (8).

2.2.1. Myocardial SPECT: Resting myocardial SPECT imaging with technetium-99m tetrofosmin (500 MBq, injected at rest) was performed using a triple-head SPECT camera system (GCA 9300/HG, Toshiba Corp), equipped with low-energy, high-resolution collimators. Around the 140-KeV energy peak of technetium-99m tetrofosmin, a 20% window was used. A total of 90 projections (step and shoot mode, 35 seconds per projection; imaging time, 23 minutes) was obtained over a 360° circular orbit. Data were stored in a 64x64 matrix. This was performed one week after MI to detect viability of LAD territories (9).

2.2.2. Conventional echocardiography: A Philips IE33 phased array system, equipped with STE technology was used. All the patients were examined in the left lateral decubitus position. Echocardiographic images were acquired from the standard views (parasternal long-axis, apical four chambers, apical long axis, and
apical two-chamber views). Recordings and different measurements were obtained as per the guidelines of American Society of Echocardiography (ASE) (10) and included the following:

1) Recordings of different cardiac chambers dimensions, 2) LV systolic function: by calculating the EF using the M-mode and 2D Simpson biplane method, 3) Color flow Doppler for assessment of valvular heart disease, 4) Regional wall motion was assessed according to the standard 17-segment model. Wall motion score (WMS) had been evaluated by two independent operators. Visual analysis of the contractile function of all the 17 segments was interpreted according to the ASE criteria using a four-point score: normal, hypokinetic, akinetic or dyskinetic. Wall motion score index was calculated as WMS/17. 5) LAD territory included seven segments: basal anterior, basal anteroseptal, mid-anteroseptal, apical anterior, apical septal, and apex (apical cap).

2.2.3. Speckle-tracking echocardiography: Two dimensional global and segmental strain and strain rate according to recommendations of ASE using AFI were used to assess segmental and global LV function. This was done with conventional Echocardiography and 3 months after PCI (13). The mean frame rate of the obtained images was 70 (40–100) frames/second. The AFI algorithm tracks the percent of wall lengthening and shortening in a set of three longitudinal 2D image planes (apical long, two chambers and four chambers) and displays the results for each plane. It then combines the results of all three planes in a single bull’s-eye summary (agreeing with the standard 17-segment model), which presents the analysis for each segment along with a global peak systolic value for the LV (5).

2.3. Patient follow-up: All the patients during the 90 days follow-up period were on optimal medical treatment in the form of double antiplatelets, statins, B-blockers, and angiotensin-converting enzyme inhibitors. Three months after percutaneous revascularization to LAD, all patients were re-evaluated for clinical findings, major adverse cardiovascular events, and assessment of global and segmental functions using conventional TTE and strain imaging (13).

Post-PCI LV functional recovery was defined as an improvement of LVEF% by ≥ 5% (14). Based on the occurrence of LV functional recovery, the studied population was divided into two groups: Group A (24 patients) included patients who showed post-PCI LV function recovery, while Group B (26 patients) included patients who did not show post-PCI LV function recovery.

2.4. Data analysis: Data were presented as a mean ± standard deviation for continuous data and as frequencies and percentages for categorical data. For group comparison, we performed an unpaired t-test for numerical data between both groups, a paired t-test for the same group and used the Chi-square test for categorical data. Further, we used the ANOVA with post-hoc Tukey’s test to compare quantitative data obtained at different times in the same group. The optimal cutoff points were determined by the receiver operating characteristic (ROC) curves, and the sensitivity, specificity, positive (PPV) and negative predictive values (NPV), and accuracy were calculated. All analyses were conducted using the SPSS software (version 22), and results were considered significant if the p-value was < 0.05.

RESULTS

3.1. Demographic and baseline characteristics: This study included 50 patients who were treated with thrombolytic therapy and showed viability on LAD territories by SPECT imaging after thrombolysis, then underwent successful PCI to LAD within one week of admission and were followed up by conventional TTE and STE after 90 days. Patients were divided after 90 days according to left ventricular function recovery into two groups: Group A included 24 patients who showed post-PCI LV function recovery, while Group B included 26 patients who did not show post-PCI LV function recovery.

The control group included 15 apparently healthy individuals, 6 females and 9 males, with a mean age of 49.1 ± 7 years, which was not significantly different from the enrolled patients. Table 1 illustrates that groups A and B were comparable in most baseline characteristics, except for diabetes mellitus, dyslipidemia and smoking, which were significantly more frequent in group B than in group A.
Table 1 shows a comparison between groups A and B regarding the demographic criteria and risk factors for cardiac disease.

<table>
<thead>
<tr>
<th>Variants</th>
<th>Group A (N=24)</th>
<th>Group B (N=26)</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (mean ± SD)</td>
<td>51.6 ± 5.5</td>
<td>52.9 ± 5.4</td>
<td>0.729</td>
</tr>
<tr>
<td>Gender Male</td>
<td>15 (62.5%)</td>
<td>19 (73.1%)</td>
<td>0.423</td>
</tr>
<tr>
<td>Diabetes Mellitus</td>
<td>20 (80.8%)</td>
<td>13 (50%)</td>
<td>0.032</td>
</tr>
<tr>
<td>Hypertension</td>
<td></td>
<td></td>
<td>0.749</td>
</tr>
<tr>
<td>Dyslipidemia</td>
<td></td>
<td></td>
<td>0.032</td>
</tr>
<tr>
<td>Smoking</td>
<td></td>
<td></td>
<td>0.019</td>
</tr>
<tr>
<td>FH of CAD Positive</td>
<td>8 (33.3%)</td>
<td>8 (30.8%)</td>
<td>0.846</td>
</tr>
<tr>
<td>FH of CAD Negative</td>
<td>16 (66.7%)</td>
<td>18 (69.2%)</td>
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</tr>
</tbody>
</table>

Unless otherwise indicated, data are n (%). CAD: Coronary artery disease, FH: Family history, SD: Standard deviation

3.2. Echocardiographic characteristics: We recorded significant differences between patients who had post-PCI LV recovery (group A) and those who did not (group B) in terms of LVEF at baseline and 90-day follow up, wall motion score index at baseline and 90-day follow-up, number of affected LAD segments at baseline and 90-day follow up, LAD strain by STE at baseline and 90-day follow up, and global longitudinal strain by STE at baseline and 90-day follow up (p<0.001). However, we observed no statistically significant differences between both groups in terms of LV end-systolic or diastolic diameters (at baseline and 90-day follow up); Table 2. Detailed echocardiographic images of some selected cases are displayed in the Appendix.

Table 2 shows the comparison between groups A and B regarding the echocardiographic characteristics.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Group A (N=24)</th>
<th>Group B (N=26)</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>LVEDD (pre)</td>
<td>55.04 ± 2.65</td>
<td>56.31 ± 2.93</td>
<td>0.115</td>
</tr>
<tr>
<td>LVEDD (post)</td>
<td>54.75 ± 3.31</td>
<td>56.42 ± 2.82</td>
<td>0.083</td>
</tr>
<tr>
<td>LVESD (pre)</td>
<td>43.73 ± 1.81</td>
<td>44.37 ± 2.25</td>
<td>0.275</td>
</tr>
<tr>
<td>LVESD (post)</td>
<td>42.47 ± 2.86</td>
<td>44.21 ± 3.32</td>
<td>0.056</td>
</tr>
<tr>
<td>LVEF% (pre)</td>
<td>41.21 ± 1.32</td>
<td>32.12 ± 2.52</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>LVEF% (post)</td>
<td>49.08 ± 1.06</td>
<td>33.92 ± 2.26</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>WMSI (pre)</td>
<td>1.65 ± 0.15</td>
<td>1.9 ± 0.14</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>WMSI (post)</td>
<td>1.32 ± 0.11</td>
<td>1.87 ± 0.12</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>NALS (pre)</td>
<td>4.21 ± 0.51</td>
<td>6.12 ± 0.50</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>NALS (post)</td>
<td>2.38 ± 0.49</td>
<td>5.97 ± 0.51</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>LAD strain by STE (pre)</td>
<td>-13.2 ± 2.05</td>
<td>8.47 ± 2.12</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>LAD strain by STE (post)</td>
<td>14.61 ± 2.41</td>
<td>-8.61 ± 2.12</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>GLS of LV by STE (pre)</td>
<td>13.19 ± 2.18</td>
<td>8.80 ± 1.96</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>GLS of LV by STE (post)</td>
<td>14.59 ± 2.56</td>
<td>8.97 ± 1.99</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>

LVEDD: left ventricular end-diastolic diameter, LVESD: left ventricular end-systolic diameter, LVEF: left ventricular ejection fraction, WMSI: wall motion score index, LAD: left anterior descending artery, NALS: Number of affected LAD segments, STE: speckle tracking echocardiography, Pre: baseline assessment during admission, Post: follow up assessment after 90 days.

3.3. Mean territorial LAD strain measured by 2D STE: The mean territorial LAD strains measured by 2D STE for the control, A, and B groups were -20.4 ± 0.62, -13.20 ± 2.05 and -8.47 ± 2.12. The difference between the control group and group A was 35.29% (p<0.001), while the difference between the control group and group B was 58.48% (p<0.001). Thus, the more shift from the normal values of the mean territorial LAD strain as measured by 2D STE, the less likely for LVEF to recover after revascularization.

3.4. Receiver-Operating Characteristic Curves for mean territorial LAD and global longitudinal strain: Regarding mean baseline territorial LAD strain measured by 2D STE, the ROC curve was used for obtaining a cut off value of -11.3% (with sensitivity= 84.6%, specificity= 83.3%, PPV= 84.6%, NPV= 83.3%, and accuracy= 85%) for prediction of LV function recovery after revascularization (Figure 1).

Regarding mean GLS of the LV measured by 2D STE, the ROC curve was used for obtaining a cut off value of -11.8% (with sensitivity = 88.5%, specificity = 83.3%, PPV = 85.2%, NPV = 87% and accuracy = 86%) for prediction of LV function recovery after revascularization (Figure 2).
Figure 1: Diagram showing the ROC curve plotted for obtaining the cutoff value of mean territorial LAD strain as measured by 2D STE, predicting post-PCI LV function recovery.

Figure 2: Diagram showing the ROC curve plotted for obtaining the cutoff value of mean global longitudinal strain of the left ventricle as measured by 2D STE, predicting post-PCI LV function recovery.
DISCUSSION

This study shows that assessment of global and territorial LV strains using STE at baseline (early after anterior STEMI) is of good predictive value for LV function recovery that adds to SPECT studies. Higher baseline STE-based strain values (territorial and global) are significantly associated with post-PCI LV function recovery. Baseline LVEF% is considered a predictor of LV function recovery; higher baseline LVEF% (modified Simpson’s method) is significantly associated with post-PCI LV function recovery. However, the STE-based strain is more accurate than LVEF%. Baseline global and territorial LV strains, measured using STE, may serve as markers of residual myocardial viability after infarction.

As regards the cut-off value for prediction of LV function recovery after revascularization, our study revealed a cut-off value of -11.8% for GLS in the prediction of LV function recovery after revascularization (sensitivity 88%, specificity 83%). This is close to Mollema et al. who reported a cut-off value for LV GLS of -13.7%, but with slightly lower sensitivity (86%) and specificity (74%) among a larger number of STEMI patients (N=147) and for a longer follow up period (one year) (14). Moreover, Andrea et al. concluded that longitudinal LV global and regional speckle-tracking strain measurements are powerful independent predictors of LV remodeling and LV function recovery after reperfusion therapy. However, they studied NSTEMI patients, not anterior STEMI patients as in our study (15).

As regards territorial LAD strain, our study concluded that territorial LAD strain is a powerful predictor of LV function recovery after reperfusion therapy and higher baseline LAD strain values were significantly associated with LV function recovery after 90 days. We showed a cut-off value of -11.3% for territorial LAD strain in predicting LV function recovery after PCI (sensitivity= 84% and specificity = 83.3%). Shehata reported a cutoff value of -6.5% for territorial LAD strain (at peak dose of dobutamine with sensitivity= 84% and specificity= 75%) for predicting LV function recovery after revascularization; however, he used dobutamine echocardiography instead of SPECT to assess viability before PCI (16).

In terms of predicting viability by strain Imaging, Bansal et al. reported that strain imaging by Color-coded DTI could predict viability in both anterior and posterior circulations, while 2D STE-based measurements could predict viability only in the anterior circulation (17). However, strain imaging by color-coded DTI has many limitations as angle dependency and inability to differentiate between active and passive segmental contractility. In our study, we used only 2D STE for strain measurement, which is more accurate and for only anterior STEMI patients.

In our study, we found that both LVEF and LV GLS were strong predictors of LV function recovery in anterior STEMI patients. Delgado et al. studied the relation between LV GLS by AFI and LVEF by the Simpson method in 99 acute STEMI patients (among 222 CAD patients). They reported that LV GLS, assessed with AFI, is linearly related to biplane LVEF. However, in acute STEMI patients, a less strong correlation between them was observed. This suggests that these 2 parameters reflect different aspects of LV systolic function and that GLS is more accurate than LVEF by Simpson method. This is because, in patients with extensive MI, the presence of regional hyperkinesis may result in almost normal LVEF; thereby, affecting the prognostic value of this parameter (18).

Limitations: The relatively small sample size makes it difficult to generalize the results to all patients surviving an acute STEMI. Moreover, we only included patients with anterior wall STEMI. Thus, other studies are required to evaluate patients with more than one territory affection. Further, our study is limited by the lack of long-term follow-up of functional recovery after LAD revascularization on both levels (territorial and global).

In conclusion, assessment of global and territorial LV strains using STE at baseline (early after anterior STEMI) has a good predictive value for LV function recovery. Therefore, baseline global and territorial LV strains, measured using STE, may serve as markers of residual myocardial viability after infarction.

myocardial infarction, TDI: Tissue Doppler Imaging, WMS: Wall motion score

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