Assessment of the Effect of Percutaneous Coronary Intervention on Left Ventricular function in patients with Coronary Artery Disease Using Tissue Doppler Strain Rate Imaging

Mohamed Elsayed Abou Ellail1, Mahmoud Shawky Abd El Moneum1, Hany Hassan Ebaid1, Eman Said El-Kishk1

1Department of Cardiology, Benha University Hospital, Benha City, Egypt

Abstract

Objectives: This study aimed to assess the effects of percutaneous coronary intervention (PCI) on regional and global left ventricular (LV) functions (systolic and diastolic) in patients with coronary artery disease (CAD) using tissue Doppler strain rate (SR) imaging. Patients and Methods: in this study, we randomly assigned 100 Egyptian adult symptomatic patients with CAD that underwent coronary angiography and candidate for PCI on the left anterior descending artery. LV early diastolic and systolic SR were measured 24 h before and 48 h after PCI. Results: Most of the LV diastolic and systolic parameters (A, E', E/A, E/E', and isovolumic relaxation time [IVRT]) showed significant difference before and after elective PCI, while mitral E velocity, DT, and pulmonary vein flow before and after PCI did not show significant difference. SR imaging findings showed high significant difference mean peak systolic and mean early diastolic SR of ischemic regions after PCI; mean early diastolic SR before PCI was 1.86 ± 0.13 while after PCI was 2.57 ± 0.18 (P < 0.001) and mean peak systolic SR before PCI was 0.65 ± 0.18 while after PCI was 0.901 ± 0.15 (P < 0.001). Conclusion: Most of the LV diastolic and systolic parameters (A, E', E/A, E/E', and IVRT) improved after PCI in CAD patients. Furthermore, regional myocardial function as measured by mean peak systolic and mean early diastolic SR in the ischemic segments improved significantly compared with that in nonischemic segments.

Keywords: Percutaneous coronary intervention, strain rate, systolic function diastolic function

INTRODUCTION

Left ventricular (LV) systolic and diastolic dysfunction is an important clinical parameter which is associated with a substantial risk of subsequent development of congestive heart failure and reduced survival of patients. This point is more important when we know the rate of mortality in patients with asymptomatic ventricular dysfunction is fivefold in comparison with general population.[1] Evaluation of regional LV function could be a good strategy to identify myocardial regions with impaired coronary artery flow and reduced myocardial perfusion. Echocardiographic Doppler tissue strain rate (SR) imaging is a new method of echocardiography that yields information regarding regional function in coronary artery disease (CAD) patients using tissue velocity data to calculate velocity gradients between two distinct points along the ultrasound beam.[2] Unfortunately, the treatment strategies of regional myocardial dysfunction in patients with CAD have not been well characterized, and literature is very limited in regional dysfunction. Percutaneous coronary intervention (PCI) is reperfusion strategy in the improvement of global and regional myocardial function and provides a feasible advance in the management of quality of life.[3] However, the widespread use and recurrent improvements of this method have resulted in a significant enhancement in survival rate compared with pharmacological reperfusion therapy.[4]

PATIENTS AND METHODS

The study was conducted on one hundred patients presented to catheterization laboratory in Benha University Hospitals for elective PCI of left anterior descending (LAD) with significant...
lesion (stenosis >70%). Patients with single-vessel CAD (LAD) based on coronary angiography and echocardiography (EF more than 40%) were eligible for inclusion. Exclusion criteria included previous history of STEMI, creatinine >2, heart block, interventricular septal hypertrophy, pulmonary HTN, atrial fibrillation, significant valvular disease, hypertrophic or idiopathic or restrictive cardiomyopathy or metabolic diseases as diabetes mellitus which can affect deformation indices or inability to consent for the study. An informed consent was obtained from the patients or their legal guardians after approval of the Ethical Committee of Benha University of Medical Science. Demographic variables and CAD risk factors are presented in Table 1.

All study population underwent the following diagnostic workup:

- Full medical history including age, sex, symptoms suggestive of cardiac disease, and current medications
- Twelve-lead electrocardiogram to exclude established AF and to measure PR interval and P-wave morphology to exclude heart block of any degree or nodal rhythm
- Echocardiography data: an echocardiographic examination was performed at baseline within 24 h before PCI and was repeated 48 h thereafter using a Philips EPIQ ultrasound system with a 2.5 MHz phased-array transducer to perform.

**Conventional two dimensional**

Images from standard views, including the parasternal long axis, short axis at the papillary muscle level, apical (4) chamber, and (2) chamber views were recorded. Then, LV ejection fraction (EF) will be estimated by M-mode and modified Simpson’s method as well as left diastolic function parameters such as deceleration time (DT) (ms), isovolumic relaxation time (IVRT) (ms), peak transmitral early diastolic flow velocity (E wave), peak transmitral late diastolic flow velocity (A wave), mitral E/A ratio, and pulmonary veins flow.[7,8]

**Doppler tissue and strain rate (rate of deformation)**

Real-time two-dimensional color-coded tissue Doppler data were recorded from the interventricular septum using an apical long axis, (4) chamber, and (2) chamber view during brief held expiration. The image sector was kept as narrow (30°) as possible to achieve frame rates of at least higher than 200 frames per second with real-time display of SR color images. Recordings were stored digitally and analyzed offline with software (Echo PAC PC; Philips Epiq Ultrasound). Sample volumes were placed in the inner half of the myocardium on the basal, mid, and apical portions of LV at the anteroseptal, anterior, lateral, posterior, inferior, and posteroseptal walls in the apical views. Thus, the LV was divided into 16 segments.[9,10] Of all segments, segments that received supply from LAD were considered as ischemic segments, and other segments were considered as nonischemic segments. Mean early diastolic and mean peak systolic SR were measured in all ischemic and nonischemic segments 24 h before and 48 h after PCI. The SR imaging was equal to the spatial myocardial velocity gradient expressed by the equation: $SR = \frac{v(r + \Delta r) - v(r)}{\Delta r}$ and is measured in s−1 (1/s), where v is the longitudinal velocity component, r is the distance along the beam, and delta r is the small offset between the two points. An offset (sample volume of SR) of delta r = 9.2 mm was used in all studies.[11,12]

PCI details: PCI details include coronary angiographic data before PCI and PCI data; before PCI detect site of LAD lesion either proximal, mid, or distal segment significant lesion (55 patients show mid, 30 patients show distal, and 15 patients show proximal lesion) after PCI; (type and numbers of stents used, thrombolysis in myocardial infarction flow, and any complications).

**Statistical analysis**

Data collected throughout history, basic clinical examination, laboratory investigations, and outcome measures were coded; entered; and analyzed using Microsoft Excel software. Data were then imported into the Statistical Package for the Social Sciences (SPSS version 20.0) software for analysis. According to the type of data qualitative represent as number and percentage, quantitative continues group represent by mean ± standard deviation, the following tests were used to test differences for significance. Difference of paired qualitative variable by Mac namer. Differences between quantitative paired groups by paired t-test. $P<0.05$ for statistical significant results and $<0.001$ for high significant result.

**RESULTS**

All 100 patients consisting of 61 male and 39 female (mean age, 55.8±5.5) had a mild degree of ventricular dysfunction, PCI was performed successfully in all of them, and no complication was observed during hospital stay. Most of the LV systolic and
diastolic parameters (A, E’, E/A, E/E’, and IVRT) showed significant difference before and after elective PCI; while mitral E velocity, DT, and pulmonary vein flow before and after PCI did not show any significant differences. The echocardiographic measurements before and after PCI are presented in Table 2. SR imaging findings showed high significant increase in mean peak systolic and mean early diastolic SR of ischemic regions after PCI, while comparison of peak systolic and early diastolic SR before and after PCI in nonischemic regions was not statistically significant.

**Comparison before and after percutaneous coronary intervention**

**Echocardiography parameters**

Echocardiography parameters are EF, DT (ms), IVRT (ms), peak transmitral early diastolic flow velocity (E wave), peak transmitral late diastolic flow velocity (A wave), mitral E’ septal velocity, mitral E/A ratio, mitral E/E’ ratio, and pulmonary veins flow.

**Comparison between echo parameters before and after percutaneous coronary intervention**

- Peak transmitral late diastolic flow velocity (A wave): the mean result before PCI was 74.18 ± 3.58 while the mean result after PCI was 66.5 ± 5.78; there was statistically significant difference between the two results (P < 0.001) [Table 2]
- Mitral E’ septal velocity: the mean result before PCI was 6.7 ± 0.49 while the mean result after PCI was 8.41 ± 0.63; there was statistically significant difference between the two results (P < 0.001) [Table 2]
- Mitral E/A ratio: the mean result before PCI was 0.72 ± 0.04 while the mean result after PCI was 0.83 ± 0.07; there was statistically significant difference between the two results (P < 0.001) [Table 3]
- Mitral E/E’ ratio: the mean result before PCI was 8.06 ± 0.59 while the mean result after PCI was 6.6 ± 0.7; there was statistically significant difference between the two results (P < 0.001) [Table 2]
- IVRT (ms): the mean result before PCI was 107.02 ± 15.5 while the mean result after PCI was 97.01 ± 10.04; there was statistically significant difference between the two results (P < 0.001) [Table 2]
- EF: the mean result before PCI was 50.72 ± 5.25 while the mean result after PCI was 97.01 ± 10.04; there was statistically significant difference between the two results (P = 0.0751) [Table 3]
- DT (ms): the mean result before PCI was 262.54 ± 12.25 while the mean result after PCI was 261.19 ± 12.38; there was statistically no significant difference between the two results (P = 0.232) [Table 2]
- Peak transmitral early diastolic flow velocity (E wave): the mean result before PCI was 53.12 ± 2.23 while the mean result after PCI was 54.79 ± 5.74; there was statistically no significant difference between the two results (P = 0.0751) [Table 2]

- Pulmonary veins flow, diastolic (D), and systolic (S) before and after PCI: there was statistically no significant difference between the two results (P = 0.21) [Table 3].

**Doppler strain rate imaging**

- Ischemic regions early diastolic: the mean result before PCI was 1.86 ± 0.13 while the mean result after PCI was 2.57 ± 0.18; there was statistically significant difference between the two results (P < 0.001) [Table 4]
- Ischemic regions peak systolic: the mean result before PCI was 0.65 ± 0.18 while the mean result after PCI was 0.901 ± 0.15; there was statistically significant difference between the two results (P < 0.001) [Table 4]
- Non ischemic: The mean result before PCI was 2.46 ± 0.14 while the mean result after PCI was 2.47 ± 0.14, there was statistically no significant difference between the two results (P = 0.590) [Table 4].

**DISCUSSION**

LV systolic and diastolic dysfunction has been reported in many patients with CAD, and although most frequently, it is

---

**Table 2: Echo parameters distribution before and after percutaneous coronary intervention**

<table>
<thead>
<tr>
<th></th>
<th>Pre-PCI</th>
<th>Post-PCI</th>
<th>Paired t</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>E (cm/s)</td>
<td>53.12±2.23</td>
<td>54.79±5.74</td>
<td>−1.717</td>
<td>0.0751</td>
</tr>
<tr>
<td>A (cm/s)</td>
<td>74.18±3.58</td>
<td>66.5±5.78</td>
<td>−10.798</td>
<td>&lt;0.001*</td>
</tr>
<tr>
<td>E’ (cm/s)</td>
<td>6.7±0.49</td>
<td>8.41±0.63</td>
<td>−21.380</td>
<td>&lt;0.001*</td>
</tr>
<tr>
<td>E/A</td>
<td>0.72±0.04</td>
<td>0.83±0.07</td>
<td>−13.463</td>
<td>&lt;0.001*</td>
</tr>
<tr>
<td>E/E’</td>
<td>8.06±0.59</td>
<td>6.6±0.7</td>
<td>15.691</td>
<td>&lt;0.001*</td>
</tr>
<tr>
<td>IVRT (ms)</td>
<td>107.02±15.5</td>
<td>97.01±10.04</td>
<td>5.182</td>
<td>&lt;0.001*</td>
</tr>
<tr>
<td>DT (ms)</td>
<td>262.54±12.25</td>
<td>261.19±12.38</td>
<td>1.146</td>
<td>0.232</td>
</tr>
<tr>
<td>EF %</td>
<td>50.68±4.26</td>
<td>50.72±5.25</td>
<td>−1.014</td>
<td>0.235</td>
</tr>
</tbody>
</table>

**Table 3: Pulmonary veins flow**

<table>
<thead>
<tr>
<th></th>
<th>Pre-PCI, n (%)</th>
<th>Post-PCI, n (%)</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>D and S</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>D &gt; S</td>
<td>16 (16.0)</td>
<td>10 (10.0)</td>
<td>0.21</td>
</tr>
<tr>
<td>S &gt; D</td>
<td>84 (84.0)</td>
<td>90 (90.0)</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>100 (100.0)</td>
<td>100 (100.0)</td>
<td></td>
</tr>
</tbody>
</table>

**Table 4: Tissue Doppler distribution before and after percutaneous coronary intervention**

<table>
<thead>
<tr>
<th></th>
<th>Pre-PCI</th>
<th>Post-PCI</th>
<th>Paired t</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ischemic diastolic SR</td>
<td>1.86±0.13</td>
<td>2.57±0.18</td>
<td>−33.84</td>
<td>&lt;0.001*</td>
</tr>
<tr>
<td>Ischemic systolic SR</td>
<td>0.65±0.18</td>
<td>0.901±0.15</td>
<td>−10.468</td>
<td>&lt;0.001*</td>
</tr>
<tr>
<td>Nonischemic</td>
<td>2.46±0.14</td>
<td>2.47±0.14</td>
<td>−0.54</td>
<td>0.590</td>
</tr>
</tbody>
</table>

*P<0.001 significant difference. PCI: Percutaneous coronary intervention, EF: Ejection fraction, DT: Deceleration time (ms), IVRT: Isovolumic relaxation time (ms), E wave: Peak transmitral early diastolic flow velocity, A wave: Peak transmitral late diastolic flow velocity, E velocity, E’ septal velocity, mitral E/A ratio, mitral E/E’ ratio, pulmonary veins flow.
diagnosed as a preclinical disease, it constitutes a predictor of all-cause mortality. Thus, the evaluation of LV functions could provide valuable data to determine the condition of the heart to prevent heart failure and preserve suitable EF. Echocardiographic Doppler tissue SR imaging is a new method of providing information regarding regional myocardial function using tissue velocity gradients between two distinct points. Several studies have demonstrated that this method is an appropriate tool for evaluating regional myocardial function in diastole and systole and provides significant parameters such as DT (ms), IVRT (ms), peak transmitral early diastolic flow velocity (E wave), peak transmitral late diastolic flow velocity (A wave), mitral E’ septal velocity, mitral E/A ratio, mitral E/E’ ratio, and pulmonary veins flow.\[13\]

In this study, we evaluate global and regional myocardial function using tissue Doppler SR imaging and echocardiographic parameters. All 100 patients consisting of 61 male and 39 female (mean age, 55.8 ± 5.5) had a mild degree of ventricular dysfunction; PCI was performed successfully in all of them, and no complication was observed during hospital stay. Most of the LV systolic and diastolic parameters showed significant difference before and after elective PCI, while mitral E velocity, DT, and pulmonary vein flow before and after PCI did not show any significant differences. The echocardiographic measurements before and after PCI are presented in SR imaging findings showed significant increase in peak systolic and early diastolic SR of ischemic regions after PCI, while comparison of peak systolic and early diastolic SR before and after PCI in nonischemic regions was not statistically significant.\[14\]

In a similar study, Hashemi et al. investigated the effects of PCI on global and regional LV function, using (SR) imaging in 27 patients and finally concluded that Mitral E velocity, mitral A velocity, DT, and E/A did not reveal significant improvement after PCI. On the other hand, regional myocardial function as measured by early diastolic SR and peak systolic SR in the ischemic segments. Our results showed that mean SR in ischemic regions before and after PCI was significantly different, and this parameter after PCI showed significant increase. Utilizing SR imaging Tanaka et al. in agreement with our study showed that myocardial systolic and diastolic dysfunction improved in patients with CAD after PCI. They noted that PCI resulted in a significant increase in early diastolic SR and peak systolic SR in the ischemic but not in the nonischemic segments. The peak early diastolic transmitral flow velocities and peak systolic SR after PCI improved in patients with greater extent of improvement of peak systolic SR and early diastolic SR in the ischemic segments. These findings suggest that the improvement in LV function after PCI may be associated with the degree of improvement in impaired regional myocardial function.

Nozari et al. in another study disagreed with our study investigated the effect of PCI on LV systolic and diastolic function. The authors in this study measured echocardiographic findings of 115 patients with CAD before PCI, the day after, and 3–6 months later. In this study, diastolic dysfunction was mild to moderate before PCI, which in 74% (86 patients) improved to mild dysfunction the day after PCI but not changed 3–6 months later.

Ha et al. also disagreed with our study and evaluated 22 patients with stable angina pectoris with angiographically significant coronary artery stenosis but normal wall motion and showed PCI caused a significant increase in peak systolic strain and peak early diastolic SR but not peak systolic SR and peak late diastolic SR in the ischemic segments.

Furthermore, our results showed that regional myocardial function in the ischemic segments significantly improved after PCI. In addition, this study found that the improved global LV function after PCI was associated with the degree to which impaired regional myocardial function improved in the ischemic segments. Improvement in myocardial function in CAD caused by PCI and that regional myocardial function are associated with the improvement in dynamics of global LV function. According to this study, regional diastolic SR and systolic SR significantly were improved in segments of LAD territory that is a clue for the diagnosis of CAD in asymptomatic patients and especially determination of type of vessel involvement in CAD patients before coronary angiography.\[15,16\] However, more studies requisiteness is needed to confirm these justifications.

**Conclusion**

Most of the LV systolic and diastolic parameters (A, E’, E/A, E/E’, and IVRT) showed significant difference before and after elective PCI, while mitral E velocity, DT, and pulmonary vein flow before and after PCI did not show any significant differences. SR imaging findings showed significant increase in peak systolic and early diastolic SR of ischemic regions after PCI, while comparison of peak systolic and early diastolic SR before and after PCI in nonischemic regions was not statistically significant.\[17\]

**Financial support and sponsorship**

Nil.

**Conflicts of interest**

There are no conflicts of interest.


References


