Abstract

Introduction: Coronary Artery Disease (CAD) is the most common cause for left ventricular dysfunction. Unfortunately, the treatment strategies of regional myocardial diastolic dysfunction in patients with CAD have not been well characterized and benefit of Percutaneous Coronary Intervention (PCI) as a treatment strategy is not clear. So the present study aimed to assess the effects of PCI on isolated left ventricular diastolic dysfunction in patients with CAD by using Strain Rate (SR) imaging.

Methods: Thirty adult patients with coronary artery disease candidate for PCI on left anterior descending artery were enrolled to our study. Echocardiographic finding and early diastolic SR was measured before and 48 hours after PCI.

Results: Mean age of the patients was 59.9±8.3 years. All of the left ventricular diastolic parameters showed significant difference before and after elective PCI; while pulmonary vein flow before and after PCI did not show any significant differences by using McNemar exact test. Also before PCI, mean (SD) SR in ischemic region (1.89±0.22) was smaller than of non ischemic region (2.53±0.26) while after PCI this parameter was became similar in ischemic region (2.55±0.27) and non-ischemic region (2.55±0.26).

Discussion: Left ventricular diastolic parameters improved after PCI in CAD patients. Also regional myocardial relaxation as measured by peak early diastolic SR (ESR) in the ischemic segments improved significantly compared with that in non-ischemic segments.

INTRODUCTION

Left ventricular diastolic dysfunction is important clinical parameters which are associated with a substantial risk of subsequent development of congestive heart failure and reduced survival of patients similar to what happens in systolic dysfunction [1]. The prevalence of diastolic dysfunction is more than systolic dysfunction and is increased with aging [2]. This point is more important when we know rate of mortality in patients with asymptomatic diastolic dysfunction is fivefold in comparison with general population [3].

Evaluation of regional left ventricular diastolic 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 yield information regarding regional diastolic function in Coronary Artery Disease.

(CAD) patients by using tissue velocity data to calculate velocity gradients between two distinct points along the ultrasound beam.

Unfortunately, the treatment strategies of regional myocardial diastolic dysfunction in patients with CAD have not been well characterized [4] and literature is very limited in isolated diastolic dysfunction in comparison with systolic dysfunction.

Percutaneous Coronary Intervention (PCI) is reperfusion strategy in improvement of global and regional myocardial function and provides a feasible and non-invasive advance in management of quality of life [5].

However the widespread use and recurrent improvements of this method have resulted in a significant enhance in survival rate compared with pharmacological reperfusion therapy [6] but results of echocardiographic assessment of systolic and diastolic ventricular function following successful elective PCI have been contradictory and confusing [7]. So the present study aimed to assess the effects of PCI on isolated ventricular diastolic dysfunction in patients with CAD by using SR imaging [8-11].

METHODS

Study population

Thirty adult patients who were known cases of CAD with mild left ventricular diastolic dysfunction (LV ejection fraction: 53.5±5.7%; range 45%-68%) and presented to the cardiology department of Shahid Modarres University Hospital in Tehran-Iran were enrolled. Patients with single vessel CAD based on coronary angiography (LAD stenosis over than 70%) and echocardiography (EF over than 40%) were eligible for inclusion. Exclusion criteria included previous history of STEMI, metabolic problems such as diabetes and thyroid disease, Ceratinine >2, heart block, interventricular septum hypertrophy, pulmonary HTN, atrial fibrillation, significant valvular disease, hypertrophic or idiopathic restrictive cardiomyopathy or inability to consent for the study. Demographic variables and CAD risk factors are presented in Table 1.

All patients were candidates for PCI on left anterior descending artery via femoral approach after diagnostic angiography. All echocardiographic examinations were performed by an expert cardiologist in all patients.

Coronary Angiography and Percutaneous coronary intervention (PCI)

Coronary diagnostic angiography was performed and minimal lumen and reference diameters were determined and the degree of coronary diameter stenosis was calculated from at least two views.

After diagnostic angiography PCI was performed in the usual manner with balloon catheters and a 0.014-inch, 15-MHz, Doppler-tipped angioplasty guidewire (Flo- Wire, Cardiometrics). This was performed after the administration of additional heparin to maintain the activated clotting time at 300 seconds. Also for all patients aspirin (ASA) 325 mg as well as dospidogrel (Plavix) 600mg before PCI were administered. PCI was considered successful if the final stenosis was reduced to lower than 20%.

After the PCI, the stented patients were maintained on a regimen of ASA 325 mg daily and Plavix 75 mg bid for 2 days and 75mg daily after that.

Echocardiography

An echocardiographic examination was performed at baseline within 24 hours before PCI and were repeated 48 hours thereafter using a digital ultrasound system (Ultrasound Vivid 7, General Motor Cor., USA) with a 2.5-MHz phased-array transducer. Standard views, including the parasternal long-axis, short-axis at the papillary muscle level, and apical 4- and 2-chamber views were recorded. We then determined left diastolic function parameters such as deceleration time (DT) (ms), isovolumic relaxation time (IVRT) (ms), peak transmitral early diastolic flow velocity (E wave), peak transmittal late diastolic flow velocity (A wave), mitral E/A ratio and pulmonary veins flow.

Doppler tissue and Strain rate imaging

Real-time 2-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 degree) as possible to achieve frame rates of at least higher than 200 frames per second with real-time display of Strain Rate (SR) color images (Figure 1). Recordings were stored digitally and analyzed off-line with software (EchoPAC PC; GE Vingmed Ultrasound AS, Horten, Norway). Sample volumes were placed in the inner half of the myocardium on the basal, mid, and apical portions of LV at the anterosepsest, anterior, lateral, posterior, inferior, and posteroseptum walls in the apical views. Thus, the LV was divided into 18 segments (Figure 1). Of all segments, segments that received supply from LAD were considered as ischemic segments and other segments was considered as non-ischemic segment. Early diastolic SR was measured in all ischemic and non ischemic segments before and 48 hours after PCI.

The SR imaging was equal to the spatial myocardial velocity gradient expressed by the equation: $SR = \frac{v[r]}{r} - \frac{r[\Delta r]}{\Delta r}$ 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 2 points. An offset (sample volume of SR) of delta $r = 9.2$ mm was used in all studies. Finally peak myocardial early diastolic flow velocity (E’ wave) and E/E’ in the medial annulus were measured.

Ethical approval

The study was approved by the ethics committee of the
university before its initiation, and the protocols used conformed to the ethical guidelines of the 1975 Helsinki Declaration.

Statistical analysis

The statistical evaluation was performed by computer analysis with SPSS Software (Statistical Package for the Social Sciences, version 16.0, SPSS Inc, Chicago, Ill, USA). Student’s paired t test or McNemar exact test were used, where appropriate, for comparing clinical data between results before and after PCI. Continuous data were demonstrated as mean ± standard deviation. P- Value less than 0.05 were considered significant.

RESULTS

All 30 patients consisting of 20 male and 10 female (mean age, 59.9±8.3; range 43-79) had a mild degree of diastolic dysfunction, PCI was performed successfully in all of them and no complication was observed during hospital stay.

Mean (SD) mitral E velocity was 53.7±10 cm/s and 57.8±10.5 cm/s before and after PCI respectively. Mean (SD) mitral A velocity was 72.6±11.3 cm/s and 68.6±10.9 cm/s before and after PCI. Also mean (SD) mitral E’ septal velocity was 6.7±1.1 cm/s before treatment which changed to 8.6±1.1 cm/s after treatment and E/E’ ratio in the medial annulus was 8.1 ± 1.1 before treatment versus 6.8 ± 1.2, 48 hours after PCI. Also IVRT was 119.4 ±27.8 ms before treatment versus 99 ± 17.7 ms after treatment, and E/A ratio was 0.72 ± 0.09 before treatment versus 0.84 ± 0.12 after PCI. All of the left ventricular diastolic parameters showed significant difference before and after elective PCI; while pulmonary vein flow before and after PCI did not show any significant differences by using McNemar exact test. The echocardiographic measurements before and after PCI are presented in (Table 2).

Strain rate imaging findings showed significant increase in ischemic region after PCI; while comparison of mean SR before and after PCI in non-ischemic region was not statistically significant (Table 3). Also before PCI, mean (SD) SR in ischemic region (1.89±0.22) was smaller than of non ischemic region (2.53±0.26) while after PCI this parameter was became similar in ischemic region (2.55±0.27) and non-ischemic region (2.55±0.26).

DISCUSSION

Left ventricular diastolic dysfunction has been reported in many patients with CAD [12-18] and although most frequently it is diagnosed as a preclinical disease, it constitutes a predictor of all-cause mortality [19,20].

Thus evaluation of left ventricular diastolic function could provide valuable data to determine condition of heart to prevent heart failure and preserve suitable EF. Echocardiographic Doppler tissue SR imaging is a new means of providing information regarding regional myocardial function by using tissue velocity gradients between two distinct points.

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Before PCI</th>
<th>After PCI</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mitral E velocity (cm/s)</td>
<td>10±53.7</td>
<td>10.5±57.8</td>
<td>0.001*</td>
</tr>
<tr>
<td>A(cm/s)</td>
<td>11.3±72.6</td>
<td>10.9±68.6</td>
<td>0.003*</td>
</tr>
<tr>
<td>E(cm/s)</td>
<td>1.1±6.7</td>
<td>1.1±6.8</td>
<td>&lt;0.0001*</td>
</tr>
<tr>
<td>E/ E’</td>
<td>1±8.1</td>
<td>1.2±6.8</td>
<td>&lt;0.0001*</td>
</tr>
<tr>
<td>IVRT(ms)</td>
<td>27.8±119.4</td>
<td>17.7±99</td>
<td>&lt;0.0001*</td>
</tr>
<tr>
<td>DT(ms)</td>
<td>15.4±264.8</td>
<td>20.6±253.4</td>
<td>&lt;0.0001*</td>
</tr>
</tbody>
</table>

Table 2: Echocardiographic findings in patients before and after PCI.
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 IVRT, the interval from the peak of (E) velocity to its extrapolation to baseline (DT), E/A ratio and ect. to assess diastolic dysfunction [21-24].

Authors believe that some indexes are not accurate to assess LV diastolic function, principally in patients with normal EF [25-27]. On the other hand, some tissue Doppler parameters such as the ratios of E/E′ and E′/A′ have been reported to be sensitive enough in the assessment of the LV diastolic function although the E/E′ ratio has greater specificity compared to E′/A′ ratio in detecting diastolic dysfunction [27,28].

We used peak early diastolic SR (ESR) to represent the maximal velocity gradient of longitudinal wall thickening in early diastole, and ESR is thought to be closely related to regional myocardial relaxation. Therefore, the finding that the reduced ESR in the ischemic segments was increased after successful PCI suggested that impaired global myocardial relaxation was improved in ischemic segments with PCI.

Our study demonstrated improved regional LV early diastolic function after PCI and except pulmonary vein flow all of the left ventricular diastolic parameters such as Mitral E velocity, Mitral A velocity, mitral E′ septal, E/E′ ratio, IVRT and E/A ratio showed significant improvement after elective PCI. In a similar study Hashemi et al. [11] evaluated diastolic echocardiographic findings before PCI, 48 hours and 3 months after PCI in 30 patients with EF of more than 40% scheduled for elective PCI. Except mitral E/A ratio and mitral E′ septal velocity all of the left ventricular diastolic parameters showed no significant improvement after 48 hours. Of course Hashemi et al. provided significant improvement in Mitral A velocity moreover two previous parameter after 3 month. Tanaka et al. [1] investigated the effects of PCI on global and regional left ventricular diastolic 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 relaxation as measured by ESR in the ischemic segments was impaired compared with that in the nonischemic segments before PCI. Our results showed that mean SR in ischemic region before and after PCI was significantly different and this parameter after PCI showed significant increase; while mean SR before and after PCI in non-ischemic region did not change significantly.

Utilizing SR imaging Tanaka et al. [1] in agreement with our study showed that myocardial diastolic dysfunction improved in patients with CAD after PCI. They noted that PCI resulted in a significant increase in ESR in the ischemic but not in the nonischemic, segments. The peak early diastolic trans-mitral flow velocities after PCI improved in patients with greater extent of improvement of ESR in the ischemic segments. These findings suggest that the improvement in left ventricular early diastolic filling after PCI may be associated with the degree of improvement in impaired regional myocardial relaxation.

Derumeaux et al. [29] evaluated left ventricular isovolumic relaxation blood flow as Doppler-echocardiographic parameter for the diagnosis of acute cardiac rejection and finally concluded that regional diastolic function was impaired during PCI and improved in the early period after successful PCI.

Nozari et al. [30] in another study investigated the effect of PCI on Left Ventricular (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.

Furthermore our results showed that regional myocardial relaxation in the ischemic segments significantly improved after PCI. In addition, this study found that the improved global LV early diastolic filling after PCI was associated with the degree to which impaired regional myocardial relaxation improved in the ischemic segments. Improvement in myocardial relaxation in CAD caused by PCI and that regional myocardial relaxation are associated with the improvement in dynamics of global LV early diastolic filling. According to this thread, mechanism of impaired left ventricular myocardial relaxation at rest might be a manifestation of chronic ischemia or a residual manifestation of previous active ischemia, or myocardial stunning.

According to this study regional diastolic SR significantly was improved in segments of LAD territory that is a clue for diagnosis of CAD in asymptomatic patients and specially determination of type of vessel involvement in CAD patients before coronary angiography. However more studies requites these justifications. All improvements observed in this study were more significant in comparison to similar previous studies in the literature. This discrepancy may be difference in basic ventricular diastolic dysfunction and LV ejection fraction before PCI, global condition of the patients and degree and type of coronary artery stenosis on the basis of angiography.

**Limitation**

Our results of our study showed a more improvement in results of PCI in comparison with similar study. A limitation to the current study could have been the relatively small number of patients evaluated. Moreover, early assessment of myocardial performance without any follow up could be another limitation of this study. The final shortcoming may have been the fact that we did not consider clinical improvement along with echocardiographic parameters. To our knowledge, this study is, however, the first to cover a wide range of echocardiographic indices for post-PCI functional assessment in patients with stable CAD.

**CONCLUSION**

Left ventricular diastolic parameters improved after PCI in CAD patients. Also regional myocardial relaxation as measured
by $E_{in}$ in the ischemic segments improved significantly compared with that in non-ischemic segments.

**REFERENCES**


