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Research Article

Assessment of Left Atrial Function After Percutaneous Coronary Intervention: A Doppler-Based Strain and Strain Rate Study

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Abstract

Background: Left atrial function can be critical for risk assessment and prediction of adverse cardiac events. Tissue Doppler of atrial contraction can provide regional and global snapshots of atrial systolic function.

Objectives: The present study aimed to assess left atrial function by tissue Doppler parameters of strain and strain rate following percutaneous coronary intervention (PCI).

Patients and Methods: This prospective study recruited 77 consecutive patients with coronary artery disease who underwent PCI. The study end point was to assess left atrial function by regional strain and strain rate parameters before and after PCI via tissue Doppler imaging.

Results: Regarding changes in left trial functional parameters after PCI, those such as the strain of the septal wall and the anterior and inferior walls and the strain rate of the anterior and lateral walls significantly increased following PCI, while the strain of the lateral wall and the strain rate of the septal wall significantly decreased.

Conclusions: PCI was accompanied by some improvement in left atrial deformation indices as assessed by tissue Doppler imaging. Revascularization can, therefore, improve patient outcome.

Keywords: Strain, Strain Rate, PCI

1. Background

The resurgence of interest in atrial size and function has enhanced our understanding of the atrial contributions to cardiovascular performance in health and disease. The main role of the left atrium (LA) is to modulate left ventricular (LV) filling and cardiovascular performance by functioning as a reservoir for pulmonary venous return during ventricular systole, a conduit for pulmonary venous return during early ventricular diastole (1). Maximal LA volume is most strongly associated with cardiovascular disease and is the most sensitive in predicting cardiovascular outcomes and providing uniform and accurate risk stratification (2, 3). Thus, LA function can be critical for risk assessment and prediction of adverse cardiac events. However, quantifying LA size is difficult, in part because of the LA's complex geometry and intricate fiber orientation and the variable contributions of its appendage and pulmonary veins. Tissue Doppler of atrial contraction can provide regional and global snapshots of atrial systolic function (4, 5). Reproducible data with acceptable variability can be obtained with proper attention to technical details. Tissue velocities during ventricular systole and early diastole correspond to reservoir and conduit function, respectively. However, tissue Doppler velocities are subject to error because of angle-dependency and the effects of cardiac motion and tethering and have been superseded by deformation analysis. In this regard, strain and strain rate represent the magnitude and rate, correspondingly, of myocardial deformation, (6) which can be assessed using tissue Doppler velocities and can be used successfully to assess LA global and regional function (7, 8).

Although LA function has been assessed using tissue Doppler in those with acute myocardial infarction (AMI), LA functional status has yet to be meticulously evaluated by tissue Doppler parameters following cardiac interventions such as percutaneous coronary intervention (PCI).

2. Objectives

Our study aimed to assess LA functional parameters by tissue Doppler parameters of strain and strain rate following PCI.

3. Patients and Methods

This prospective study recruited 77 consecutive patients with coronary artery disease who were candidated for PCI. Patients with atrial fibrillation were excluded. Baseline characteristics were collected by reviewing the recorded files or conducting face-to-face interviews.

All the patients were imaged in the left lateral decubitus position using a commercially available system (Vivid 7, General Electric-Medical systems, Horton, Norway). Images were obtained with a simultaneous ECG signal, using a 3.5-MHz transducer at a depth of 16 cm in the parasternal and apical views. Standard 2-dimensional tissue Doppler images were acquired during a breath hold and saved in a cine-loop format (3 cycles). Analysis of the echocardiographic images was performed offline by a single independent observer using dedicated software (EchoPAC version 108.1.5, General Electric-Vingmed). Longitudinal LA wall deformation was assessed in the apical views using tissue Doppler imaging. The study end point was to assess LA functional parameters such as the regional strain and strain rate of the anterior, inferior, septal, and lateral walls of the LA before and 24 hours after PCI, which were measured by the insertion of the sample volume in the middle of the walls. All the images were recorded with a frame rate of > 100 fps for reliable analysis. Therefore, LA peak systolic longitudinal strain and strain rate were assessed at each mid-LA segment (septal, lateral, anterior, and inferior) in the apical views.

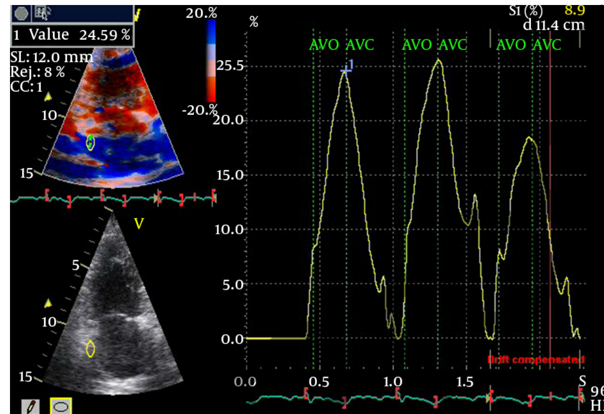
Diastolic function was assessed by obtaining the pulsed-wave Doppler of the mitral valve inflow by placing the Doppler sample volume between the tips of the mitral leaflets. Early (E) and late (A) peak diastolic velocities were measured. The E/E' ratio was obtained by dividing E by E′, which was measured using color-coded tissue Doppler imaging at the septal side of the mitral annulus in the apical 4-chamber view.

The results were presented as mean ± standard deviation (SD) for the quantitative variables and were summarized by frequency (percentage) for the categorical variables. Normal distribution of quantitative variable were checked by Kolmgorov-Smirnov test. Changes in LA indices after PCI compared with those before that were assessed using the paired t-test (for normal distribution variables) or the Wilcoxon test (for non-normal distribution variables). For the statistical analyses, the statistical software SPSS, version 19.0, for Windows (SPSS Inc., Chicago, IL) was used. $P \leq 0.05$ were considered statistically significant (Figures 1 and 2).

4. Results

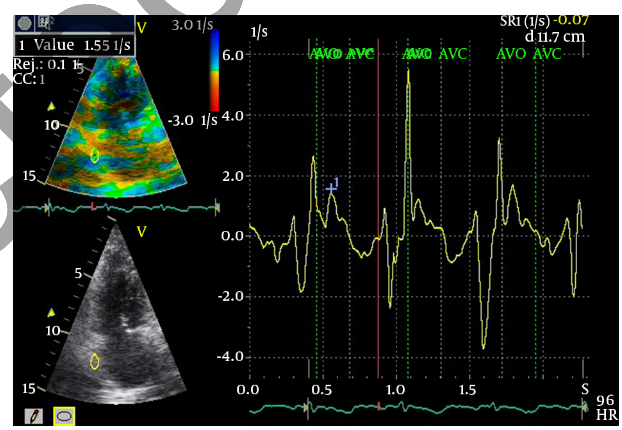
The average age of the patients was 59.71 ± 1.21 years, ranging between 36 and 88 years, and 51.9% of the patients were male. In terms of the number of procedures, 48.1% of the study population underwent 1, 48.1% underwent 2, and 3.9% underwent 3 PCI procedures on their stenotic coronary arteries. Mean LV ejection fraction was 47.01 ± 1.19%, mean LA diameter was 3.31 ± 0.67 cm, mean LA area was 23.20 ± 8.15 mm^2, and mean LA volume was 45.58 ± 13.33 mm^3. The basic characteristics of the patients are depicted in Table 1. Apropos changes in LA functional parameters after PCI, those such as the strain of the septal and the anterior and inferior walls and the strain rate of the anterior and lateral walls significantly increased following PCI, whereas the strain of the lateral wall and the strain rate of the septal wall significantly decreased. Furthermore, the strain rate of the inferior wall remained unchanged (Table 2).

Figure 1. Strain of the Left Atrium by Tissue Doppler Imaging



Peak systolic strain of mid inferior wall of LA is measured; abbreviations: AVC, aortic valve closing; AVO, aortic valve opening.

Figure 2. Strain Rate of the Left Atrium by Tissue Doppler Imaging



Peak systolic strain rate of mid inferior wall of LA is measured; abbreviations: AVC, aortic valve closing; AVO, aortic valve opening.

Table 1. Basic Characteristics of the Patients[a]

Basic Characteristics	VALUE
Age, y	59.71 (1.21)
Left atrial dimension, cm	3.31 (0.67)
Left atrial area, cm^2	23.20 (8.15)
Left atrial volume, cm^3	45.58 (13.33)
Left ventricular ejection fraction, %	47.01 (1.19)

[a]Values are expressed as mean (SD).

Table 2. Tissue Doppler Indices for Left Atrial Function Assessment Before and After Percutaneous Coronary Intervention (PCI)[a]

Index	Pre PCI	Post PCI	P Value
E-wave, cm/sec	60.82 (21.33)	62.47 (21.83)	< 0.001[b]
E'- wave, cm/sec	6.38 (1.91)	6.68 (1.71)	0.001[c]
E/E' ratio	9.79 (2.55)	9.49 (2.59)	0.143[b]
Strain septal, %	27.1 (6.8)	28 (6.5)	< 0.001[c]
Strain lateral, %	30.3 (22.9)	28.1 (6.88)	< 0.001[c]
Strain anterior, %	28.1 (6.45)	28.4 (6.8)	0.012[c]
Strain inferior, %	25.7 (6.8)	28.8 (23.1)	0.004[c]
Strain rate septal, l/s	1.40 (2.9)	1.11 (0.28)	< 0.001[c]
Strain rate lateral	1.11 (0.3)	1.15 (0.32)	< 0.001[c]
Strain rate anterior	1.12 (0.24)	1.17 (0.25)	< 0.001[b]
Strain rate inferior	0.99 (0.24)	1.01 (0.23)	0.090[b]

[a]Values are expressed as mean (SD).
[b]t-test.
[c]Wilcoxon signed-rank test.

5. Discussion

The present study showed that most of LA and LV diastolic function indices improved early post PCI such as the E/E', strain, and strain rate of the LA wall. As was previously pointed, impairment in LA functional parameters has been revealed as a strong prognosticator for long-term adverse cardiac events following cardiac attacks, especially after cardiac revascularization. However, only a few studies have assessed changes in LA parameters following these procedures. To the best of our knowledge, the present study is the first to assess changes in LA parameters after PCI using tissue Doppler indices. In this context, we showed an increase in some LA tissue parameters such as the strain of the septal wall, strain of the lateral wall, strain of the anterior and inferior walls, and strain rate of the anterior and lateral walls, while there was a decrease in some other limited tissue Doppler indices such as the E/E' strain of the lateral wall and the strain rate of the septal wall. Following PCI, changes in most LA functional parameters, not least velocity indices and regional wall motion indices, are expected. Most of the previous studies have focused on the value of LA functional parameters to predict the outcome of patients with AMI or those undergoing cardiac procedures.

Antoni et al. (9) reported that LA maximum volume and LA strain were independently associated with an adverse outcome. In addition, LA strain provided an incremental value to LA maximum volume for the prediction of an adverse outcome. On the other hand, more adverse changes in LA strain or volume could result in a higher rate of long-term morbidities in patients with AMI.

Wierzbowska-Drabik et al. (10) also showed that the highest relative risk of a poor outcome was related to an LA enlargement > 44 mm. Additionally, LA enlargement was an independent predictor for both combined end point and cardiac death.

Ersboll et al. (11) demonstrated the prognostic value of peak atrial longitudinal strain for the prediction of the combined end point of death and hospitalization due to heart failure.

Esmaeilzadeh et al. (12) reported significant differences in LA volume index and strain in patients with systolic heart failure versus normal subjects. Their multivariate analysis of separate walls revealed a significant inverse relationship between LA size and volume and total and regional (2-chamber view) 2D strains of the LA. The authors found that a cutoff value of total average LA strain $\geq$ 23.28% was able to differentiate between normal and abnormal LA function with sensitivity of 93% and specificity of 100% and that a cutoff value of total LA strain = 17.2% (on average) was able to differentiate between mild and moderate and severe diastolic dysfunction with sensitivity of 100% and specificity of 97%. LA strain measurement has been proposed as an alternative method for the estimation of LV filling pressure (13, 14). Decreased LA strain has been correlated with increased LV end-diastolic pressure (13, 15). Cameli et al. (16) demonstrated that in a group of patients with advanced systolic heart failure, the E/Em ratio correlated poorly with invasively obtained LV filling pressures. Nevertheless, LA longitudinal deformation analysis by speckle-tracking imaging correlated well with pulmonary capillary wedge pressure, providing a better estimation of LV filling pressure in this particular clinical setting.

It seems reasonable to conclude that LA 2D strain is a useful noninvasive tool for the evaluation of LA function in patients with systolic heart failure in that it correlates well with diastolic dysfunction and LV filling pressure (17).

The following 2 techniques have dominated the research arena of echocardiography: 1, Doppler-based tissue velocity measurements, frequently referred to as tissue Doppler or myocardial Doppler; and 2, speckle tracking on the basis of displacement measurements (18). Angle dependency is the major weakness of Doppler-based methodology; however, it has the advantage of online measurements of velocities and time intervals with excellent temporal resolution, which is essential for the assessment of ischemia (19).

Speckle-tracking echocardiography or non-Doppler 2D strain echocardiography is a relatively new, largely angle-independent technique that analyzes motion by tracking natural acoustic reflections and interference patterns within an ultrasonic window. The image-processing algorithm tracks elements with approximately 20 to 40 pixels that contain stable patterns and are described as speckles or fingerprints. The speckles, seen in gray scale B-mode (2D) images, are tracked consecutively frame to frame (20, 21). The assessment of 2D strain by speckle-tracking echocardiography is a semiautomatic method that requires definition of the myocardium. Consequently, suboptimal tracking of the endocardial border may be a problem with speckle-tracking echocardiography (22).

Bayat et al. (23) found that improvement in global LV early diastolic filling after PCI was associated with the degree to which impaired regional myocardial relaxation improved in the ischemic segments.

In sum, because changes in LA indices are predictable following PCI and also given the high value of LA parameters for the prediction of an adverse outcome in patients with MI, monitoring changes in LA parameters following PCI using tissue Doppler imaging can be useful for the prediction of further cardiac events in these patients.

5.1. Conclusions

PCI is likely to be accompanied by some early changes in LA functional parameters, which can be demonstrated by post-PCI tissue Doppler imaging. In light of our results, improvement in these indices assessed early after PCI is suggestive of effective revascularization of vessels and improvement in patient outcome.

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Footnotes

Authors' Contribution: Fariba Bayat, designing the study, interpreting the data, writing, revising and submitting the manuscript; Mehdi Nazmdeh, concept and design of the study, data collection, analysis, interpretation, and drafting of the manuscript; Morteza Safi, interpreting the data, revising the manuscript; Amirsaeed Karimi, interpretation of the data and manuscript; Latif Gachkar, doing statistics and data analysis.

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