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ORIGINAL ARTICLE

Longitudinal Tissue Velocity and Deformation Imaging in Patients with Significant Stenosis of Left Anterior Descending Artery

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ABSTRACT

Introduction: Myocardial longitudinal tissue velocity imaging and strain rate imaging indices may have a role in the prediction of significant proximal stenosis of left anterior descending by echocardiography. **Materials and Methods:** Total 20 patients with proximal left anterior descending stenosis >70% by angiography and ejection fraction ≥50%, without wall motion abnormality at resting echo (stenotic group) and 20 angiographically normal coronaries subjects with normal echocardiography (non-stenotic group) were included in the study. Strain rate imaging and tissue velocity imaging were performed in nine segments of the left anterior descending territory at rest. Parameters of interest included: peak systolic strain (%), strain rate (Second^{-1}), and peak systolic velocity (Sm, cm/s). **Results**: Overal mean systolic strain and strain rate showed a significant reduction in the stenotic group compared to non-stenotic group (P<0.001), while the mean Sm had no significant difference. A segment-by-segment comparison revealed a reduction of systolic strain in 4/9 (two apical and two anteroseptal) and strain rate in 5/9 (three apical, septal, and anteroseptal midportion) in the stenotic group (P<0.05). Both systolic strain and strain rate showed a significant reduction in three segments: anterior-apical, lateral-apical, and anteroseptal midportion. **Conclusion**: There is an overall reduction in the mean systolic strain and strain rate in the segments of left anterior descending territory with significant proximal stenosis and normal wall motion at rest and an acceptable specificity and sensitivity of strain rate imaging for the detection of stenosis in these segments.

INTRODUCTION

Tissue velocity imaging (TVI) and strain rate imaging (SRI) parameters have been suggested for quantitative assessments of regional myocardial function. Velocities are measured relative to the transducer; therefore, values depend on the site of measurement and are influenced by overall heart motion (1). SRI measures myocardial deformation (strain) and deformation rate (strain rate) by the Doppler velocity gradient. These parameters are relatively homogenous in all the myocardium regions and are less influenced by cardiac motion (2).

Initial studies have revealed an alteration in diastolic tissue velocities (3) and no significant change in systolic velocities in ischemic regions (1). Consequently, the role of SRI in evaluating infarction at rest and detection of ischemia during dobutamine stress echocardiography has been studied (2, 4). The accuracy of SRI in the assessment of regional myocardial function has also been reported (5). But the role of SRI in evaluating normal functioning myocardium with significant stenosis in the regional artery at rest remains to be determined.

This study compared the SRI and TVI parameters segment by segment between regions with and without significant proximal stenosis in the left anterior descending (LAD) territory via transthoracic and tissue Doppler echocardiography all at rest.

MATERIALS AND METHODS

Study population: This study was conducted between 2012 and February 2015. The study population comprised of

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two groups: group1(stenotic group) which consisted of 20 patients (15 male and 5 female) with angiographically proved stenosis ≥ 70% in the proximal part of the LAD, normal left ventricular (LV) systolic function (left ventricular ejection fraction ≥ 50%), and no wall motion abnormality as assessed by echocardiography. Patients not in sinus rhythm as well as those with bundle branch block or more than mild valvular heart disease were excluded. Group2 (normal group) comprised 20 subjects with angiographically normal coronary arteries (13 male and 7 female) with normal echocardiography. Demographic information including age, sex, history of hyperlipidemia, hypertension, cigarette smoking, and diabetes mellitus was collected.

Two-dimensional echocardiography, SRI, and TVI were performed with an ultrasound scanner VIVID 7D, GE. Three heart cycles of the apical 4-, 3-, and 2-chamber views were captured in conventional 2-dimensional (2D) and color tissue Doppler. The frame rate above 100 ms for SRI, and a 16-segmental model of the left ventricle was used for all the analyses. Off-line analysis was done by two expert cardiologists.

Peak systolic strain (ST) and strain rate (SR) were measured via SRI. Peak systolic velocity (Sm) was measured via TVI. The values are expressed in percentages (ST), seconds^{-1} (SR), and cm/s (Sm). For a quantitative analysis, all the indices were reconstructed from 3 myocardial levels (apical, mid, and basal) including 9 segments in the LAD territory: anterior (basal, midportion, and apical), septal (midportion and apical), anteroseptal (basal and midportion), lateral-apical, and inferior-apical (6).

The SRI and TVI parameters were compared segment by segment between the stenotic and normal group.

To evaluate the intra-observer variability, 10 randomly selected patients were assessed by an observer twice at an interval of two weeks. These 10 patients were assessed by a second observer to obtain inter-observer reproducibility. The inter- and intra-observer variability was calculated by dividing the mean difference between the observations by their average measurement (7, 8).

Statistical analysis: The numerical variables were presented as mean ± standard deviation and were compared using the Student's *t*-test. The categorical variables were summarized in percentages. The probability values of $P< 0.05$ were considered statistically significant. The optimal cut-off values, as well as sensitivity and specificity, were obtained from the receiver operative characteristics (ROC) analysis.

RESULTS

A comparison of basic characteristics between the two groups is shown in Table 1. In the stenotic group, 19 patients underwent coronary artery bypass grafting and 1 patient underwent percutaneous coronary intervention.

SRI: Considering all the segments together, the mean ST was remarkably lower in stenotic group than that in normal group (-13.91± 8.58%; -18.90 ± 7.83%, respectively). In addition, the reduction of mean SR in the stenotic group was also significantly more than normal group (-0.99 ± 0.90; -1.46± 0.63 S^{-1}, respectively). Table 2 illustrates a comparison of ST and SR segment by segment between the two study groups. In the stenotic group, ST showed a significant reduction in 2 apical region segments: anterior-apical, lateral-apical and in 2 anteroseptal segments. In the stenotic group, SR showed a significant reduction in 3 apical segments: anterior-apical and lateral-apical and septal apical, and 2 midportion region segments: septal and anteroseptal midportion. In the basal region, none of the segments showed a significant reduction in SR.

Sensitivity and specificity of SRI: Both ST and SR showed a significant reduction in two apical (anterior and lateral) and one midportion (anteroseptal) segment. The cut-off point of ST and SR was calculated using the ROC analysis (Table 3) which showed that when both ST and SR decreased in one segment, specificity and sensitivity reached 80-95%

Table 1. Comparison between normal and case groups according to basic characteristics.

Basic Characteristics	mean ± SD Patient group (n= 20)	mean ± SD Normal group (n=20)	*P*-value
Mean age (years)	55.58 ± 10.25	52.60 ± 12.37	NS
Male sex	75%	65%	NS
Ejection fraction (%)	58.05 ± 3.873	59.40 ± 10.14	NS
Chest pain	100%	94.4%	NS
Dyspnea	57.9%	50%	NS
NYHA functional class>II	35%	5.0 %	0.044
Family history of CAD	50%	0	<0.001
Smoking	35%	45%	NS
Hyperlipidemia	75%	55%	NS
Hypertension	45%	15%	0.038
Diabetes mellitus	30%	15.8%	NS

Data are expressed as percentages or mean ± SD.
Abbreviations; NYHA: New York Heart Association , CAD: Coronary Artery Disease

Table 2. Comparison of representative SRI and TVI parameters* between two groups with and without significant stenosis in the proximal LAD at rest

Segments	Strain (%)			Strain rate (S^{-1})			Sm (cm/s)		
	With stenosis mean ± SD (n=20)	**Without stenosis mean ± SD (n=20)**	***P*-value**	**With stenosis mean ± SD (n=20)**	**Without stenosis mean ± SD (n=20)**	***P*-value**	**With stenosis mean ± SD (n=20)**	**Without stenosis mean ± SD (n=20)**	***P*-value**
Septal apical	-17.0.0±8.1 (-28.4, 0.3)**	-22.0±8.2 (-42.9, -12.5)	0.063	-0.9±0.9 (-1.9, 1.1)	-1.5±0.7 (-4.0, -1.0)	0..029	2.3±1.0 (0.7, 4.2)	2.2±0.9 (0.5, 4.3)	NS
Anterior apical	-7.7±8.1 (-31.6, 5.5)	-13.5±6.3 (-35.7, -6.3)	0.017	-0.5±1.1 (-3.9, 2.0)	-1.3±0.7 (-3.7, -0.2)	0.008	2.2±1.3 (0.2, 4.7)	2.5±1.4 (0.9, 5.5)	NS
Lateral apical	-7.1±7.1 (-22.3, 0.8)	-15.7±6.3 (-35.0, -9.0)	<0.001	-0.4±0.8 (-1.7, 1.0)	-1.6±0.9 (-4.5, -0.5)	<0.001	3.0±1.9 (1.9, 7.4)	3.5±2.0 (0.4, 7.0)	NS
Inferior apical	-17.1±7.3 (-30.4, -4.3)	-21.1±8.0 (-38.7, -7.4)	NS	-1.4±0.9 (-3.4, 0.8)	-1.5±0.6 (-2.8, -0.6)	NS	2.0±1.1 (0.1, 4.0)	2.5±1.3 (0.2, 4.7)	NS
Septal Midportion	-19.4±5.5 (-30.1, -10.2)	-21.8±7.4 (-36.0, -11.3)	NS	-1.1±0.4 (-2.0, -0.4)	-1.4±0.4 (-2.1, -0.7)	0.043	4.0±1.0 (2.2, 5.8)	4.5±0.9 (2.9, 6.4)	NS
Anterior Midportion	-14.5±6.7 (-29.3, -4.4)	-15.1±6.7 (-31.7, -3.9)	NS	-1.0±0.7 (-2.27, 0.8)	-1.2±0.5 (-2.0, -0.2)	NS	3.6±1.7 (0.7, 8.0)	4.0±1.8 (0.8,7.2)	NS
Anteroseptal midportion	-14.0±10.4 (-36.0, 1.42)	-20.8±8.7 (-32.9, 7.4)	0.008	-0.9±0.6 (-2.5, -0.1)	-1.5±0.5 (-2.3, -0.5)	0.003	3.0±1.6 (0.3, 6.2)	2.9±1.2 (1.4, 5.5)	NS
Anterior basal	-16.8±7.6 (-32.9, -7.5)	-21.0±7.0 (-38.1, -10.1)	NS	-1.4±1.2 (-5.3, 0.6)	-1.8±0.7 (-4.0, -1.2)	NS	6.2±1.7 (3.6, 10.2)	6.5±2.4 (3.8, 14.5)	NS
Anteroseptal basal	-11.5±7.7 (-21.0, 7.3)	-18.2±6.7 (-36.7, -5.5)	0.006	-1.2±0.8 (-3.5, 0.2)	-1.3±0.4 (-2.2, -0.4)	NS	4.6±1.7 (0.4, 7.4)	4.6±1.3 (2.8, 8.0)	NS

Abbreviations; LAD: Left Anterior Descending artery, SRI: Strain Rate Imaging, TVI: Tissue Velocity Imaging, * Data are presented as mean ± SD, **Range of value and 55-60%, respectively, for the diagnosis of stenosis >70% in proximal LAD artery (Table 4).

TVI: The mean peak systolic velocity (Sm) of all the segments in the stenotic group was unremarkably lower than that of the segments in non-stenotic group (3.36 ± 1.99, 3.70 ± 2.01 cm/s; *P*= 0.181). A segment by segment Sm comparison between the groups showed a non-significant difference.

Table 3. Cut-off levels with related areas under ROC curve, sensitivity and specificity of strain and strain rate

Segments	Strain (%)				Strain rate (S^{-1})			
	C	Cut-off	Sen (%)	Sp (%)	C	Cut-off	Sen (%	Spe %)
Septal-apical	-	-	-	-	0.6262	-1.18	50	65
Anterior-apical	0.7700	-9.99	65	75	0.8187	-0.90	85	75
Lateral-apical	0.8575	-10.3	85	80	0.8512	-0.89	70	85
Inferior-apical	-	-	-	-	-	-	-	-
Septal midportion	-	-	-	-	0.6887	-1.26	60	65
Anterior midportion	-	-	-	-	-	-	-	-
Anteroseptal midportion	0.7600	-16.01	75	80	0.7912	-1.03	75	85
Anterior-basal	-	-	-	-	-	-	-	-
Anteroseptal-basal	0.7275	-15.00	65	75	-	-	-	-

Abbreviations; TDI: Tissue Deformation Imaging, TVI: Tissue Velocity Imaging, Sen: Sensitivity, Spe: Specificity C: Area under the ROC Curve

Reproducibility: There was a good reproducibility for the TVI and SRI parameters. The intra-observer variability for ST, SR and Sm was 0.080 ± 0.005% (mean ± SD), 0.050 ± 0.002 S^{-1}, and 0.080 ± 0.005 cm/s, respectively. The inter-observer variability was 0.090 ± 0.006%, 0.140 ± 0.010 S^{-1}, and 0.040 ± 0.001cm/s, respectively.

DISCUSSION

This study showed a reduction of ST in 4/9 and reduction of SR in 5/9 segments in the LAD territory in patients with significant stenosis at resting echocardiography compared to patients without the stenosis. There was no difference in terms of Sm between the segments of the two groups.

Quantitative 2-dimensional color Doppler tissue imaging is a new method to reveal left ventricular and right ventricular longitudinal functions; a potential marker of myocardial disease. Tissue Doppler, strain, and strain rate echocardiography provide a quantification of regional wall motion at rest and during stress (9,10,11).

Many studies have been conducted to evaluate the role of these techniques in detecting regional ischemia during dobutamine stress echocardiography (1, 5, 12). This study compared TVI and SRI parameters at rest segment by segment in the LAD territory between patients with significant stenosis in proximal LAD who have normal wall motion and angiographically and normal subjects. In this design, we found a substantial difference between the mean ST in LAD territory segments with significant stenosis (-13.91 ± 8.58%) and in the same segments without the LAD stenosis (-18.90 ± 7.83%). In addition, the difference in mean SR was significant between the two groups (-0.99 ± 0.90 and -1.46 ± 0.63 S^{-1}, respectively). Voigt JU et al. (1) reported a mean ST of -17 ± 6% and SR of -1.6 ± 0.6 S^{-1} in non-ischemic and a mean ST of -16 ± 7% and SR of -1.6 ± 0.8 S^{-1} in ischemic segments at a baseline evaluation of the LV with no significant differences. They defined ischemia as an ischemic response to dobutamine.

We performed a segment-by-segment comparison between the LAD territory segments with and without stenosis in proximal LAD in a different setting and found a significant reduction in ST in half (2/4) of the apical segments. We also found a significant reduction in ST in anteroseptal wall (2 segments). Overall, 4/9 of the segments in the stenotic LAD region had ST reductions; and in the remaining segments, there was a reduction, although non-significant.

In this study, SR had a significant reduction in 3/4 of the apical segments in the stenotic group. The SR of the septal and anteroseptal mid portion was also remarkably lower, while no remarkable reduction in SR was found in the other segments. Overall, 5/9 of segments in the stenotic group had SR reduction with a non-significant reduction in the remaining segments.

In TVI parameters, we found no remarkable difference in Sm between the stenotic and non-stenotic groups at rest, which is in line with previous reports in humans (1, 13). However, a previous study showed that during ischemia, myocardial peak systolic velocity, strain, and strain rate decreased (12). Urheim S. et al. showed that in dogs with LAD occlusions, peak velocities decreased and the strain was positive in the apical but not in the basal segments during the systolic phase (14).

In our study, despite a remarkable reduction in the mean

ST and SR in some of the stenotic group at rest, they overlapped with ST and SR ranges of the same segments in non-stenotic cases (Table 1). We can conclude that normal values of these indices may be found, but reduced values can suggest significant stenosis of proximal LAD in the presence of normal wall motion. A more detailed analysis showed a cut-off level of each of the indices with reasonable sensitivity and specificity in every related segment. In three segments with concomitant reductions in both ST and SR below the cut-off levels, specificity reached 95% and sensitivity to 60% for the detection of stenosis in proximal LAD.

The main advantage of this study is the segment-by-segment comparison between stenotic and non-stenotic groups at rest. Separate cut-off values for each segment with reduced ST or SR were presented; nonetheless, reductions in ST or SR were not observed in all the stenotic LAD territory segments. A recently published article concluded that mean and segmental SRs and segmental strain independently predicted mortality over a 7-year follow-up in a study of 646 patients undergoing dobutamine stress echocardiography (15).

CONCLUSION

This study demonstrated an overall reduction in the mean ST and SR in the segments of LAD territory with significant proximal stenosis and normal wall motion at rest. A reduction in SRI in the resting echocardiography may suggest remarkable stenosis of proximal LAD with normal motion. Further studies are required to investigate the usefulness of myocardial deformation imaging in a resting echo for the identification of coronary occlusion.

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None

Table 4. Cut-off levels disclosing sensitivity and specificity of TDI and TVI indices in individual segments in identifying significant stenosis in the proximal LAD.

Segments	Parameters	Sen (%)	Sp (%)	Accuracy%	Area under the ROC curve
Septal-apical	SR≥-1.18	50	65	55	-
Anterior-apical	ST≥-9.99 and SR≥-0.90	55	80	67.5	0.6750
Lateral-apical	ST≥-10.30 and SR≥-0.89	55	95	75	0.7500
Inferior-apical	-	-	-	-	-
Septal midportion	SR≥-1.26	60	65	63	-
Anterior midportion	-	-	-	-	-
Anteroseptal midportion	ST≥-17.64 and SR≥-1.03	60	90	75	0.7500
Anterior-basal	-	-	-	-	-
Anteroseptal-basal	ST≥-15.00	60	85	0.70	-

Abbreviations; TDI: Tissue Deformation Imaging, TVI: Tissue Velocity Imaging, Sen: Sensitivity, Sp: Specificity

AUTHOR CONTRIBUTIONS

Authors contributed equally in this study.

CONFLICT OF INTERESTS

None

ETHICAL STANDARDS

The study protocol has been approved by our institutional review board.

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