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DIAGNOSTIC VALUE OF 2D STRAIN IMAGING IN PATIENTS WITH SUSPECTED CORONARY ARTERY DISEASE

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Abstract

Background and Objectives: Strain imaging (SI) has been shown to quantify regional myocardial function in both acute ischemic myocardium and infarcted myocardium. The aim of this study is to determine the diagnostic value of SI for the detection and localization of coronary lesions in patients with chest pain, but without apparent wall motion abnormalities.

Methods: SI for advanced wall motion analysis was performed in 59 patients with suspicious stable angina (SA) and in 57 patients with suspicious unstable angina (UA), prior to coronary angiography. All the patients had normal conventional wall motion scoring. Longitudinal strain was measured in 3 apical views, and assessments of the strain value for individual segments with using an 18-segment division of the left ventricle were performed to determine the average strain value. For the identification of ischemia a magnitude parameter, being defined as a reduction of the peak systolic strain, was used. A homogenous pattern or constant strain was defined as relatively uniform distribution of the peak systolic strain. Heterogeneity of strain was considered abnormal; these segments were called the strain-positive segments and the rest of the segments were called strain negative. Significant coronary artery disease (CAD) was considered present if stenosis above 70% was noted on the quantitative angiography.

Results: Of the 59 SA patients, 28 had >70% stenosis (ischemic-SA) and 31 had normal coronary anatomy or 50% stenosis (normal-SA). Of the 28 patients in the ischemic-SA group, 9 patients (32%) showed a homogeneous pattern of peak systolic strain throughout the wall (strain negative) and 19 patients (67%) showed heterogeneity of strain (strain positive). Of 31 patients with normal coronary anatomy or <50% stenosis (normal-SA), 6 patients (19%) showed heterogeneity of strain (strain positive) and 25 patients (80%) showed a homogeneous pattern of peak systolic strain throughout the wall (strain negative). The positive predictive value of strain was 76% in the SA group.

Of the 57 UA patients, 32 had >70% stenosis (ischemic-UA) and 25 had normal coronary anatomy or 50% stenosis (normal-UA). Of the 32 patients in the ischemic-UA group, 7 patients (22%) were determined to be strain negative, and 25 patients (78%) were determined to be strain positive. Of 25 patients with normal coronary anatomy or 50% stenosis (normal-UA), 25 patients (80%) showed a homogeneous pattern of peak systolic strain throughout the wall (strain negative) and 6 patients (19%) showed heterogeneity of strain (strain positive). The positive predictive value of strain was 78,1% in the UA group.

Sensitivity and specificity of 2D strain was evaluated using diagnostic test. The results were: 76% and 80,6% respectively in the stable angina group and 78,1% and 73% respectively in the unstable angina group.

Conclusion: Ultrasound-based SI demonstrates a strong correlation with coronary angiography and it has potential as a noninvasive diagnostic tool for detecting CAD in patients with chest pain, but who are without apparent wall motion abnormalities on conventional echocardiography.

Key words: Coronary artery disease (CAD); Echocardiography; Strains.

Introduction

Evaluation of left ventricular (LV) regional ischemia was traditional based on the visual assessment of wall motion and wall thickening, which were derived from two-dimensional (2D) grayscale imaging.

This echo technique has its limitations, with relatively high for both intra-observer and inter-observer variability (1), and the limited ability of the human eye to resolve rapid and short-lived myocardial motion (2). Acute myocardial ischemia induces a delay in the

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onset of the contraction, a progressive decrease in the rate and degree of thickening and a progressive delay in the timing of the peak thickening. Finally, systolic thickening is virtually or completely abolished by total occlusion, and only late systolic/early diastolic thinning occurs (3). Another approach to define the regional myocardial properties could be to evaluate the deformation of a myocardial segment during the cardiac cycle. Two parameters that reflect myocardial deformation properties can be extracted from the cardiac ultrasound data: the regional strain and the strain rate (3).

In this investigation, we aimed to evaluate the relative diagnostic value of the strain parameters for detecting ischemic changes in the myocardium with normal wall motion scores on conventional echocardiography. Our goals were to determine whether the strain parameters would help detect ischemia at rest and if these parameters could present useful information before performing coronary angiography.

Methods

Patients

In this study were prospectively enrolled 59 consecutive patients (36 (61%) men and 23(39%) women, age 59±12 years) with suspected stable angina (SA) and 57 patients (38(66,7%) men and 19 (33,3%) women, age 60±9 years) with suspected acute coronary syndrome (ACS) awaiting for elective coronary angiography. All included patients had normal global conventional wall motion scoring (WMS) based on the standards of the American Society of Echocardiography. Patients with a prior history or electrocardiogram (ECG) signs of transmural myocardial infarction, dilated cardiomyopathy, myocardial hypertrophy, significant valve disease, atrial or ventricular arrhythmia, pacemaker implantation, bundle brunch blocks, apparent wall motion abnormality or LV ejection fraction (EF) less than 50% were not included in the study.

Echocardiographic data acquisition

Echocardiographic studies were performed with a MyLab 60, Esaote equipment. The left ventricular chamber size was obtained in the M-mode, and the ejection fraction was determined using the modified Simpson method.

All the patients' images (routine 2D grayscale and 2D speckle-tracking) were recorded at 3 apical views prior to coronary angiography. We performed real-time analysis of the longitudinal peak systolic strain of the individual segments using an 18- segment division of the left ventricle (each wall in each apical view was divided into the basal, middle and apical segments). For the identification of ischemia a magnitude parameter, being defined as a reduction of the peak systolic strain, was used. A homogenous pattern or constant strain was defined as relatively uniform distribution of the peak systolic strain (Fig 1). Heterogeneity of strain was considered abnormal; these segments were called the strain-positive segments and the rest of the segments were called strain negative.

Coronary angiography

The coronary angiography was quantitatively analyzed, and significant coronary artery disease (CAD) was defined if the stenosis was more than 70% of the lumen diameter. The normal coronary group was defined as there was no stenosis or the stenosis was <50% of the lumen diameter. If the patients had stenosis that was more than 50% and under 70%, then they were not included in the study. The demographic data, including age and gender, as well as cardiovascular risk factors, were recorded.

Statistical analysis

All the data is expressed as means ± standard deviations (SDs). The data was analyzed using standard statistical software (Statistical Package for Social Science; SPSS package version 11.0), and comparisons of all measurements were done with a paired Student's t-test for the continuous variables. Sensitivity, specificity and VPP (positive predictive value), were used to evaluate the efficacy of the diagnostic test.

A $p \leq 0.05$ was considered to indicate significance.

Results

The major demographic and clinical characteristics of SA and ACS are given in Table 1.

Table 1. The demographic and clinical characteristics

CVD Risk factors	Stable angina (n=59)	Unstable anginal (n=57)
Age (years)	59±12*	60±9
Gender (M/F)	36/23	38/19
Hypertension (%)	41 (69)±	38(66)
Diabetes mellitus (%)	29 (49)	38(63)
Smoker (%)	27 (45)	32 (54)
Heart rate	66±12	62±17
Ejection fraction (%)	64.4±4.3	63.6±8.3
Left ventricular mass index (g/sqm)	122.4±22.7	108.2±13.8

* values are means ± SDs
± number (percentage)

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The peak systolic strains in the normal coronary group were relatively homogenous throughout the left ventricle (Fig 1). The peak systolic strains in the patients with significant coronary artery disease showed a marked heterogeneous pattern (Figs. 2 and 3) and this strain was significantly decreased in the ischemic segments as compared with the corresponding nonischemic segments (Table 2).

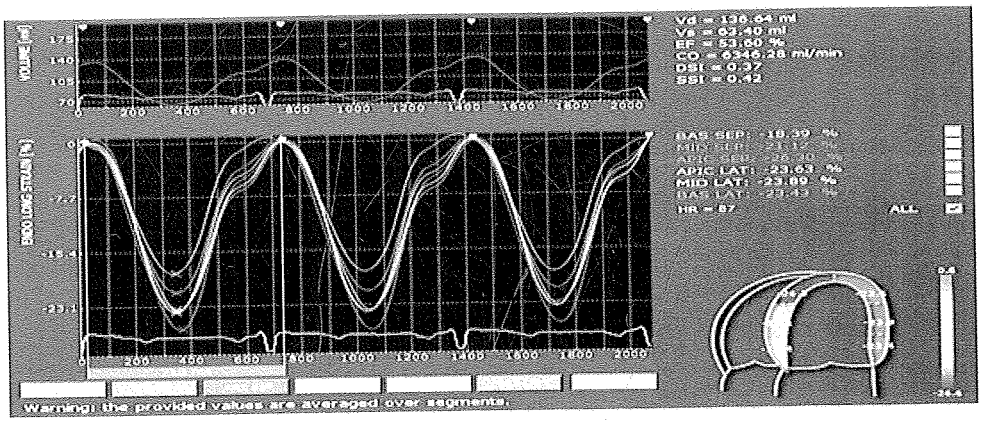

Fig 1. Strain echocardiography in a patient with normal angiography shows a relatively homogeneous pattern of peak systolic strains throughout the LV in the apical 4-chamber view

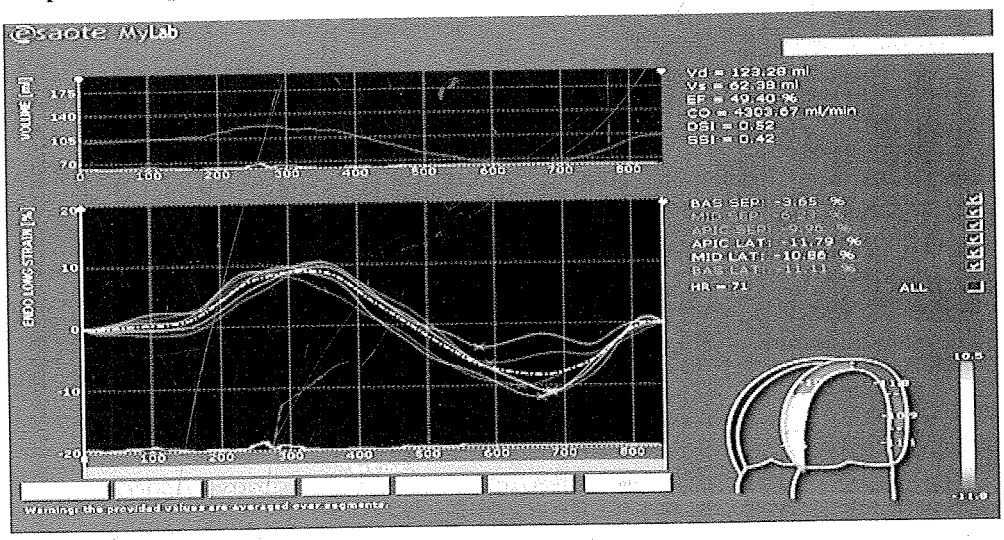

Fig 2

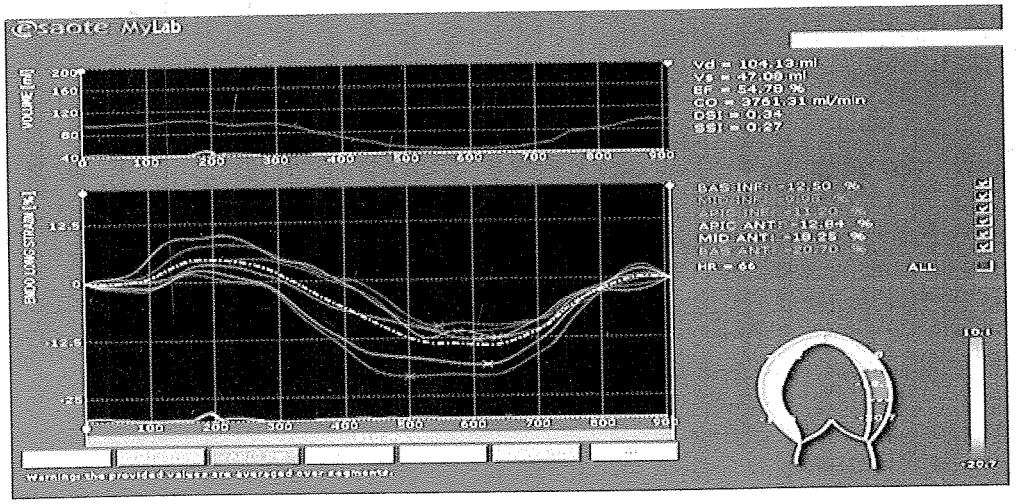

Fig. 3. Strain echocardiography in a patient with significant left anterior descending coronary artery stenosis and right coronary artery stenosis shows a marked heterogeneous pattern of peak systolic strain in the apical 4-chamber view (Fig 2) and the apical 2-chamber view (Fig 3).

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Table 2. Comparison of regional peak systolic strain between the normal segments and the ischemic segments at the 4-chamber views

Apical view	Normal	Stenosis	p*
Basal septum	-16.12±4.6	-3.65±1.3	<0.01
Mid septum	-18.3±4.3	-6.23±3.2	<0.01
Apical septum	-18.8±3.7	-7.1±1.4	0.04
Apical lateral	-17.4±8.1	-8.8±4.9	0.03
Mid lateral	-16.7±5.2	-7.4±3.7	<0.01
Basal lateral	-17.7±6.9	-8.2±2.6	0.01
Basal inferior	-16.3±7.4	-4.5±3.3	<0.01
Mid inferior	-17.8±4.9	-6.8±2.3	<0.01
Apical inferior	-18.2±5.3	-7.3±4.1	<0.01
Apical anterior	-17.4±4.5	-6.5±3.7	0.01
Mid anterior	-16.3±2.8	-5.3±2.4	<0.01
Basal anterior	-16.6±3.6	-4.3±5.2	<0.01
Basal posterior	-16.2±7.3	-7.8±2.6	0.01
Mid posterior	-16.3±4.8	-6.1±3.4	0.03
Apical posterior	-17.2± 6.4	-4.5±4.0	<0.01
Apical ant.septum	-15.6±7.3	-4.3±6.2	<0.01
Mid ant.septum	-14.9±4.2	-5.3±2.7	<0.01
Basal ant.septum	-14.8±5.6	-3.6±3.4	<0.01

*t-test for two independent samples

Of the 59 SA patients, 28 had >70% stenosis (ischemic-SA) and 31 had normal coronary anatomy or 50% stenosis (normal-SA). Of the 28 patients in the ischemic-SA group, 9 patients (32%) showed a homogeneous pattern of peak systolic strain throughout the wall (strain negative) and 19 patients (67%) showed heterogeneity of strain (strain positive).

Of 31 patients with normal coronary anatomy or 50% stenosis (normal-SA), 6 patients (19%) showed heterogeneity of strain (strain positive) and 25 patients (80%) showed a homogeneous pattern of peak systolic strain throughout the wall (strain negative). The predictive positive value of strain was 76% in the SA group.

Of the 57 UA patients, 32 had >70% stenosis (ischemic-UA) and 25 had normal coronary anatomy or 50% stenosis (normal-UA). Of the 32 patients in the ischemic-UA group, 7 patients (22%) were determined to be strain negative, and 25 patients (78%) were determined to be strain positive.

Of 25 patients with normal coronary anatomy or 50% stenosis (normal-UA), 25 patients (80%) showed a homogeneous pattern of peak systolic strain throughout the wall (strain negative) and 6 patients (19%) showed heterogeneity of strain (strain positive).

The predictive positive value of strain was 78,1% in the UA group.

Table 3. Comparison of strain imaging and coronary angiography in patients with chest pain

	Stable angina (n=59)		
	Strain positive (n=25)	Strain negative (n=34)	
Significant coronary stenosis (%)	19 (76%)*	9 (26%)	VPP=76% Sensitivity 76%
Normal CAG (%)	6 (24%)	25 (74%)	Specificity 80.6%
	Unstable angina (n=57)		
	Strain positive (n= 31)	Strain negative (n=26)	
Significant coronary stenosis (%)	25 (80%)	7 (27%)	VPP=78,1% Sensitivity 78,1%
Normal CAG (%)	6 (20%)	19 (73%)	Specificity 73,1%

CAG: coronary angiography
* (percentage in columns)
Sensitivity and specificity of 2D strain was evaluated using diagnostic test. The results were: 76% and 80,6% respectively in the stable angina group and 78,1% and 73% respectively in the unstable angina group.

Discussion

Echocardiographic strain and strain-rate imaging (deformation imaging) is a new non-invasive method for assessment of myocardial function. Strain and strain-rate describe wall deformation. The amount of deformation (positive or negative strain) is usually expressed in %. Positive strain values describe thickening, negative values describe shortening, of a given myocardial segment related to its original length. During myocardial contraction, as the wall shortens it also thickens and thus assessment of all parameters, radial thickening (positive strain), circumferential shortening (negative strain) and longitudinal shortening (negative strain), is useful

for the evaluation of contractile function. Strain rate (SR) is the rate by which the deformation occurs (deformation or strain per time unit) (4). Due to its ability to differentiate between active and passive movement of myocardial segments, to quantify intraventricular dyssynchrony and to evaluate components of myocardial function, such as longitudinal myocardial shortening, that are not visually assessable, it allows comprehensive assessment of myocardial function and the spectrum of potential clinical applications is very wide. The high sensitivity of both tissues Doppler imaging (TDI) derived and two dimensional (2D) speckles tracking derived myocardial deformation (strain and strain rate) data for the early detection of myocardial dysfunction recommend these new non-invasive diagnostic methods for extensive clinical use.

Non-Doppler 2D-strain imaging derived from speckle tracking is a newer echocardiographic technique for obtaining strain and SR measurements. The advantage of this method is that it tracks in two dimensions, along the direction of the wall, not along the ultrasound beam, and thus is angle independent (5). The longitudinal systolic strain/rate has been shown to be linearly correlated with the maximal value of the first LV pressure time derivative and also with the peak elastance, which are both global measures of LV systolic function and contractility (6,7).

Similar to tissue velocity imaging, strain echocardiographic imaging can be accomplished in real time, thus facilitating its clinical feasibility (8). The normal values for LV longitudinal shortening (9), correspond well with our measurements: 19% for the average peak systolic strain versus 16.8% in our study. The slightly lower values of strain in our study would be due to the larger proportion of patients with hypertension and diabetes mellitus in our enrolled patients; and these diseases are known to cause abnormalities in tissue velocities. Myocardial strain is relatively independent of translational motion and other through-plane motion effects, and it should be relatively homogeneous throughout the normal LV myocardium (10). As opposed to normal hearts, the LV of the ischemic heart in our study was characterized by marked heterogeneity of myocardial systolic strain, and speckle tracking imaging demonstrated reduced shortening or stretching in the interrupted vessel territories. This was in contrast to the non-ischemic region, where near-normal shortening was observed. The present study suggests that examination of systolic deformation with 2D strain echocardiography may have significant diagnostic benefit for patients who have chest pain during effort and at rest. This study has several limitations. It was not blinded and some analysis of the strain parameters might be dependent on the clinical information. Therefore, further large-scale, blinded studies are required. Third, as was mentioned, the values of the strain for the patients with stenosis more than 50% and under 70% were not analyzed to get a more unambiguous result, among several strain parameters, we analyzed only the peak systolic strain because of signal noise, so the strain rate values were not compared with peak systolic strain and the coronary angiography results.

Conclusion:

Ultrasound-based strain imaging demonstrates a strong correlation with coronary angiography and it has potential as a noninvasive diagnostic tool for detecting coronary artery stenosis in patients with chest pain, but who are without apparent wall motion abnormalities on conventional echocardiography. This study is the first to compare the diagnostic value of strain echocardiography with coronary angiography in patients with suspected CAD in Albania.

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