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# Two-dimentional speckle tracking strain imaging in the assessment of myocardial diastolic function in patients with stable angina pectoris

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**ABSTRACT**

**Introduction:** Ischemic heart disease is caused mainly by obstruction of coronary arteries. The ischemic assessment through echocardiography is dependent on wall motion abnormality detection during systole. In patients with ischemic heart disease the diastolic function is impaired before systolic function and measurement of regional diastolic dysfunction if possible will be most sensitive for assessment of obstructed coronary artery region. This study was designed to determine whether regional left ventricular delayed relaxation diagnosis could be detected with strain imaging derived from two-dimensional speckle tracking echocardiography in patients with coronary artery disease.

**Methods:** All the articles reviewed were obtained using MEDLINE & ScienceDirect (up to October 2014). All data extracted by speckle tracking echocardiography. The index which is used is strain imaging diastolic index which is calculated as: (A-B) A×100. A is the amount of strain at the time Aortic value closure and B is the amount of strain in first one-third point of diastolic duration.

**Result:** Four articles were reviewed. Three articles assessed patients with echocardiography at rest and one with stress echocardiography. All articles showed the coronary artery tracking with significant stenosis is possible by regional deformation analysis through two-dimensional strain.

**Discussion:** The usage of strain images obtained through two-dimensional speckle tracking has been validated for the quantitation assessment of regional dysfunction in ischemic heart disease. Regional LV delayed relaxation diagnosis with strain imaging is a reliable method after treadmill stress test.

**Conclusion:** Strain imaging is reasonable for evaluation of ischemia as a low cost noninvasive test with high accuracy.

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## Introduction

Ischemic heart disease (IHD) is caused mainly by obstruction of coronary arteries due to atheromatous plaque and it's main symptom is chest discomfort. It usually become worse by activities and it is related to an impairment in myocardial function. The patient usually feels the pain in retrosternal region, but it commonly radiates and is felt down the ulnar surface of the left arm, right arm and the outer surfaces of both arms. This pain usually grows step by step and maximizes in

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a few minutes and is relieved soon by resting or the use of short-acting nitroglycerin.

49% of men and 32% of women are suffering from symptomatic coronary artery diseases (CAD) after the age of forty (1).

The increase of annual income is accompanied with the population increase in cities and the rate of obesity in Middle East (including in Iran), the cardiovascular disease mortality is increasing quickly and the CAD is the main cause of death (25-45%) in this region.

A high fiber and low fat diet is being transfered to western diets. And in recent decades daily fat consumption has increased in these countries (2).

CAD is the main cause of mortality throughout the world and thus it's accurate assessment is vital.

Diagnostic procedures for this disease are invasive and noninvasive tests. Among noninvasive tests we can name stress tests which gives useful information about diagnosis confirmation, exercise capacity and tolerance, prognosis and also the ischemic severity (1).

Echocardiographic images are so valuable for the assessment of cardiac function because it is dynamic (3). The myocardial ischemic assessment through echocardiography is dependent on the wall motion abnormality detection and wall thickness reduction during systole. Traditionally this assessment is done visually and therefore is subjective (4).

Echocardiographic CAD diagnosis is usually dependent on stress tests, because the systolic impairment is not always visible at rest unless if infarcted myocardium exists. Stress echocardiography is the started method for coronary artery disease diagnosis (5).

On the other hand in patients with IHD the diastolic function is impaired before systolic function and the measurement of regional diastolic dysfunction if possible will be most sensitive for assessment of obstructed coronary artery region(6).

Visual analysis of wall motion abnormality is not capable to assess diastolic dysfunction accurately (7,8). Therefore new automated techniques has been created for advance analysis of cardiac mechanics. Due to difference in interpretations in last decades two such technique has been demonstrated in echocardiographic research fields. 1) The measurement of tissue velocity base on Doppler 2) speckle tracking base on displacement measurement (3). It has been reported that the modern echocardiographic technology in combination with standardized image processing and uniform reading criteria has resulted to more coordination in echocardiographic interpretation in compared to previous reports (9). Speckle tracking echocardiography (STE) is based on tracking of frame myocardial speckles in grayscale images. Speckles are very small structure in images which are visible after noise filtering. STE can be used for myocardial velocity and strain measurement (10). This technique is not limited to angle like TDI. And is obtained from 50-80 frame rate per second images. Velocity vector imaging is base on the similar principle and deformation measurements has been validated by vector velocity imaging against sonomicrometry (11).

The index which is used in many studies to analysis strain images is strain imaging diastolic index (SIDI) which is calculated as follows:

(A-B)A×100.

In this equation A stands for the amount of strain at the time Aortic value closure and B stands for the amount of strain in first one-third paint of diastolic duration (12).

## Methods

The search was carried out with these keywords: diastolic dysfunction AND strain imaging AND ischemic heart disease (Figure 1). All the articles reviewed here were obtained using MEDLINE & SScienceDirect (up to October 2014), all were controlled trials with consensus on patients with CAD confirmed by selective coronary angiography. The studies had focused on those with suspicious CAD cases without any significant valvular disease, conduction abnormalities, pacemaker, ongoing arrhythmia, congenital heart disease, previous cardiac surgery, emergency angiograms, hemodynamic instability. The collected data have been summarized in Table 1.

## Result

In a research done by Liang et all. In 2006 the

**Figure 1.** PRISMA flowchart of the study

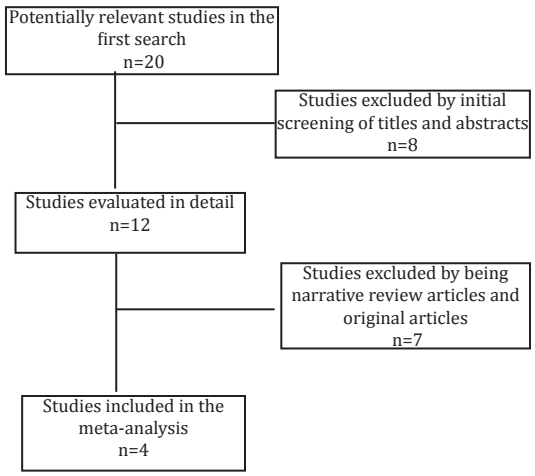

**Table 1**. The results and the study characteristics of four articles that were reviewed

| Author Year | Type of study | Number of patients | *CAD group characteristics | Method confirming CAD | Segments of study |
|---|---|---|---|---|---|
| Liang 2006 (8) | Prospective, controlled study | 61 | Patients referred for a clinically indicated-coronary angiogram witn no moderate or severe valvular disease, conduction abnormalities, pacemaker, ongoing arrhythmia, congenital heart disease, previous cardiac surgery, emergency angiograms, hemodynamic instability. | Coronary angiography | 3 standard apical views |
| Kimura 2011 (5) | Retrospective controlled study | 85 | Patients with probable CAD, **EF>50 which had undergone coronary angiography and echocardiography with no EF < 50%, myocardial infarc- tion, previous cardiac surgery, non-sinus rhythm, conduction abnormalities, left main trunk stenosis, significant valvular heart disease. | Coronary angiography | Three major coronary perfusion territories were assigned as defined in the American Society of Echocardiography guidelines |
| Ishii 2009 (7) | Prospective, controlled study | 162 | Patients who had Canadian Cardiovascular Society Classification II stable effort angina and normal ***LV wall motion detected by standard echocardiography without unstable angina, left main trunk disease, previous myocardial infarction, previous cardiac surgery, artificial pacemaker, nonsinus rhythm, significant valvular heart disease, chronic obstructive pulmonary disease, or congestive heart failure | Coronary angiography | Three major coronary perfusion territories were assigned as defined in the American Society of Echocardiography guidelines |
| Ishii 2009 (17) | Prospective, controlled study | 35 | Patients with stable angina in whom elective ****PCI procedures were performed without electrocardiographic evidence of transmural myocardial infarction, previous coronary bypass grafting, a coronary collateral Rentrop classification of 2 or 3, atrial or ventricular arrhythmia, pacemaker bundle branch block, significant valvular heart disease, or congestive heart failure | Coronary angiography | Three major coronary perfusion territories were assigned as defined in the American Society of Echocardiography guidelines |

*CAD: coronary artery disease; **EF: ejection fraction; ***LV: left ventricle; ****PCI: percutaneous coronary intervention

objective was to analyse the impact of stenosis of more than 70% of coronary arteries on deformation of the regional diastolic function during rest by the usage of strain echocardiography. In this research the patients underwent echocardiography in 24h after the angiography and strain and strain rate in systole and diastole were measured. 39 patients out of 61 participants had coronary artery stenosis more than 70% and 15 subjects had normal coronary arteries. Systolic and diastolic strain rate reduced significantly in ischemic regions in comparision to the normal regions. This research concluded that the coronary artery tracking whit significant stenosis is possible by regional deformation analysis through two dimentional strain at rest. The altered diastolic deformation revealed the ischemic territories with higher specificity. Control and ischemic subjects were matched for invasive left ventricular and aortic pressures and noninvasive hemodynamic details. The control subjects were not patients with low possibility of cardiovascular disease and this might affect on sensitivity of two dimentional speckle tracking echocardiography parameters (8).

In another research by Kimura et all. Which was carried out in 2011 the goal was to determine coronary artery stenosis in clinical patients by SI-DI at rest. 85 patients with probable CAD, EF>50 which had undergone coronary angiography and echocardiography were studied retrospectively. They observed that the SI-DI decreases significantly in regions with sever stenosis (more than 75%) but the peak strain was stable. This research proved that SI-DI is a new strategy for sever coronary stenosis diagnosis. They showed that even a mild stenosis may cause ischemic changes in diastolic dysfunction. Coronary branch stenosis and also anatomic variations were ignored in this study which may impact the myocardial function (5).

A research was done by Ishii et all in 2009 in order to study LV relaxation delay after ischemia by 2D strain echocardiography images in patients with stable angina. The changes in regional LV strain curve in the first one-third of diastolic duration was measured in 162 patients with stable angina 5 and 10 minutes after the exercise test. SI-DI and SI-DI ratio (SI-DI before and after the test) was used in order to demonstrate regional LV delayed relaxation. 117 patients had significant coronary artery stenosis. The average SI-DI decrease in 191 patients with significant stenosis in coronary perfusion territory while it did not

change in 280 patients with non significant stenosis. Regional delayed relaxation was observed in 85% of subjects with significant stenosis in coronary perfusion territory 10 minutes after the exercise. They concluded that determining regional LV delayed relaxation after the treadmill test by strain imaging is a sensitive and reliable method for CAD diagnosis. It has recently been reported that regional tardorelaxation has been observed after the treadmill stress test in patients with stable exertional angina and CAD and even remained an hour after the exercise while systolic function had completely become normal (7).

In another study that Ishii et al performed in 2009 their objective was to assess regional LV function in systole and diastole after PCI by strain imaging. Peak transverse strain and strain in first one-third of diastolic duration (SI-DI) was studied in 30 CAD patients. The result of the strain data in the involved segments was compared with values obtained from normal segments. It was observed that coronary artery stenosis significantly decreases systolic strain in proximal and distal segments and systolic disorders approached the normal values just after reperfusion. Even so proximal and distal SI-DI values decreased 35 minute after the reperfusion and was still lower in distal segments 24h after the reperfusion. This study shows that diastolic stunning remain despite the complete recovery of systolic function after reperfusion. This study was done with a small population of patients which may reduce the power of statistical inference and it remained undetermined that how long the regional diastolic dysfunction persists after reperfusion (13).

## Discussion

### *Strain clinical application in CAD*

Regional diastolic function assessment like systolic function disturbance is an old concept in CAD. But nowadays it is become possible through TDI and strain imaging (14).There are increasing evidences that ischemia causes regional diastolic mechanical dysfunction and is diagnostic through new echocardiographic technique and these changed patterns can inhance the diagnosis of CAD by echocardiography (15). The usage of strain images obtained through 2D speckle tracking (2DST) has recently been validated for the quantitation assessment of regional dysfunction in IHD (9,16,17). During ischemia the diastolic regional function is disturbed faster than systolic regional function (13). Delay in diastolic relaxation caused by ischemia has been demonstrated regionally in the territory of the perfusion of involved vessel in animal and clinical models (6,8,18-21). Studies has suggested that it is possible to reveal myocardial ischemia by detecting regional motion abnormality in diastole or tardorelaxation through 2DST. The regional delayed relaxation site is coordinated with the territory of the vessel which causes angina (13).

### *STE in stress echocardiography*

Most of the information released about the diastolic mechanic in CAD are concentrated on dysfunction during rest. An important diastolic mechanic role is for CAD diagnosis can be in stress echocardiography (15). There have always been discussions about the strain validity obtained through speckle tracking in stress echocardiography due to lower frame rates compare to the obtained strain by TDI. However the obtained strain from speckle tracking has recently been approved in a study on stress echocardiography with Dobutamine. In this research the correlation among sonomicrometry and strain obtained from speckle was the highest for longitudinal strain and lowest for radial strain (22).

### *Diastole as a memory*

Diastolic stunning assessment may be a new ischemic diagnostic approach (23). Dongdong et all. 2013 conducted an experiment on lab animals, proved that the regional diastolic dysfunction persistency is longer compare to regional systolic dysfunction after prolonged ischemia witch suggests that recent myocardial ischemia can be diagnosed via regional diastolic assessment (24). It was shown Azevedo et all study that the persistence of diastolic dysfunction with cardiac MRI lasts 48h after episodic ischemia in injured non-infarcted segments (25). Neizel et all reported that diagnose regional diastolic dysfunction by cardiac MRI lasts even 6 months after the successful reperfusion of acute myocardial infarction (26).

### *Sensitivity and Specificity*

Schuijf et all conducted is studies with a population of 1849 patients and discovered 84% sensitivity and 82% specificity for CAD detection by dobutamine tress echocardiography (27). A recent study evaluated CAD detection with perfusion Dipyridamole echocardiography by a new ultrasound imaging instrument in comparison with perfusion imaging. The accuracy of perfusion echocardiography (66-71%) was not inferior to radionuclide imaging (67-70%) (28). LV diastolic dysfunction is sensitive and is also an early sign of myocardial ischemia and remains longer than systolic dysfunction. Diastolic deformation analysis with the usage of strain echocardiography can improves the accuracy of echocardiography in significant CAD detection (7,13). Wijns and et all reported that diastolic component may have

a lower threshold than the systolic component for ischemia detection. Therefore the region which is less damaged may only show diastolic dysfunction (29). In Kimura et all.2011 study, transverse SI-DI at rest showed 79% sensitivity and 73% specificity for sever CAD (5). In Ishii et all's 2009 study SI-DI ratio had 97% sensitivity and 93% specificity for stenosis detection more than 50%. Regional LV delayed relaxation diagnosis with strain imaging is a sensitive and reliable method after treadmill stress test (7).

### *Limitation*

The success of this new algorithm depends on the quality of 2D echocardiography images (10). Image quality may change the test accuracy. The presence of other circumstances like HTN and cardiomyopathies may also alter the accuracy of the test. In most studies major vessel territories are appointed with one segment. Diastole is severely affected by heart rate and no study has been done for tachycardia impact on diastolic strain. Moreover, diastolic dysfunction remains in recovery phase for a long time and the heart rate is low in this phase. So worrying about heart rate may not be appropriate (12).

## Conclusion

Using strain imaging for assessment of regional diastolic dysfunction has limitations. Although it is a non invasive method and has accebtable sensitivity and specificity. During ischemia the diastolic regional function is disturbed faster than systolic regional function and persists so longer. Thus, strain imaging is reasonable for evaluation of ischemia as a low cost noninvasive test with high accuracy.

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## Conflict of Interest

The authors declare no conflict of interest.

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