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Tissue doppler imaging in the assessment of myocardial systolic and diastolic functions in patients with stable angina pectoris

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ABSTRACT

Coronary artery diseases affect both systolic and diastolic functions and can be assessed both globally and regionally. Tissue doppler imaging is a novel technique with additional advantages to the currently used two-dimensional echocardiography. This paper is a review of the published articles on documented Coronary artery diseases patients confirmed by angiography, without any previous myocardial infarction and with normal left ventricular ejection fraction. Accordingly, a significant relationship was achieved between systolic rather than diastolic parameters with Coronary artery diseases. Furthermore, major heterogeneity was noticed among the available studies in this respect.
The incremental values of tissue doppler imaging in patients with stable angina in addition to other non invasive tests has led to its recommendation by ACC/AHA.

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Introduction

The estimated prevalence of ischemic heart disease (IHD) in the United States is about 17,600,000 and 1020000 of them suffer from angina pectoris (1). Nowadays, IHD is the major cause of death worldwide, while more than half of the deaths attributed to cardiovascular disease are the result of IHD (2). Its debilitating effects on a country economy and its attitude toward developing and poor socioeconomic regions necessitate its early diagnosis and treatment via different modalities (3).

In our country, the minister of health and medical education announced that 43.7% of all-cause mortality was cardiovascular related (2). Myocardial perfusion scan

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are commonly used in daily practice Echocardiography in order to measure global left ventricular (LV) function stress, both at rest and during resting and stress wall motion abnormalities (4).

In 1989, tissue doppler imaging (TDI) was introduced as a novel technique for assessing both the systolic and diastolic functions of the myocardium. It is excessively being used in stress echocardiography today (5). Regarding that, the myocardial tissue exhibits much lower velocities and greater amplitudes in comparison to blood; therefore, doppler ultrasound uses high frame rates. Since its presentation, TDI spectrum of usage extended from pulse tissue acquisition toward color-coded images. Perhaps the strongest application of TDI is its usage in stress echocardiography for assessing myocardial functional reserve. In addition, TDI of the mitral annulus has a good relationship with global systolic and diastolic functions and is able to assess regional myocardial function by placing the sample volume in the aimed segment. TDI is mostly applied for determination of myocardial relaxation and LV diastolic function (6).

Tissue doppler imaging in form of strain and strain rate is used in stress echocardiography and quantifies regional myocardial function on the basis that 5 seconds after ischemia onset, myocardial velocities decreases (7).

This paper aims to have a brief review on the role of TDI in coronary artery disease (CAD) patients.

Method and Data

All the reviewed articles were obtained from MEDLINE (up to January 2013). All were controlled trials with consensus on patients with CAD confirmed by selective coronary angiography. The studies had focused on those documented CAD cases without any previous history of myocardial infarction and with normal LV systolic function.

Most data extracted by tissue doppler imaging focused on maximum systolic (s) velocity, maximum early diastolic (e) velocity or maximum late diastolic (a) velocity. The diastolic parameter E/e (the ratio of early diastolic transmitral flow velocity and early diastolic tissue velocity) was also analyzed.

The results and the study characteristics of seven articles were reviewed. The collected data have been summarized in Table 1.

Tissue doppler at rest

Bolognesia et al detected significant reduced systolic peak velocity (13±0.9 vs 11.2 ±2), significant early diastolic peak velocity (17±1.4 vs 12.6±2.5) and non-significant late diastolic peak velocity (13.3±1.6 vs 12.2±2.4) in patient group. Peak E velocity (cm/s) was also significantly reduced in CAD patients (75±13.2 vs 55.2 ±12). They suggested that in early stages of ischemic LV, while LVEF is still normal, some abnormalities in systolic and diastolic functions are already present, which can be detected by tissue doppler imaging. Peak Em velocity is a reliable marker of diastolic dysfunction. It has linear reverse relationship with diastolic function whereas peak E velocity does not. Therefore, tissue doppler imaging is more sensitive than conventional transmitral doppler flow in CAD patients (7).

Dounis et al published an article focused on patients with diabetes type 2 and compared it among four groups of 66 patients including control, type 2 diabetic, CAD and diabetic subjects with CAD (DCAD). Pulsed tissue doppler was utilized for the assessment of systolic and diastolic myocardial velocities. In 20 patients, angiography had not been done. Therefore, they underwent

Table 1. Summary of the preformed studies that used tissue doppler imaging at rest or in stress

Author Reference	Year	Type of study	Number of patients	CAD group characteristics	Method confirming CAD	Segments of study
Bolognesi (7)	2001	Prospective, controlled study	16	Normotensive, stable angina pectoris, no previous MI, normal LVEF	Volunteer for cardiac catheterization	Septal and anterolateral sites in the apical 4-chamber view and in the anterior and inferior sites in the apical 2-chamber view
Madler (8)	2003	Prospective, controlled study	283	Unselected patients referred for chest pain, all had exercise ECG and then dobutamine stress echocardiography	Coronary angiograph (>50% stenosis)	Apical four and two chamber view: basal septal, basal anterior, basal lateral and basal inferior and mid septal, mid anterior,mid lateral and mid inferior
Williams (9)	2005	Prospective, controlled study	26	Chronic stable symptoms, normal LVEF, no history of MI	Coronary angiography (>75% luminal area)	16 segment Model of ASE
Dounis (10)	2006	Prospective, controlled study	66	CAD patients who had 1_2 vessel disease, normal ejection fraction, no previous MI	Coronary angiography or stress test	Apical four, two and three chamber views: septal,anteroseptal, anterior, lateral,posterior and inferior
Zagatina (11)	2007	Prospective, controlled study	123	Significant LAD stenosis	Coronary angiography	Basal and mid-septum, basal and mid lateral, inferior and anterior
Hofman (12)	2010	Prospective, controlled study	82	Suspected angina pectoris, no previous cardiac history, and a normal EF	Coronary angiography	Septal, lateral, inferior, anterior, posterior, and anteroseptal
Golmohammadi (13)	2011	Prospective, controlled study	73	Coronary stenosis >50%	Coronary angiogrphy	All basal segments

traditional stress echocardiography. Twelve myocardial segments were assessed by TDI and were matched with the involved territories of stenotic coronary arteries.

In type 2 diabetic patients compared to controls, Ve was reduced at rest and during stress (P=0.02). This was also true for CAD patients and DCAD patients compared to the control group (P=0.001). Vs was also reduced in CAD and DCAD patients (P=0.008).

This study revealed that Ve reduced in the diabetic group to the same degree as the CAD patients but Vs was not significantly impaired in this study. Diastolic dysfunction was attributed to macro/microvascular dysfunctions, which can be alleviated by preventive strategies (10).

Hoffman et al, in 2010, tried to find out whether the distinct pattern of tissue doppler had any relationship with the severity of coronary artery stenosis. Fourty-seven patients with stable angina and 35 controls were involved. Single vessel disease was defined as only left anterior descending (LAD) stenosis and 2 vessel disease patients were those with LAD and left circumflex artery (LCX) stenosis. 6 mitral annular regions were assessed to obtain tissue doppler parameters.

Global diastolic (E/e) and systolic (s velocity) functions were impaired with respect to increased severity. Early diastolic velocity (e) reduced in SVD and 2VD patients but was normal in 3VD cases. Late diastolic velocity (a) increased in SVD patients but not in 2VD and 3VD cases. Significant regional systolic velocity (s) especially in 3VD ischemic segments reduced significantly, whereas in SVD and 2VD patients it reduced to a lesser degree. In addition, significant reduction of e velocity in SVD and 2VD patients in the anterior and anteroseptal walls was recognized (11).

Golmohammadi et al in Iran performed a study for the prediction of severity of coronary stenosis by tissue doppler in the absence of infarction. They examined 73 patients without history of previous MI, atrial fibrillation and left bundle branch block. TDI velocities (SV, E'V and A'V) were measured at 6 basal segments of LV. Peak mitral inflow early diastolic velocity (mitral E) and peak late diastolic velocity (mitral A), deceleration time of mitral E velocity and E/A ratio were measured by doppler imaging. They concluded that TDI study was not sensitive enough in the diagnosis of coronary stenosis (13).

Tissue doppler at stress

Madler et al. in 2003, applied tissue doppler imaging in stress echocardiography as a noninvasive technique for diagnosis of CAD. They evaluated 289 patients, 92 subjects previously known to be normal, 48 subjects had known coronary disease and the remaining 149 patients were referred because of chest pain. Five segments were excluded due to unreliable off line velocities. The sensitivity and specificity of regression models achieved for each territory were as follows: 80% and 80% for LAD disease, 91% and 80% for LCX and 93% and 82% for RCA, respectively; giving a high negative predictive value especially for the exclusion of LCX and RCA. In this study, only peak systolic velocity was evaluated which was adjusted for maximal heart rate, age and sex (8). Williams et al. in 2005 selected 26 patients and compared them with 12 controls to investigate whether tissue doppler strain and strain rate changed in the stunned myocardium after stress echocardiography. Nine patients had SVD, another 9 had 2VD and 8 had 3VD, giving totals of 23 patients with LAD disease, 16 with LCX and 12 with RCA disease. Tissue doppler parameters in the base of the anterior segment were assessed in 16 patients with documented proximal LAD lesions (9). Peak systolic velocity showed a lower rise in the base of the anterior segment in the study group versus the controls right after maximum exercise (31% vs. 92%). Diastolic velocity did not rise in the study group despite the increase in the control group. Strain and strain rate reduced at peak exercise whereas the control group exhibited increased amplitude. Both early and late diastolic strain responses were blunted in the study group and in the reverse direction. Dysfunctional stunned myocardium manifested in this study after an exercise episode (9).

Zagatina et al. studied 106 patients and 17 controls aimed to obtain quantitative diagnostic criteria for TDI in order to detect CAD in stress echocardiography. They used pulse doppler in 8 LV segments by excluding the apical segments because of low accuracy. They assessed LAD and LCX territories matched with their angiography. Visual interpretation of regional wall motion abnormalities depended on the observer experience. TDI provided less interobserver variability and helped especially in situations such as poor quality image, subtle abnormalities in motion and marginal lesions.

Systolic velocities had a greater correlation with coronary artery stenosis than diastolic velocities. Two segments of LAD and one segment of LCX revealed a relationship with the stenosis (11).

Discussion

A review article recently published by Agarwal et al. analyzed the use of tissue doppler imaging in coronary artery disease. Few studies have focused on this subject all over the world and have shown major heterogeneity in their results, most probably due to differences in study populations, echocardiography devices, mode of doppler used, degree of hypertensive patients and LVH, and the modality used to confirm CAD beside angiography. All such studies were controlled trials in which the cut off point for tissue doppler values were not achieved (14).

This review article supported the use of systolic parameters of tissue doppler study at rest combined with wall motion indices, which gave a quantitative parameter rather than just a qualitative parameter for CAD detection. It even concluded that there was not only a relationship between systolic velocity and CAD, but abnormal velocities showed more severe degrees of CAD (14).

Systolic velocity is both sensitive and specific in detecting regional myocardial dysfunction comparing weak relationship with diastolic function. In just one study during dobutamine stress echocardiography, early diastolic velocity reduction was more sensitive than systolic velocity for the detection of CAD (15).

Myocardial relaxation is an energy consuming process, which is affected by ischemia even earlier than systolic function (16). Animal model studies have established this fact previously (17). TDI could detect diastolic dysfunction at rest if recurrent ischemia induced structural changes exist (18). Regional e velocity reduction in SVD and 2VD was detected in one of the studies, which assessed CAD degree and its correlation with tissue Doppler parameters, but in 3VD increased LV pressure neutralized this regional effect. This conclusion is true for the segments in the center of the ischemic region whereas peripheral regions may be supplied by the other nonstenotic or collateral vessels. E/e velocity had also a direct relationship with CAD severity, a marker of global diastolic function. It can also be explained by recurrent ischemia and its following consequences.

Hoffman et al. drew the final conclusion that even single regional reduced systolic or diastolic velocities should bring up the possible diagnosis of ischemia in the cardiologist mind (11).

In two studies by Hoffman et al. it was shown that incremental values of tissue doppler in patients with stable angina in addition to exercise tolerance test and single photon emission computed tomography (SPECT) and improved their sensitivity (15,16).

ACC/AHA guideline stated that TDI is largely beneficial because it is both available and quantitative (17).

Further studies are needed to brighten the use of TDI in CAD patients and in the assessment of their disease severity.

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Conflict of Interest

The authors declare no conflict of interest.

References

1. Lloyd-Jones D, Adams RJ, Brown TM, et al. Heart disease and stroke statistics-2010 update: A report from the American Heart Association. Circulation. 2010;121:e46-e215.
2. Ford ES, Capewell S. Coronary heart disease mortality among young adults in the U.S. from 1980 through 2002: Concealed leveling of mortality rates. J Am Coll Cardiol. 2007;50:2128-2132.
3. American Heart Association: International Cardiovascular Disease Statistics. Dallas, American Heart Association, 2009.
4. Lee TH, Boucher CA. Clinical practice. Noninvasive tests in patients with stable coronary artery disease. N Engl J Med. 2001;344:1840-1845.
5. Leung DY, Ng AC. Emerging clinical role of strain imaging in echocardiography. Heart Lung Circ. 2010;19:161–174.
6. Sohn DW, Chai IH, Lee DJ, et al. Assessment of mitral annulus velocity by Doppler tissue imaging in the evaluation of left ventricular diastolic function. J Am Coll Cardiol. 1997;30:474-480.
7. Bolognesi R, Tsialtas D, Barilli AL, et al. Detection of early abnormalities of left ventricular function by hemodynamic, echo-tissue Doppler imaging, and mitral Doppler flow techniques in patients with coronary artery disease and normal ejection fraction. J Am Soc Echocardiogr. 2001;14:764–772.
8. Madler CF, Payne N, Wilkenshoff U, et al. Myocardial Doppler in Stress Echocardiography(-MYDISE) Study Investigators: Non-invasive diagnosis of coronary artery disease by quantitative stress echocardiography: optimal diagnostic models using off-line tissue Doppler in the MYDISE study. Eur Heart J. 2003;24:1584-1594.
9. Williams RI, Payne N, Phillips T, et al. Strain rate imaging after dynamic stress provides objective evidence of persistent regional myocardial dysfunction in ischaemic myocardium: regional stunning identified? Heart. 2005;91:152-160.
10. Dounis V, Siegmund T, Hansen A, et al. Global myocardial perfusion and diastolic function are impaired to a similar extent in patients with type 2 diabetes mellitus and in patients with coronary artery disease–evaluation by contrast echocardiography and pulsed tissue Doppler. Diabetologia. 2006;49:2729-2740.
11. Zagatina A, Zhuravskaya N, Kotelnikova A. Application of tissue Doppler to interpretation of exercise echocardiography: diagnostics of ischemia localization in patients with ischemic heart disease. Eur J Echocardiogr. 2007;8:463-469.
12. Waggoner AD, Bierig SM. Tissue Doppler imaging: a useful echocardiographic method for the cardiac sonographer to assess systolic and diastolic ventricular function. J Am Soc Echocardiography. 2001;14:1143-1152.
13. Mohammadi B, Toufan M, Ashouri D, et al. Prediction of Severity of Coronary Stenosis in the Absence of Infarction by Tissue Doppler Imaging and Conventional Echocardiography at Rest. J Cardiovasc Thorac Res. 2011;3:11-15.
14. Agarwal R , Gosain P, Kirkpatrick J, et al. Tissue Doppler imaging for diagnosis of coronary artery disease: a systematic review and meta-analysis. Cardiovasc Ultrasound. 2012;10:47-52.
15. Hoffmann S, Jensen JS, Iversen AZ, et al. Tissue Doppler echocardiography improves the diagnosis of coronary artery stenosis in stable angina pectoris. Eur Heart J Cardiovasc Imaging. 2012;13:724-729.
16. Hoffman S, Mogelvang R, Sogaard P, et al. Tissue Doppler echocardiography reveals impaired cardiac function in patients with reversible ischemia. Eur J Echocardiogr. 2011;12:628-634.
17. Derumeaux G, Ovize M, Loufoua J, et al. Doppler tissue imaging quantitates regional wall motion during myocardial ischemia and reperfusion. Circulation. 1998;97:1970-1977.
18. Hess OM, Schneider J, Nonogi H, et al. Myocardial structure in patients with exercise-induced ischemia. Circulation. 1988;77: 967–977.