The Role of Speckle Tracking Echocardiography in Detecting Myocardial Ischaemia in Patients with Suspected Stable Angina Pectoris

Thesis

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Table of Content

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ACS: Acute Coronary Syndrome

CAD: Coronary Artery Disease

CCA: CT Coronary Angiography

CMR: Cardiac Magnetic Resonance

DSE: Dobutamine Stress Echocardiography

DTS: Duke Treadmill Score

FFR: Fractional Flow Reserve

GLS: Global Longitudinal Strain

GLSR: Global Longitudinal Strain Rate

GRS: Global Radial Strain

GRSR: Global Radial Strain Rate

ICA: Invasive Coronary Angiography

LM: Left Main

MCS: Mid Circumferential Strain

MCSR: Mid Circumferential Strain Rate

MPI: Myocardial Perfusion Imaging

PET: Positron Emission Tomography

PTP: Pretest Probability

PW: Pulsed Wave

SAP: Stable Angina Pectoris

SCAD: Stable Coronary Artery Disease

SIHD: Stable Ischaemic Heart Disease

SPECT: Single Photon Emission Computed Tomography

SR: Strain Rate

STE: Speckle Tracking Echocardiography

TDI: Tissue Doppler Imaging

TVI: Tissue Velocity Imaging

UA: Unstable Angina

Introduction: LM CAD & three-vessel CAD are both high-risk subsets of stable angina pectoris, in which the majority of LVs are exposed to ischaemia. Although exercise or pharmacological stress testing has a higher sensitivity for three-vessel and LM CAD, the risk of stress test is higher also in this patient population. Exercise myocardial perfusion imaging may not show any transient or fixed myocardial perfusion abnormalities due to balanced ischaemia. 2D STE showing subtle strain or SR reduction in patients with stable angina might provide an important diagnostic clue &a higher pretest probability for CAD. **Objective:** to determine the role of STE performed at rest to predict the presence of CAD in patients suspected of having SIHD.Toassess the power of STE to determinedegree of CAD; and its role to localisethe diseased coronary vessel.**Methods:** 81 candidates were evaluated by 2D STE in parasternal short axis, apical 4, apical 2 & apical long axis views. Global longitudinal & radial strain& SR&mid circumferential strain& SR were calculated. The results of the strain &SR were correlated to the results of coronary angiography for each patient.**Results:**There was a statistically significant difference in the means of the different strain &SR between normal coronaries & the different degrees of CAD. Global radial SR showed the highest sensitivity for the diagnosis of low risk CAD (95%, specificity 81.5%, cutoff value: 2.6967, AUC: 0.924) & global longitudinal SR showed the highest specificity (92.6%, sensitivity 90%, cutoff value -1.5506, AUC: 0.957). Circumferential strain (at cutoff value -20.8300, sensitivity & specificity of 88.9%; AUC 0.901) & radial SR(at cutoff value 2.1861 a sensitivity of 85.2% & specificity of 77.8%; AUC 0.899,) showed the highest sensitivity & specificity for diagnosis of high risk CAD. The effect of LM as a cause of CAD on strain &SR remains less than that of three vessel disease although it is considered equal to three vessel disease in terms of prognosis & mortality. Strain &SR also showed statistical significance for localization of the affected vessel. **Conclusion:**STEovercomes the many limitations of strain measurements acquired by tissue Doppler imaging.Strain & strain rate measurements can differentiate between normal coronaries & CAD, between low & high risk CAD, & may localize the affected coronary artery.

Key words

Specle Tracking Echocardiography, Radial strain, longitudinal strain, circumferential strain, Stable Ischemic Heart Disease, Tissue Doppler

Introduction

Despite a decline in mortality due to coronary artery disease (CAD) in general, stable angina pectoris (SAP) remains a very common and disabling disorder. In order to establish the right diagnosis and initiate appropriate therapy, the use of simple, reliable, and non-invasive methods is often necessary. Echocardiography is the dominant cardiac imaging technique in patients with suspected cardiac disease. However, conventional echocardiography provides little information regarding risk stratification of patients with suspected stable angina.

Left main (LM) CAD is a well-known predictor of long-term prognosis in ischaemic heart disease, since occlusion of this artery may result in extensive myocardial ischaemia. Three-vessel CAD is another high-risk subset, in which the majority of left ventricle (LV) is exposed to ischaemia, and thus, coronary bypass surgery is frequently required to improve long-term prognosis in these subsets of patients with symptoms.

Although exercise or pharmacological stress testing has a higher sensitivity for three-vessel and LM CAD, the risk of stress test is higher also in this patient population. Furthermore, in some patients with LM CAD, exercise myocardial perfusion imaging may not show any transient or fixed myocardial perfusion abnormalities due to balanced ischaemia.

Most of these patients do have normal wall motion at rest unless there is a history of previous myocardial infarction or myocardial stunning. Therefore it will be beneficial if another resting parameter can distinguish severe CAD from less severe CAD.

Two dimensional (2D) speckle tracking echocardiography (STE) is a promising new imaging modality. Similar to tissue Doppler imaging (TDI), STE permits offline

calculation of myocardial velocities and deformation parameters such as strain and strain rate (SR). It is well accepted that these parameters provide important insights into systolic and diastolic function, ischaemia, myocardial mechanics and many other pathophysiological processes of the heart.

So far, TDI has been the only echocardiographic methodology from which these parameters could be derived. However, TDI has many limitations. It is fairly complex to analyse and interpret, only modestly robust, and frame rate and, in particular, angle dependent. Assessment of deformation parameters by TDI is thus only feasible if the echo beam can be aligned to the vector of contraction in the respective myocardial segment.

In contrast, STE uses a completely different algorithm to calculate deformation: by computing deformation from standard 2D grey scale images, it is possible to overcome many of the limitations of TDI. In comparison with TDI, receiver operating characteristic curve analysis has shown that longitudinal and radial strain measured using STE has a significantly greater area under the curve than TDI strain in differentiating normal and dysfunctional segments. Furthermore Speckle tracking–derived strain and strain rates do not require scaling for any index of LV morphology. Overall, speckle tracking appears to be highly reproducible and minimally affected by intraobserver and interobserver variability.

Exercise-induced regional myocardial ischemia impairs regional diastolic wall motion in patients with CAD, and this impairment persists for 10 min after exercise. Echocardiographic evaluation of regional myocardial wall motion or delayed relaxation by STE is a useful noninvasive method for detection of prolonged post-ischemic diastolic dysfunction or stunning and for identification of the angina-provoking vessel. Detection of post-ischemic regional LV delayed relaxation after treadmill exercise using STE is a sensitive and reliable method for the diagnosis of CAD.

However, it is unknown if STE is able to predict the presence of significant CAD in consecutive patients referred with suspected stable angina. Therefore, the aim of this study was to determine if STE performed at rest can predict the presence of significant CAD in consecutive patients referred with suspected stable angina & correlate the results with Coronary Angiography performed for the enrolled patients, to detect if STE is also able to predict the degree of Coronary stenosis present.

It has been previously reported that tissue Doppler longitudinal velocity is reduced in patients with three-vessel CAD, but the number of study patients was small and results were inconsistent. With technical improvements in (2D) echocardiography & the temporal and spatial resolutions of two-dimensional echocardiography, systolic strain (longitudinal, circumferential and radial) can now be measured using the 2D speckle tracking method. This method might provide a useful means of detecting subtle changes in LV systolic function which could be caused by myocardial ischaemia.

Thus, a subtle strain or strain rate reduction in patients with LM or three-vessel CAD might provide an important diagnostic clue and allow stress testing to be performed more safely and provide a higher pretest probability for the presence of high-risk CAD.

In this study, we hypothesized that repetitive ischaemic insults to LV, which occurs with any fixed significant stenosis of LM or epicardial vessels, during repeated attacks of provoked ischaemia during exercise, would reduce systolic function, although resting regional wall motion remains normal. Therefore, we aimed to evaluate whether global and segmental circumferential, longitudinal and radial strains measured by the 2D speckle tracking method could be useful for detecting CAD.

Aim of Work

The aim of the work was:

1. To study the value of STE performed at rest to predict the presence of CAD in patients suspected of having stable angina pectoris.

2. To study the value of STE in predicting extent and to localize coronary artery affection in patients with proven coronary artery disease by coronary angiography.

Definition of Stable Coronary Artery Disease

Stable coronary artery disease (SCAD) is generally characterized by episodes of reversible myocardial demand/supply mismatch, related to ischemia or hypoxia, which are usually inducible by exercise, emotion or other stress and reproducible—but, which may also be occurring spontaneously. Such episodes of ischemia/hypoxia are commonly associated with transient chest discomfort (angina pectoris). SCAD also includes the stabilized, often asymptomatic, phases that follow an acute coronary syndrome (ACS).[1]

Because the transition from unstable to stable syndromes is a continuum, without a clear boundary, angina at rest may be regarded within the scope of SCAD[2], as in the "2013 ESC guidelines for management of stable coronary artery disease" & "ACC/AHA 2012 guidelines for the management of patients with Stable Ischaemic Heart Disease"[3]; if it can be categorized as low-risk ACS [no recurrence of chest pain, no signs of heart failure, no abnormalities in the resting electrocardiogram (ECG), no rise in markers of myocardial necrosis (preferably troponin)][4]. Recent use of ultrasensitive troponin tests has shown that episodes of minute troponin release— below the threshold for acute myocardial infarction— often occur in patients with stable CAD and this has been shown to have prognostic implications[5,6] thus also demonstrating the continuum of CAD subgroups.

Pathophysiology

The various clinical presentations of SCAD are associated with different underlying mechanisms that may act singly or in combination; the mechanisms mainly include[7]:

i. Plaque-related obstruction of epicardial arteries;

ii. Focal or diffuse spasm of normal or plaque-diseased arteries;
iii. Microvascular dysfunction and
iv. Left ventricular dysfunction caused by prior acute myocardial necrosis and/or hibernation (ischaemic cardiomyopathy)

Major determinants of myocardial oxygen demand are heart rate, blood pressure, and myocardial wall tension, in turn influenced by preload, afterload, and contractility. Since myocardial oxygen extraction from coronary arterial blood at rest is normally high, about 75% of arterial oxygen content, adjustments in oxygen extraction cannot correct an imbalance. Physiological increases in myocardial oxygen needs are normally provided by rises in coronary blood flow.

Coronary autoregulation is the ability of coronary arteries to increase flow to meet myocardial metabolic demand, called coronary flow reserve, is about 4–6 times the resting value at maximum dilatation of the coronary arteries,[8] which can be somewhat expanded pharmacologically. Coronary auto-regulation is a complex phenomenon with many regulating variables.[9] Superimposed upon the hierarchy are the influences of disease upon each variable – atherosclerosis, ischemia, hypertrophy, alterations in autonomic nerve function, endothelial function, electrophysiology, etc. Endothelial dysfunction within atherosclerotic coronary arteries is abnormal, and nitric oxide production may be reduced and contribute to myocardial oxygen imbalance.

In the patient with chronic coronary artery disease and fixed obstructive coronary lesions, sudden increases in myocardial oxygen demand, usually due to effort, in face of the inability to raise myocardial blood flow and oxygen supply, result in a transient myocardial energy imbalance and demand ischemia. The fixed areas of stenosis responsible are those which are likely to be seen on coronary angiography.

Up to 95% of the resistance in coronary vessels arises within small intramural vessels, about 10 nm to 140 nm in diameter, which are not visualized during coronary