Original article

Diagnostic utility of tissue tracking echocardiography for the diagnosis of ischaemic heart disease

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Abstract

Introduction: Both the resting electrocardiogram and standard echocardiography have limited value in detecting ischaemic heart disease (IHD) in patients with atypical symptoms or asymptomatic subjects. Tissue tracking (TT) is a novel method based on tissue Doppler echocardiography for the assessment of longitudinal apical myocardial motion.

Aim: To assess diagnostic utility of TT mode in the diagnosis of IHD.

Methods: The study was performed in a group of 36 patients (aged 58±8 years, 15 males) with good acoustic window, sinus rhythm and normal left ventricular ejection fraction on standard echocardiography who were previously selected for coronary angiography. Systolic displacement of myocardium (TT) was assessed in all patients using apical views (4, 2, and 3-chamber) and 7-colour-coded visualisation expressing various apical displacements of the myocardium during systole. Group IHD(–) consisted of 16 patients with normal coronary angiography or insignificant lesions and group IHD(+) consisted of 20 patients with significant (>70%) coronary lesions.

Results: Despite similar prevalence of arterial hypertension and diabetes as well as similar pharmacological treatment patients from the IHD(+) group had a lower TT index (ratio of the sum of regional TT values to the number of analysed segments than the IHD(–) (patients 4.5±0.8 mm *vs* 5.9±0.9 mm respectively, p <0.001).

Conclusions: Resting echocardiography with tissue tracking enables fast, non-invasive and semiquantitative evaluation of left ventricular function. This method of assessment of longitudinal layers of the left ventricle may be useful in the diagnosis of ischaemic heart disease.

Key words: tissue tracking, echocardiography, coronary artery disease

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Introduction

Despite progressive decline of mortality owing to novel pharmacological and invasive treatments, cardiovascular disease remains the most common cause of death [1, 2]. Ischaemic heart disease (IHD) causes death in every 4th male and 5th female and is the main cause of early deaths. Early detection of IHD, before the onset of typical symptoms which often manifest very dramatically, allows primary prevention and pharmacological and invasive treatment, particularly in patients with silent ischaemia [3]. Standard methods of early IHD detection include, but are not limited to, electrocardiography (ECG) and resting echocardiography (ECHO). Unfortunately, both methods have limitations when diagnosing patients with single vessel disease, without history of prior myocardial infarction, and predominantly with atypical symptoms or silent IHD.

Tissue tracking (TT) is a novel echocardiographic technique based on tissue Doppler, which enables the assessment of longitudinal apical motion of myocardial segments using a 7-point colour-coded scale identifying the degree of systolic wall displacement [4].

The aim of the study was to determine the diagnostic utility of TT imaging in the diagnosis of IHD

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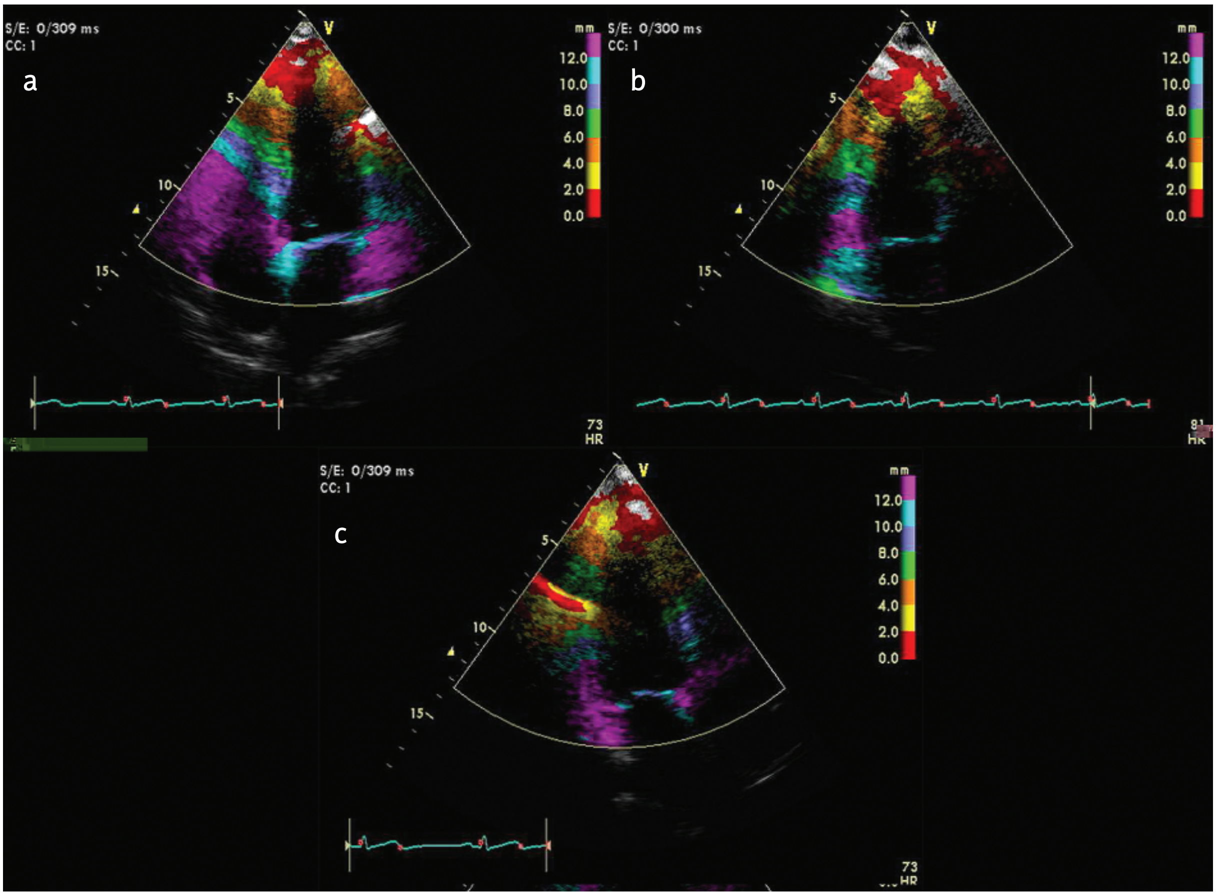

Figure 1. Appropriate imaging of apical displacement of left ventricular segments using tissue tracking technique in the following views: a) four-chamber apical view; b) dual-chamber apical view; c) three-chamber apical view

in patients with normal resting left ventricular ejection fraction (LVEF) on standard echocardiography.

Methods

Patients

Initially, the study included 39 patients with sinus rhythm, good acoustic window for echocardiography and normal LVEF on standard echocardiography. The patients were hospitalised to undergo coronary angiography due to a suspicion of IHD that was based on reported chest pain and/or positive exercise stress test performed at optimal pharmacological treatment. Twenty-two consecutive patients with significant IHD and 17 other patients without significant lesions in the coronary arteries were enrolled into the study.

The following exclusion criteria were applied: age <18 years, past myocardial infarction, unstable angina, impaired LVEF (<50%), LV hypertrophy, non-sinus rhythm, valvular disease and implanted pacemaker.

Standard echocardiography

Echocardiography was performed at rest using the Vivid 7 system (GE Vingmed, Norway) with a 2.5 MHz probe; 3 apical views of LV were obtained: 4-chamber, 2-chamber and 3-chamber views. The endocardial border was enhanced using second harmonic imaging. The LV echocardiographic image was divided into 16 segments [5]. Each segment was rated as normo-, hypo-, a-, or dyskinetic using a 1- to 4-point score based on the evaluation of ventricular wall motion amplitude and systolic myocardial thickening. Contractility index was calculated as the sum of regional contractility and number of visualised segments [6]. Systolic and diastolic LV volumes were mean volumes determined in 4-chamber and 2-chamber views using Simpson's formula. LVEF was calculated as a percentage of the difference between LV systolic and diastolic volumes [5].

Tissue tracking echocardiography

Following resting conventional echocardiography, all patients underwent an evaluation of the systolic longitudinal myocardium motion in the apical 2-, 3- and 4-chamber views. Tissue tracking technique requires simultaneous ECG recording for the determination of the onset and end of the systolic phase of the cardiac cycle. Maximum systolic displacement depends on the systolic effectiveness of longitudinal LV myocardial layers and is expressed on a 7-score colour-coded scale reflecting the motion of individual segments from the mitral ring towards the heart apex. Pink colour stands for the apical motion of basal segments with an amplitude of up to 12 mm. Bright blue colour expresses LV systolic displacement by 10-12 mm, dark blue: 8-10 mm, green: 6-8 mm, orange: 4-6 mm, yellow: 2-4 mm, while red indicates the motion of below 2 mm (Figure 1) [4, 7]. ECHOPAC Software (GE Vingmed, Horten Norway, ver. 2.0) enables a quantitative analysis of the displacement of selected segments by placing an ellipsoidal sample sized 8x4 mm in each of 16 segments of LV and reading displacement values on the projected graph (Figure 2). Subsequently, these data were used to estimate the tissue tracking index (aTT), which is the ratio of the sum of regional TT values to the number of analysed segments and indicates global systolic function of longitudinal fibres of LV.

Coronary angiography

A coronary angiography referral process was always carried out prior to the enrolment into this study. Angiography of the left coronary artery was performed in three consecutive views and the right coronary artery was examined in two views. Coronary stenosis greater than 70% of the proximal or mid portions of one of the two major epicardial arteries was defined as significant (group IHD (+)). Patients with normal or subcritical coronary lesions were classified as the IHD (–) group.

Statistical analysis

Statistical analysis was performed using the Statistica software package ver. 6.0. Relations between categorised variables were determined using the Fisher test. Classification of patients into group IHD (+) or IHD (–) was based on the ROC curves which determined the borderline value of mean TT, allowing the identification of patients with IHD. Distribution of the analysed variables was normal (Kolmogorov-Smirnov test). Parametric analyses were used for the verification of hypotheses. The groups were compared by the t test, and correlations were determined with the Pearson test. A p value <0.05 was considered significant.

Results

In 3 patients, despite good acoustic window, difficult-to-interpret echocardiographic images were acquired using the TT technique. Therefore, the data of these patients were discarded. Finally, the study was conducted in 36 patients aged 58±8 years, including 15 males, divided into two groups based on coronary angiographic findings. Group IHD(–) consisted of 16 subjects and group IHD(+) included 20 subjects. Study population characteristics are detailed in Table I. The two analysed groups did not differ with respect to the incidence of diabetes mellitus or arterial hypertension. No differences regarding pharmacological treatment

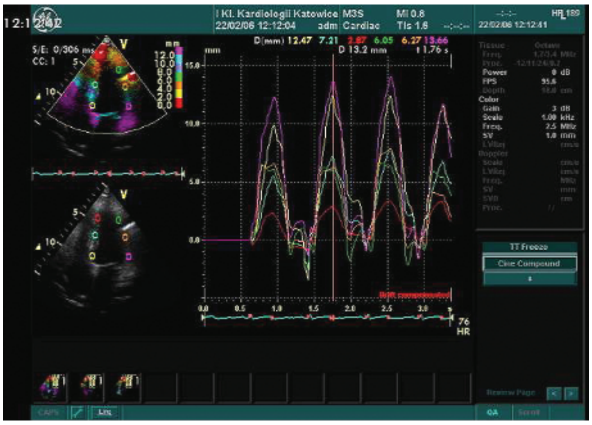

Figure 2. Quantitative analysis of displacement of the left ventricular segments in the apical four-chamber view

Table I. Study population characteristics

Parameter	IHD(–)	IHD(+)	P <
Gender (F/M)	11/5	10/10	NS
Age [years]	54±7	62±9	0.01
Hypertension	7	8	NS
Diabetes mellitus	5	5	NS
Exercise stress test (+)	9	12	NS
Chest pain	11	14	NS
BB	13	16	NS
Nitrates	9	16	NS
ACE-I	8	10	NS
ASA	14	18	NS
WMSI	1±0	1±0	NS
LVEF [%]	66±6	61±5	0.01
HR [min^{-1}]	63±10	69±9	NS
BPsys [mmHg]	132±12	134±17	NS

IHD(–) – patients with negative coronary angiography; IHD(+) – patients with >70% stenosis of coronary arteries found on coronary angiography; BB – β-blockers; ACE-I – inhibitors of angiotensin-converting enzyme; ASA – acetylsalicylic acid; WMSI – mean wall motion score index – LVEF – mean left ventricular ejection fraction; HR – mean heart rate; BPsys – mean systolic blood pressure

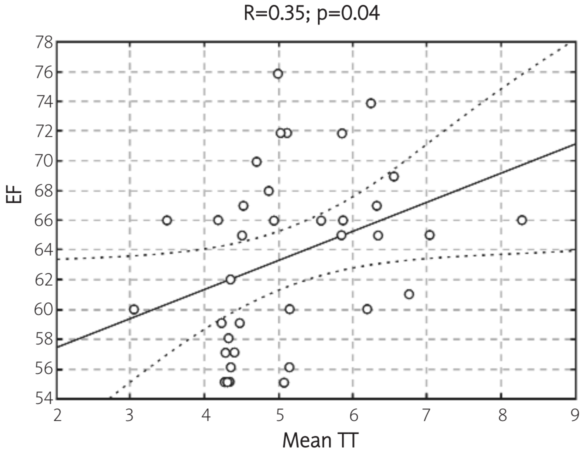

Figure 3. Relationship between left ventricular ejection fraction and mean TT

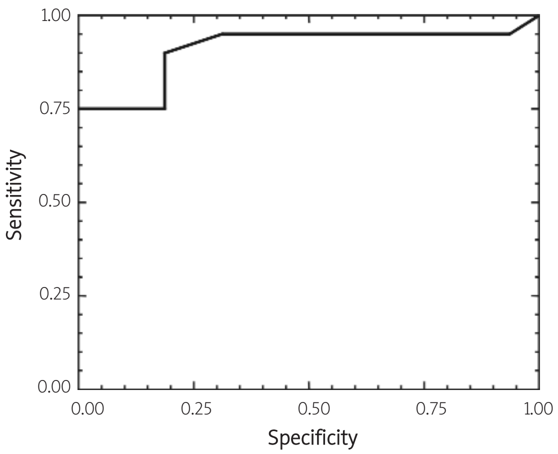

Figure 4. ROC curve showing sensitivity and corresponding specificity values for various TT cut-off values

were found apart from the more frequent use of nitrates in the IHD(+) patients. In group IHD(+) 15 (75%) patients had critical lesions in a single coronary artery, and 5 (25%) subjects had double or triple vessel disease. Normal coronary angiography was found in 9 subjects from group IHD(–) whereas 7 patients had non-critical lesions of up to 50%.

Statistical analysis including the entire study population showed a positive correlation between LVEF and aTT (Figure 3). No statistically significant correlation was found between age and aTT; however, there was a trend towards a negative correlation.

In the univariate model of logistic regression, only LVEF >60% and resting heart rate of >60 bpm were found to be independent predictors of the aTT value (Table II).

Table II. Univariate analysis of the effects of selected parameters on aTT

	RR (95% CI)	p
Hypertension	1.62 (0-36–7.32)	0.39
Male gender	0.45 (0.11–1.89)	0.21
LVEF >60%	10.5 (1.74–63.2)	0.004
HR >60/min	5.73 (1.04–34.21)	0.04

Abbreviations: as in Table I

In group IHD(–), the aTT index was 5.9±0.9 mm, and in IHD(+) it was 4.5±0.8 mm (p <0.001). In group IHD(+) with single and multi-vessel disease, aTT was 4.6±0.8 mm and 4.4±0.2 mm, respectively (NS). The optimal discrimination value for mean TT from the ROC curve (Figure 4) between groups IHD(–) and IHD(+) was 5.07 mm. The area under the ROC curve of 0.91 for the determined discrimination value proves a very high discriminative potential of this parameter. Sensitivity, specificity, positive and negative predictive value and accuracy were 90%, 81.5%, 94%, 75% and 86%, respectively.

Imaging of apical segments by means of TT is more difficult. At the same time, the pictures show a slight apical displacement. Consequently, the results acquired from the 4 apical segments were excluded from the analysis. Higher aTT was observed in group IHD(–) (7.6±0.97 mm) than in group IHD(+) (5.87±1.06 mm) (p <0.0001). As in the case of 16-segment division of LV, the selection of 12 segments failed to differentiate between patients with single- and multi-vessel disease in group IHD(+) (aTT 5.93±1.3 mm *vs* 5.79±0.34 mm, NS).

Discussion

Conventionally, the early diagnosis of IHD includes such simple and cost-saving methods as resting electrocardiography and echocardiography [5, 8]. However, normal ECG at rest may be observed in over 70% of patients with stable coronary artery disease without prior myocardial infarction and concomitant arterial hypertension. Even multi-vessel disease is not reflected in ECG in almost 50% of subjects [9]. On the other hand, patients with an abnormal electrocardiographic trace may be completely healthy. The unquestionable diagnostic value of this examination is observed in patients with myocardial ischaemia – either spontaneous or induced.

Two-dimensional echocardiography with its ability to assess the thickening of LV walls and the contractility of separate segments enables ischemia to be identified and even the definite culprit artery to be determined. Regardless of the second generation contrast agents implemented for better detection of endocardium [10], patients with chronic IHD without past myocardial infarction often present no abnormalities in conventional resting echocardiography. Animal experimental studies showed that resting regional and global function of LV remained unchanged due to various compensatory mechanisms, despite induced coronary artery stenosis of up to 85% [11].

In recent years, novel non-invasive diagnostic methods have been introduced for patients with suspected IHD. One of them, based on tissue Doppler echocardiography, is TT imaging which enables a rapid estimation of systolic apical displacement of cardiac walls with visualisation using a 7-score colour-coded scale. This scale expresses different degrees of wall motion towards the apex [4, 7, 12]. The background of this technique relies on reports by Houglund, Schiller and Gibbon [13, 14], who were the first to document change of the long axis of LV during systole, suggesting the utility of this parameter as an index of LV systolic function.

Our study showed a significantly lower aTT index in patients with confirmed IHD and with normal LVEF compared to the control group consisting of patients with normal or non-critically stenosed coronary arteries. These results are consistent with relevant single reports worldwide [7, 15]. The optimal value of the aTT calculated in this study, based on the ROC curve and discriminating between patients without significant stenoses and patients with significant IHD, has a very high accuracy, which is unattainable by any other non-invasive diagnostic methods evaluating patients at rest.

This raises a question about the pathophysiological mechanisms underlying the significant impairment of contractility observed in IHD(+) patients with intact LVEF using TT imaging. Longitudinal fibres are predominantly placed in subendocardial but also subepicardial layers and in papillary muscles. They constitute a rather small portion of LV myocardial mass but their significant role in LV systolic function was stressed in several previous studies. The left ventricle becomes more spherical during early systole [16] due to a displacement of the cardiac base towards the apex, which depends mostly on the contraction of longitudinal fibres observed with the TT technique. Longitudinal layers, due to an increase of the systolic ventricular pressure and reduction of the vasodilating potential of subendocardial arteries as compared to similar vessels in the mid and epicardial layers, are at higher risk of ischaemia than circular fibres [4]. Similarly, the recovery of the impaired function secondary to transient ischaemia was slower in the long axis when evaluated using the TT method than in the short axis where the systolic reduction rate may be assessed by LVEF [17]. Therefore, abnormal patterns for longitudinal fibres may be detected at earlier stages of ischaemic heart disease. At this stage, the global performance of LV remains normal because it is compensated by an increased function of circular fibres.

Unfortunately, both 16- and 12-segment visualisation with TT imaging of LV failed to identify patients with advanced multi-vessel disease. This was caused, in the authors' opinion, by the small number of patients with multi-vessel disease in the study population. For that reason, it requires further investigation.

Andersen and Poulsen evaluated LV longitudinal fibres using TT in 55 healthy patients [12]. They found a relatively high value of the mean aTT index of 7.8 mm compared to 5.9 mm in our IHD(–) group. Our study group IHD(–), in comparison to young volunteers taking part in the Andersen research, was definitely older, with a history of arterial hypertension and diabetes mellitus, and, most importantly, also included patients with non-critical coronary artery stenoses. In another study of Andersen et al. [18], patients with type 2 diabetes were found to have lower (5.8±1.6 mm) TT indices which were closely related to those in our group IHD(–).

Other authors also conclude that the dependence of the LV longitudinal systolic function on other factors decreases with age and increased blood pressure. An inverse relationship between the TT index and age was also established in our study; however, statistical significance was not met with respect to this finding. Previous studies showed that ageing significantly affects the contractility of circular layers of LV myocardium as measured by shortening fraction [19]. In our study this relationship was poor, which is difficult to understand and may result from differences between study populations. The analysis performed by Andersen et al. [12] focused on healthy volunteers, whereas over half of our population consisted of patients with significant IHD. An impairment of contractility of longitudinal layers may develop regardless of age in these subjects.

Pana et al. [4] observed 90 patients with past myocardial infarction, essential cardiomyopathy and subjects with normal LV systolic function. The study revealed a very close correlation between TT and LVEF (r=0.97). A similar relationship, though with a considerably lower correlation factor (r=0.35), was confirmed by our analysis. The difference originates most likely from the lower distribution of LVEF in our patients. Reduction of LVEF was one of the exclusion criteria.

Limitations

An obvious limitation of this study is the relatively small study group and thus it cannot entirely reflect the population at risk of IHD. Almost 10% of patients with good acoustic window at baseline were excluded from the study due to difficult interpretation of the acquired image.

Moreover, this method *a priori* may only provide information on the longitudinal shortening of the myocardium, while neglecting circular layers displacement.

Conclusions

Resting echocardiography with TT imaging enables a fast, non-invasive and semiquantitative evaluation of LV. Such assessment of longitudinal layers of LV may be useful in the diagnosis of ischaemic heart disease. The results justify further studies with TT in diverse groups of patients with ischaemic heart disease, also for the interpretation of functional echocardiographic tests.

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Wartość diagnostyczna badania echokardiograficznego przy użyciu techniki Tissue Tracking dla rozpoznawania choroby niedokrwiennej serca

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Streszczenie

Wstęp: Zarówno spoczynkowe badanie elektrokardiograficzne, jak i konwencjonalna echokardiografia dwuwymiarowa mają ograniczone zastosowanie w wyłanianiu chorych z nietypową symptomatologią lub bezbólową postacią choroby niedokrwiennej serca (IHD). *Tissue tracking* (TT) jest nową metodą opartą na tkankowej echokardiografii dopplerowskiej, pozwalającą oceniać podłużne, dokoniuszkowe przemieszczanie miokardium.

Cel: Określenie wartości diagnostycznej techniki przemieszczenia tkanek (TT) w rozpoznawaniu choroby niedokrwiennej serca.

Metodyka: Badanie zostało wykonane wśród 36 pacjentów (wiek 58±8 lat, 15 mężczyzn) z dobrym oknem akustycznym, rytmem zatokowym i prawidłową frakcją wyrzutową lewej komory w konwencjonalnym badaniu echokardiograficznym, zakwalifikowanych wcześniej do koronarografii. U wszystkich badanych wykonano ocenę skurczowego przemieszczenia miokardium (TT) w projekcjach koniuszkowych (4-, 2- i 3-jamowej), wizualizowaną 7-kolorową wstęgą, wyrażającą różny stopień przemieszczenia skurczowego w kierunku koniuszkowym. Grupę IHD(–) stanowiło 16 pacjentów z prawidłową koronarografią lub zwężeniami niekrytycznymi, a grupę IHD(+) 20 pacjentów z istotnym (>70%) zwężeniem w tętnicach wieńcowych.

Wyniki: Grupę IHD(+), pomimo podobnej częstości występowania nadciśnienia, cukrzycy i podobnego sposobu leczenia farmakologicznego cechowała niższa wartość wskaźnika aTT (iloraz sumy regionalnych wartości TT i liczby analizowanych segmentów): odpowiednio: 4,5±0,8 mm *vs* 5,9±0,9 mm, p <0,001.

Wnioski: Echokardiografia spoczynkowa z zastosowaniem techniki przemieszczenia tkanek pozwala szybko, nieinwazyjnie i półilościowo ocenić funkcję lewej komory. Ten sposób oceny funkcji włókien podłużnych lewej komory może być przydatny w rozpoznawaniu choroby niedokrwiennej serca.

Słowa kluczowe: *tissue tracking*, echokardiografia, choroba wieńcowa

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