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Tissue mitral annular displacement — a novel technique for rapid quantitative assessment of global left ventricular systolic function based on speckle-tracking algorithm

Skurczowe przemieszczenie pierścienia mitralnego — nowa technika szybkiej oceny globalnej funkcji skurczowej lewej komory oparta na algorytmie śledzenia markerów akustycznych

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Abstract

Introduction. Tissue mitral annular displacement (TMAD) is a new technique for rapid quantitative assessment of global left ventricular function based on tracking of acoustic markers. It allows for the assessment of mitral annulus displacement relative to the apex, based on standard apical views.

Objective was to assess the feasibility and accuracy of measurements obtained with TMAD technique for the analysis of global left ventricular function using three-dimensional (3D) left ventricular ejection fraction (LVEF) measurements as a reference technique.

Material and methods. The study included 49 patients (33 men, mean age 65 ± 10 years) admitted with stenocardia, who underwent two-dimensional and 3D transthoracic echocardiography with off-line measurement of LVEF using 3D datasets. Furthermore, measurements of mitral annulus displacement relative to apex with a TMAD algorithm were performed in all patients.

Results. Due to the suboptimal quality of the data, insufficient for tracking the acoustic markers by the TMAD algorithm, 5 patients were excluded. TMAD analysis of one apical view took 10 ± 4 s. Mean LVEF was 46.0% ± 12.3%. Among this group of patients there was a statistically significant correlation between LVEF and the midpoint mitral annulus displacement towards the apex in the apical four-chamber view ($r = 0.57$, $p < 0.0001$) and the percentage of the midpoint mitral annulus displacement ($r = 0.63$, $p < 0.0001$). A similar correlation was observed between midpoint mitral annulus displacement in the apical two-chamber view ($r = 0.6$, $p < 0.0001$) and the percentage of the midpoint mitral annulus displacement ($r = 0.65$, $p < 0.0001$).

Conclusion. Measurement of midpoint mitral annulus displacement by TMAD technique is very rapid and provides satisfactory correlation with 3D LVEF measurements. This technique, however, requires echocardiographic recording of good quality.

Key words: tissue mitral annular displacement, left ventricular ejection fraction, tracking of acoustic markers

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Introduction

Left ventricular ejection fraction (LVEF) is one of the most important echocardiographic parameters reflecting the function of the myocardium. The measurement is based on methods and algorithms of varying degrees of automation and time-consumption. The gold standard is magnetic resonance imaging; however, due to high costs and low availability, it is not widely used. The most commonly used imaging modality is echocardiography with the Simpson's method [1]. LVEF measurement using three-dimensional (3D) echocardiography is even more accurate method, but requires a special echocardiographic device and high-quality data [2]. At the same time, new methods of assessing the left ventricular systolic function are still being investigated – methods that are accurate, fast, repeatable and independent of the investigator. One of such methods may be assessment of mitral annular displacement (TMAD) relative to the apex, based on tracking of acoustic markers.

Material and methods

The study included 49 patients (33 men, mean age 65 ± 10 years) admitted with stenocardia, who underwent transthoracic echocardiography with LVEF measurement using the biplane Simpson's method and LVEF 3D (QLAB Phillips) evaluation. The basic characteristics of the study group is included in Table 1. Furthermore, measurements of mitral annulus displacement relative to the apex with a TMAD algorithm in apical four-chamber and two-chamber views (QLAB, Phillips) were performed in all patients.

TMAD measurement

The study was performed in two apical views: apical four-chamber and two-chamber view. The best available quality is required to visualize the apex and mitral annulus. The measurement consists of marking three points (ROI, region of interest): two points on the medial and lateral part of the mitral annulus and one point at the apex in apical four-chamber view (Figure 1) morover two points on the inferior and anterior wall and one point at the apex in the apical two-chamber view (Figure 2). The analysis is performed off-line using the QLAB software (Phillips Medical Systems) and involves the use of acoustic marker tracking techniques to measure longitudinal strain vectors during left ventricular

Table 1. Study group characteristics (N = 44)

Parameter	Value
Age (years)	65.4 ± 10.5
Women/men	12/32
Ischaemic heart disease	42 (95%)
Hyperlipidemia	35 (79%)
Arterial hypertension	39 (89%)
Nicotinism	30 (68%)
Diabetes	24 (54%)
Mean LVEF 2D (Simpson method)	44.4% ± 18.9%
Mean LVEF 3D	46.0% ± 12.3%
TMAD (absolute value)	8 ± 3
TMAD (percentage)	9.5% ± 3.8%

LVEF — left ventricular ejection fraction; 2D — two-dimensional; 3D — three-dimensional; TMAD — tissue mitral annular displacement

Figure 1. Apical four-chamber view. Point marking (ROI, region of interest) on the mitral annulus and at the apex for the TMAD (tissue mitral annular displacement) algorithm; TMAD 1 (yellow) — tracking of the displacement of the medial point of the mitral annulus; TMAD 2 (blue) — tracking of the displacement of the lateral point of the mitral annulus

Figure 2. Apical two-chamber view. Point marking (ROI, region of interest) on the mitral annulus and at the apex for the TMAD (tissue mitral annular displacement) algorithm; TMAD 1 (yellow) — tracking the displacement of the mitral annulus point at the base of the inferior wall; TMAD 2 (blue) — tracking the lateral displacement of the mitral annulus point at the base of the anterior

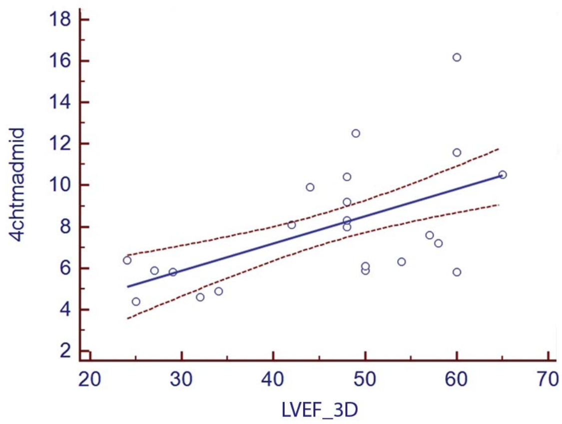

Figure 3. Correlation graph between three-dimensional left ventricular ejection fraction (3D LVEF) values and the midpoint mitral annulus displacement towards the apex in the apical four-chamber view

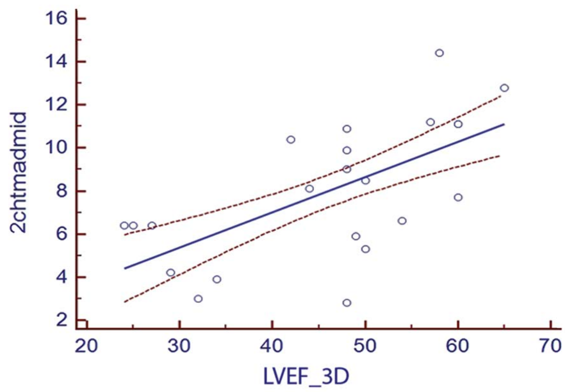

Figure 5. Correlation graph between three-dimensional left ventricular ejection fraction (3D LVEF) and midpoint mitral annulus displacement relative to the apex in the apical two-chamber view

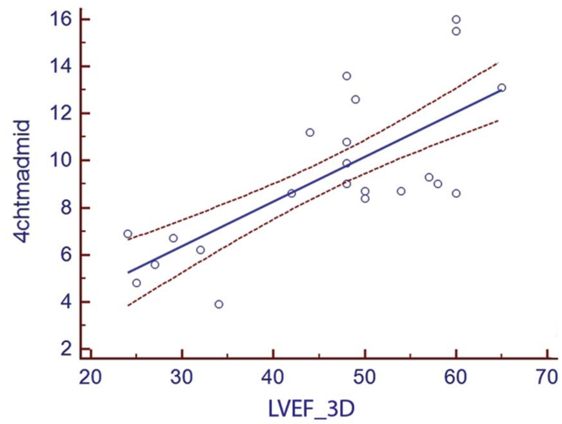

Figure 4. Correlation graph between three-dimensional left ventricular ejection fraction (3D LVEF) values and the percentage of the midpoint mitral annulus displacement relative to the apex in the apical four-chamber view

contraction. The algorithm determines the center of the mitral annulus and measures the displacement of the annulus relative to the apex during the systole in millimeters and percentages, relative to the baseline value in the left ventricular diastolic phase.

The evaluation of LVEF in all patients included: two-dimensional measurement using Simpson's method and performed off-line three-dimensional measurement using QLAB software. TMAD and LVEF measurements were performed by one echocardiographer, while the analyses of both parameters were performed independently: the LVEF parameter on the ultrasound machine during echocardiographic examination and TMAD on the workstation.

Results

Due to the suboptimal quality of the data, insufficient for accurate tracking the acoustic markers by the TMAD algorithm, 5 patients were excluded from the study. Mean LVEF values in the study group were 44.4% ± 18.9% (2D Simpson) and 46.0% ± 12.3% (3D LVEF). Among the analyzed group of patients, there was a statistically significant correlation between LVEF and the midpoint mitral annulus displacement towards the apex in the apical four-chamber view ($r = 0.57$, $p < 0.0001$) (Figure 3) and the percentage of the midpoint mitral annulus displacement ($r = 0.63$, $p < 0.0001$) (Figure 4). A similar correlation was observed between midpoint mitral annulus displacement in the apical two-chamber view ($r = 0.6$, $p < 0.0001$) (Figure 5) and the percentage of the midpoint mitral annulus displacement ($r = 0.65$, $p < 0.0001$) (Figure 6). The mean time of analysis of one apical view was 10 ± 4 s.

Discussion

Analysis of the mitral annulus motion as a reflection of the left ventricular systolic function has been studied already in the 1960s [3]. Initially, it involved the assessment of mitral annulus displacement towards the apex (MAPSE, mitral annular plane systolic excursion) in one or all apical projections using the M-mode. This analysis was simple and fast, but associated with significant disadvantages which included dependence on age, height, body surface area and heart rate [4–6].

A step forward was the analysis of regional myocardial velocities using Doppler tissue imaging (TDI), assessment of wall deformation (strain) and strain rate. The strain

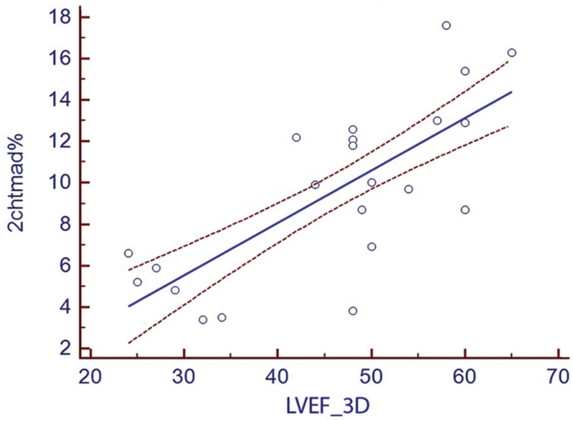

Figure 6. Correlation graph between three-dimensional left ventricular ejection fraction (3D LVEF) values and the percentage of the midpoint mitral annulus displacement relative to the apex in the apical two-chamber view

is expressed as a percentage and reflects the change in the distance between two fixed points of the myocardium at given periods of the heart cycle. The strain rate is expressed in reciprocal seconds (s^{-1}) and calculated as the difference in velocity between two points in the defined region of interest divided by the distance between them. TDI has been used in assessment of many disorders of myocardial mechanics, but it was not devoid of limitations, such as dependence on the ultrasound beam angle and the possibility of assessing parameters only along its course as well as high susceptibility to interference [2, 7–9].

Relatively new and angle-independent technique is speckle-tracking echocardiography (STE), which allows for precise, quantitative evaluation of myocardial deformation in different directions in the imaging plane. The algorithm for tracking acoustic markers uses the analysis of changes in particular points of the echocardiographic image in subsequent heart cycles. The software defines a vector of displacement of a given myocardial point, which consists of distance and speed, and analyzes changes relative to the initial position. This technique allows, regardless of the angle of ultrasound beam, obtaining detailed data that define systolic and diastolic functions of individual segments in 3 directions: transverse, longitudinal and circular. The limitations of this technique include a lower time resolution compared to the tissue Doppler technique and a high sensitivity to suboptimal image quality [7, 10–12].

In 2001, Pan at al. [13] published an analysis of several dozens of patients in whom mitral annulus displacement was measured in three apical views — a total of 6 tissue velocity measurements using TDI with respective measurements using M-mode — in relation to LVEF measurements using the Simpson method (2 apical projections). The authors showed a significant correlation of the measurements obtained using a tissue Doppler and M-mode techniques with LVEF values [13].

Currently, there are only four literature reports on the measurement of systolic displacement of the mitral annulus by means of the acoustic marker tracking technique. DeCara et al. [14] examined 65 patients using this technique and compared the obtained values with the LVEF measurements usiobtained with Simpson's method. Their results confirmed the high correlation between TMAD values and the two-plane standard LVEF measurements [14]. In 2010, Tsang et al. [15] examined a group of 118 patients using the TMAD algorithm in relation to LVEF assessment based on magnetic resonance imaging and obtained encouraging results indicating a significant correlation between both measurements. The latest reports were published in 2012 [16] and concerned a study including 152 patients with cardiac pathologies and 47 healthy volunteers. The evaluation of the left ventricular systolic function was carried out using TDI, global strain assessments and measurements of systolic mitral annulus displacement using the TMAD algorithm. The authors showed a significant correlation of peak systolic strain and strain rate with TMAD measurements [16]. On the other hand, Chiu et al. [17] compared LVEF measurements using Simson's method, global left--ventricular strain (GLS) and TMAD values in 198 hemodialyzed patients and showed that the reduced LVEF and GLS values were related to the negative prognosis in this group of patients, while the TMAD values, although were easy to apply and highly reproducible, were characterized by poor prognostic value in this population [17]. The authors assessed a specific subgroup of hemodialyzed patients in whom many other factors — not only LVEF — might affect mortality and cardiovascular events. Perhaps that is why the TMAD values in multivariate analysis were not related to long-term prognosis in these patients.

Due to the small group of patients, it was not possible to determine the cut-off value of TMAD that would indicate left ventricular systolic dysfunction. In the available literature, we also fail to find such data. The technique is new and too little data are available to estimate this parameter.

Limitations

Currently, an important disadvantage of the assessed parameter is the need to perform off-line analysis after recording the data set and transferring it to the workstation. However, considering the development of technology nowadays, it may be a temporary limitation.

The measurement of TMAD represents the change in the linear dimension, while the LVEF measurement reflects a relative change in the volume of the left ventricle, hence the presence and strength of the linear correlation between these parameters does not necessarily indicate the accuracy of the mitral displacement measurement. Further studies are needed to analyze the usefulness of this technique in a variety of clinical scenarios.

The limitation of our study is a small group of patients and the fact that the measurements were performed by one echocardiographer, without the analysis of intra- and inter-observer variability. However, due to the promising results, we believe that this technique is worth to be assessed in further, more extensive research projects.

Conclusions

Summing up the above results of global left ventricular systolic function assessment using TMAD technique, this algorithm seems to be a fast and interesting tool showing a significant correlation with 3D LVEF measurement. Hovever, both techniques require a high quality of data collection and a wider examination of its suitability in various clinical scenarios.

Conflict of interests

None declared.

Streszczenie

Wstęp. Tkankowe przemieszczenie pierścienia mitralnego (TMAD) jest nową techniką szybkiej oceny funkcji skurczowej mięśnia lewej komory opartą na śledzeniu markerów akustycznych. Pozwala ona na ocenę przemieszczenia pierścienia mitralnego w stosunku do koniuszka w typowych projekcjach koniuszkowych (cztero- i dwujamowej).

Celem pracy było porównanie parametrów otrzymanych przy użyciu TMAD z analizą trójwymiarowego (3D) pomiaru frakcji wyrzutowej lewej komory (LVEF) jako metody referencyjnej.

Materiał i metody. Badaniem objęto 49 pacjentów (w tym 33 mężczyzn, średni wiek 65 ± 10 lat) hospitalizowanych z powodu bólów stenokardialnych, których poddano przezklatkowemu badaniu echokardiograficznemu z oceną LVEF 3D podczas analizy *off-line* na podstawie zbiorów uzyskanych z badania. Poza tym dokonano pomiarów przemieszczenia skurczowego pierścienia mitralnego przy użyciu algorytmu TMAD u wszystkich pacjentów.

Wyniki. Ze względu niewystarczającą dla funkcji śledzenia markerów akustycznych jakość obrazu z badania wykluczono 5 pacjentów. Analiza TMAD w jednej z projekcji koniuszkowych zajęła przeciętnie 10 ± 4 s. Średnia wartość LVEF wyniosła 46,0% ± 12,3%. W grupie badanych pacjentów otrzymano istotną statystycznie korelację między LVEF a przemieszczeniem środka pierścienia mitralnego w kierunku koniuszka w projekcji koniuszkowej czterojamowej ($r = 0{,}57$; $p < 0{,}0001$) oraz procentowym przemieszczeniem pierścienia w kierunku koniuszka ($r = 0{,}63$; $p < 0{,}0001$). Porównywalne wyniki otrzymano dla przemieszczenia środka pierścienia mitralnego w kierunku koniuszka w projekcji koniuszkowej dwujamowej ($r = 0{,}6$; $p < 0{,}0001$) oraz jego wartości procentowej ($r = 0{,}65$; $p < 0{,}0001$).

Wnioski. Pomiar skurczowego przemieszczenia pierścienia mitralnego przy użyciu algorytmu TMAD koreluje z referencyjnym pomiarem LVEF 3D, ale technika ta wymaga zbioru danych bardzo dobrej jakości.

Słowa kluczowe: skurczowe przemieszczenie pierścienia mitralnego, frakcja wyrzutowa lewej komory, śledzenie markerów akustycznych

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