Comparison of apical left ventricular segments strain imaging by tissue Doppler and speckle tracking echocardiography

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Abstract

Background: Spatial orientation of left ventricular (LV) apical segments is a potential limitation to assessment by tissue Doppler echocardiography (TDE). Speckle tracking echocardiography (STE) is a recently developed quantification technique and has the advantage of being angle-independent as compared to TDE.

Aim: To assess matching apical segments' longitudinal strain data from TDE and STE.

Methods: A 16-segment LV model was used. The study was based on a dataset of 306 myocardial segments from 22 consecutive patients with various degrees of wall motion abnormalities. 82 available apical lateral, septal, anterior and inferior segments from 2-chamber and 4-chamber views were selected for further assessment. The Bland-Altman method was used for comparison of mean strain values of corresponding segments.

Results: An acceptable overall agreement between the two modalities was shown by the Bland-Altman method. The correlation ratio was 0.7. The measurements of apical lateral and anterior segments' longitudinal strain showed no significant difference. Speckle tracking echocardiography tended to produce lower strain results than TDE with mean values of –9 and –14%, respectively, p=0.0025.

Conclusions: Although angle-dependency of TDE may be a potential limitation in the strain imaging of apical LV segments, the overall agreement between TDE and angle independent STE technique is still acceptable.

Key words: tissue Doppler echocardiography, strain imaging, speckle tracking echocardiography

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Introduction

Echocardiography is a key diagnostic modality in cardiology used to evaluate both systolic and diastolic myocardial performance. In addition to conventional parameters such as left ventricular (LV) volume, ejection fraction (LVEF) or mitral valve inflow profile, a complex analysis of myocardial characteristics employing velocities and strain, displacement or rotation is currently also available. Such analysis is possible with the use of two different techniques, i.e. tissue Doppler echocardiography (TDE) and speckle tracking echocardiography (STE), although they are not free from specific limitations. Use of the Doppler technique enables measurement of myocardial motion velocity and calculation of several additional parameters such as myocardial strain, strain rate and further derived variables [1].

In contrast to myocardial motion velocity, where the changes of muscle position in relation to the echocardiographic probe are assessed, the above-mentioned parameters reflect the movement of adjacent points within the myocardium; thus they are independent of general heart motion inside the thorax, location of the region of interest (RoI) within the LV myocardium, or any traction caused by adjacent muscular segments [2] (Figure 1). The most important limitation of the regional analysis employing tissue Doppler imaging is its dependence on the angle of the transmitted ultrasonic beam. Correct acquisition may be provided only in the parallel axis; thus parameters calculated by means of this method identify only longitudinal function (cardiac base – apex direction) in the apical views, and in the parasternal views only tranverse and circumferential performance. Additional problems result from

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relatively low velocities in the longitudinal direction and special orientation of the LV apical segments. For these reasons it is widely accepted that their assessment using tissue Doppler may be potentially of limited value, especially in the case of significant LV remodelling [3].

Recently a technique for evaluation of strain and other myocardial function parameters in two directions for each LV segment using a special algorithm for tracing selected acoustic markers (pixels) of the grey scale image (so-called *speckle tracking*) has been introduced [4] (Figure 2). It should be pointed out that the Doppler phenomenon is not employed in this technique and the use of two-dimensional imaging eliminates limitations related to the angular error of the emitted ultrasonic wave [5].

The purpose of this study was to compare strain values of the LV apical segments in the longitudinal direction using tissue Doppler and the speckle tracking algorithm.

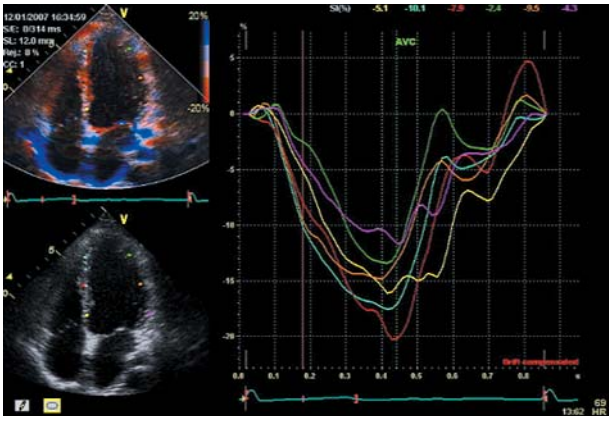

Figure 1. Four-chamber apical view; a quantitative analysis of myocardial longitudinal strain using tissue Doppler echocardiography (adopted from: Chrzanowski Ł, Lipiec P, Krzemińska-Pakuła M, et al. Echocardiographic evaluation of left ventricular strain with the use of tissue Doppler technique and speckle tracking echocardiography. *Polski Przegląd Kardiologiczny* 2007; 9: 195-202)

Abbreviation: AVC – aortic valve closure

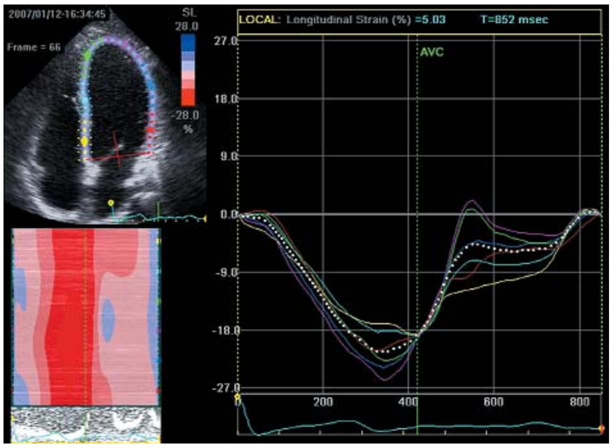

Figure 2. Four-chamber apical view; a quantitative analysis of myocardial longitudinal strain using speckle tracking echocardiography. Measurements correspond to location in Figure 1 (adopted from: Chrzanowski Ł, Lipiec P, Krzemińska-Pakuła M, et al. Echocardiographic evaluation of left ventricular strain with the use of tissue Doppler technique and speckle tracking echocardiography. *Polski Przegląd Kardiologiczny* 2007; 9: 195-202)

Methods

Studied group

Twenty-two consecutive patients (at mean age of 57 years, 73% males) with coronary artery disease (100%) and systemic hypertension (73%) with either normal systolic function or reduced LV contractility of varied degree were enrolled.

Echocardiography

Echocardiography was performed in the standard parasternal and apical views using a VIVID 7 device (GE Healthcare). Loop sequences of the tissue mode scans (colour-coded map superimposed on two-dimensional picture) were digitally recorded to enable strain analysis by means of Doppler imaging technique. Assessment by means of speckle tracking, for technical reasons, required high temporal resolution of acquired grey-scale loops reaching 50-75 frames per second (FPS). With this technique apical segments in four- and two-chamber views were analysed. After acquisition of images had been completed, strain quantitative analysis was performed using a dedicated workstation equipped with EchoPac (GE Healthcare) (*off-line* mode). Region of interest in TDE evaluation was positioned in the basal parts of the examined apical segments. STE analysis involved manual tracing of a LV endocardial contour, acceptance of appropriate reproduction quality level of the RoI, and corrections when needed, and finally automatic calculations.

Statistical analysis

Agreement of strain measurements within corresponding myocardial segments was assessed by means of the Bland-Altman method (MedCalc software, 8.2.0.2 version, 2006). The general correlation index was also calculated and two-tailed t tests were used for dependent variables in order to find any possible differences between strain values measured by means of the two echocardiographic techniques (MedCalc software, 8.2.0.2 version, 2006). Intra- and interobserver variability of the measurements was also evaluated. A p value <0.05 was considered significant.

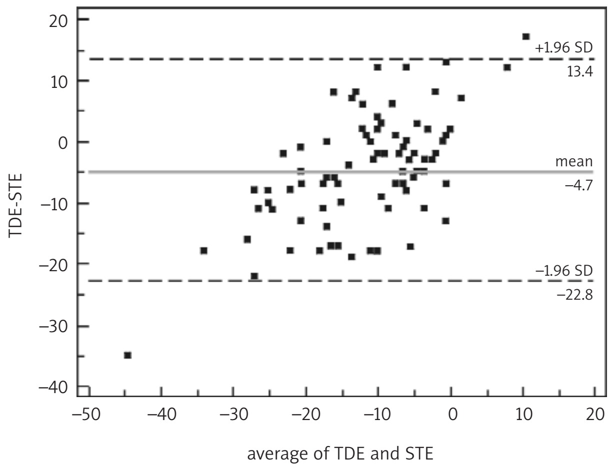

Figure 3. Bland-Altman plot presenting a comparison of left ventricular segments strain by tissue Doppler echocardiography (TDE) and by speckle tracking echocardiography (STE)

mean – mean value, SD – standard deviation

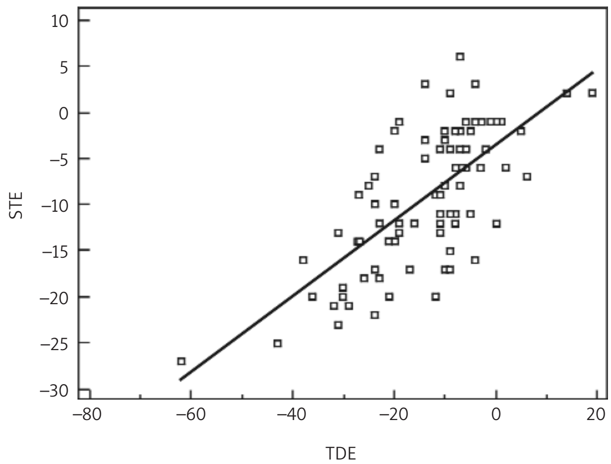

Figure 4. Linear regression plot presenting correlation of left ventricular segments, strain by tissue Doppler echocardiography (TDE) and by speckle tracking echocardiography (STE)

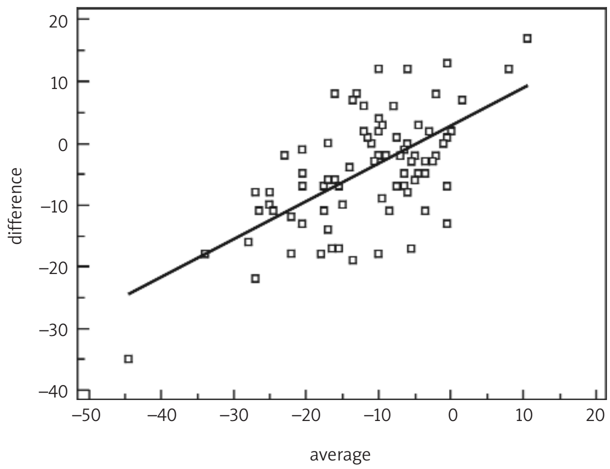

Figure 5. Linear regression plot presenting a statistically significant correlation (p <0.05) between average and difference of the measurements of left ventricular segment strain by means of tissue Doppler echocardiography (TDE) and speckle tracking echocardiography (STE)

Table I. Comparison of strain values of apical left ventricular segments in the longitudinal direction using tissue Doppler echocardiography (TDE) and speckle tracking echocardiography (STE)

Apical segments	Strain		p value	Mean difference	95% CI
	TDE [%]	STE [%]			
Overall	–14.0	–9.0	0.0025	5.0	1.8–8.2
Septal	–19.0	–13.0	0.0022	6.0	0.0–11.3
Lateral	–8.2	–5.7	NS	2.5	(–)1.4–6.3
Inferior	–24.0	–13.6	0.0001	10.4	5.9 – 14.9
Anterior	–5.0	–4.8	NS	0.2	(–)3.7–4.0

Abbreviations: NS – difference of no statistical significance, CI – confidence interval

Results

Feasibility of quantitative data and LV function parameters

Analysis involved 82 out of 88 apical segments (quantitative data feasibility was 93% for TDE and 95% for STE, respectively). Of 6 segments that were not entered for further analysis, inadequate imaging quality was found within 2 apical segments of the lateral wall, 2 of the inferior wall, 1 apical segment of the anterior wall and 1 of the interventricular septum. Mean LVEF was 51% and ranged from 23 to 65%; in 10 patients it exceeded 55%. Mean LV end-diastolic dimension was 51 mm, end-systolic dimension – 37 mm, and LV mass index – 133 g/m^2 of the body surface area.

TDE and STE comparison

The Bland-Altman method showed an acceptable level of agreement between both analytic techniques of regional function assessment (Figure 3). A correlation coefficient of r=0.7 reflected a strong linear correlation, although data collected in the STE study showed a tendency to lower strain values compared with TDE (mean values were –9 and –14%, respectively; p=0.0025) (Figure 4). Moreover, a gradual increase in differences between measurements together with an increase in the absolute values of strain assessed with the Doppler imaging technique and the grey scale algorithm was noted (Figure 5). In the analysis employing two-tailed t tests mean values of longitudinal strain of the apical segments of either lateral or anterior wall did not differ significantly with respect to both methods of quantitative assessment (Table I). The variability of results collected by one observer (*intraobserver variability*) was 17% in the Doppler analysis and 10% in evaluation based on grey scale, while these values in the case of two observers (*interobserver variability*) were 23 and 11%, respectively.

Discussion

The findings presented in this report indicate that TDE and STE represent comparable feasibility of myocardial strain quantitative data acquisition.

The values exceeding 90% in the case of STE are consistent with the earlier reports [6]. Currently, evaluation using the technique of grey scale imaging is possible only after study completion (*off-line*) and involves manual contour tracing of the myocardium of interest followed by entering this material into an automatic data processing system. Methodology and computer software are steadily being improved and generally the STE technique compared with TDE is less time-consuming and also provides a markedly higher number of tissue parameters that can be recorded after just a single contour trace of the RoI.

General agreement between both methods of apical segment regional assessment is satisfactory and shows no statistically significant differences with respect to longitudinal strain of the described segments of the lateral and anterior wall. These results seem quite surprising since the tissue Doppler technique is thought to be dependent on the angle of the transmitted ultrasonic beam and the lack of this limitation is one of the main advantages of the STE technique. Moreover, special orientation of apical segments potentially limits applicability of TDE for analysis because the examined strain may be in an oblique rather than a longitudinal direction.

Fairly significant differences regarding technical aspects of the employed methods must also be highlighted. In the case of STE, a whole LV endocardium is traced and further analysis involves more or less the entire myocardium. Meanwhile, in the Doppler imaging technique the areas of interest that cover only a small portion of the LV segment are manually selected and analysis of the instantaneous strain (also called the natural strain) is performed; the size of Doppler sample volume employed is usually between 5 and 11 mm [7]. An explanation of the high agreement achieved in our study with the two techniques might be adequate selection of the RoIs selected in TDE. It is important that they should be located in the basal part of the examined segment, especially if the apical LV area is studied. Additionally, despite including patients with a varied degree of LV systolic dysfunction, definitely in the majority of participants no significant remodelling was found and the values of LVEF were relatively high.

It should be stressed that the accuracy of strain imaging applying either TDE or STE has been validated against reference methods such as sonomicrometry and tagged magnetic resonance imaging (MRI *tagging*) [8-10].

Our findings are similar to those published previously. The reported strain values calculated by means of TDE and STE did not differ in the apical views in healthy volunteers or in individuals with systolic dysfunction of varied degree [11, 12]. In future STE would probably be more useful in clinical practice because detailed quantitative analysis of a higher number of myocardial segments is easier with this technique and variability of the measurements is lower. To acquire data of adequately high time-resolution it is crucial to perform an analysis in STE mode using grey scale images optimized with regard to the number of frames per second. It is suggested that even so TDE employment enables collection of more detailed curves and more appropriate evaluation of the time-related parameters. Even with introduction of the two-dimensional method one should remember that imaging of real myocardial strain is only a simplification because in reality it is a three-dimensional phenomenon and is determined by complex mechanisms related to changes in geometry of the cardiac anatomical structures.

Another limitation having an adverse impact on accuracy of the assessment is the assumption that myocardium is a tissue that does not change its volume under loading. In reality this assumption is not completely correct because it does not take into consideration any changes in blood volume in the intramuscular vessels throughout cardiac systole or diastole [5]. It should also be stressed that regional analysis with the use of TDE and STE is prone to bias associated, among other things, with inadequate quality of the recorded images. Further studies are needed to confirm TDE and STE agreement. Besides strain amplitude, it is of importance to consider the problem of the time-related parameters providing information about possible manifestation of post-systolic shortening, a potential marker of myocardial ischaemia [13].

Regarding current clinical practice, an assessment of tissue parameters may potentially increase the diagnostic value of dobutamine echocardiography, be helpful in detecting subclinical LV systolic dysfunction in patients with mitral regurgitation, and help determine new aspects of cardiac performance such as rotation and diastolic untwisting [14-16].

Conclusions

In spite of potential limitations resulting from angle-dependency in the echocardiographic evaluation of apical segments using the tissue Doppler technique, measurements of longitudinal strain show a satisfactory agreement with the speckle tracking method.

References

1. Sutherland GR, Stewart MJ, Groundstroem WE, et al. Color Doppler myocardial imaging: a new technique for the assessment of myocardial function. *J Am Soc Echocardiogr* 1994; 7: 441-58.
2. Heimdal A, Støylen A, Torp H, et al. Real-time strain rate imaging of the left ventricle by ultrasound. *J Am Soc Echocardiogr* 1998; 11: 1013-9.
3. Storaa C, Aberg P, Lind B, et al. Effect of angular error on tissue Doppler velocities and strain. *Echocardiography* 2003; 20: 581-7.

4. Bohs LN, Trahey GE. A novel method for angle independent ultrasonic imaging of blood flow and tissue motion. *IEEE Trans Biomed Eng* 1991; 38: 280-6.
5. Marwick TH. Measurement of strain and strain rate by echocardiography. Ready for prime time? *J Am Coll Cardiol* 2006; 47: 1313-27.
6. Serri K, Reant P, Lafitte M, et al. Global and regional myocardial function quantification by two-dimensional strain: application in hypertrophic cardiomyopathy. *J Am Coll Cardiol* 2006; 47: 1175-81.
7. Pellerin D, Sharma R, Elliott P, et al. Tissue Doppler, strain, and strain rate echocardiography for the assessment of left and right systolic ventricular function. *Heart* 2003; 89 Suppl 3: iii9-17.
8. Urheim S, Edvardsen T, Torp H, et al. Myocardial strain by Doppler echocardiography. Validation of a new method to quantify regional myocardial function. *Circulation* 2000; 102: 1158-64.
9. Edvardsen T, Gerber BL, Garot J, et al. Quantitative assessment of intrinsic regional myocardial deformation by Doppler strain rate echocardiography in humans: validation against three-dimensional tagged magnetic resonance imaging. *Circulation* 2002; 106: 50-6.
10. Amundsen BH, Helle-Valle T, Edvardsen T, et al. Noninvasive myocardial strain measurement by speckle tracking echocardiography: validation against sonomicrometry and tagged magnetic resonance imaging. *J Am Coll Cardiol* 2006; 47: 789-93.
11. Leitman M, Lysyansky P, Sidenko S, et al. Two-dimensional strain-a novel software for real-time quantitative echocardiographic assessment of myocardial function. *J Am Soc Echocardiogr* 2004; 17: 1021-9.
12. Chrzanowski Ł, Lipiec P, Wejner-Mik P, et al. Comparison of tissue Doppler and speckle tracking strain: a feasibility study. *Eur Heart J* 2006; 27 (Abstract Suppl): 564.
13. Bach DS, Armstrong WF, Donovan CL, et. al. Quantitative Doppler tissue imaging for assessment of regional myocardial velocities during transient ischemia and reperfusion. *Am Heart J* 1996; 132: 721-5.
14. Bjork Ingul C, Rozis E, Slordahl SA, et al Incremental value of strain rate imaging to wall motion analysis for prediction of outcome in patients undergoing dobutamine stress echocardiography. *Circulation* 2007; 115: 1252-9.
15. Marciniak A, Claus P, Sutherland GR, et al. Changes in systolic left ventricular function in isolated mitral regurgitation. A strain rate imaging study. *Eur Heart J* 2007; 28: 2627-36.
16. Takeuchi M, Borden WB, Nakai H, et al. Reduced and delayed untwisting of the left ventricle in patients with hypertension and left ventricular hypertrophy: a study using two-dimensional speckle tracking imaging. *Eur Heart J* 2007; 28: 2756-62.

Odkształcenie koniuszkowych segmentów lewej komory w echokardiograficznej ocenie porównawczej przy użyciu technik doplera tkankowego oraz śledzenia markerów akustycznych (ang. *speckle tracking*)

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Streszczenie

Wstęp: Orientacja przestrzenna segmentów koniuszkowych lewej komory (LV) stwarza potencjalne ograniczenie w obrazowaniu odkształcenia (ang. *strain*) za pomocą tkankowej echokardiografii doplerowskiej (TDE). Algorytm śledzenia markerów akustycznych (STE) (lub śledzenia pikseli – ang. *speckle tracking*) jest niedawno opracowaną techniką ilościową, niewykazującą zależności pomiaru od kąta obrazowania.

Cel: Porównanie wartości odkształcenia podłużnego koniuszkowych segmentów LV przy zastosowaniu TDE i STE.

Metodyka: Zastosowano 16-segmentowy model LV. Badanie przeprowadzono z wykorzystaniem 306 segmentów mięśnia sercowego obrazowanych u 22 kolejnych pacjentów z chorobą niedokrwienną serca i nadciśnieniem tętniczym, charakteryzujących się różnym stopniem zaburzeń kurczliwości LV. Do analizy włączono 82 segmenty koniuszkowe (spośród 88 dostępnych) ściany bocznej, ściany dolnej, ściany przedniej i przegrody międzykomorowej, uwidocznione w projekcji koniuszkowej czterojamowej i w projekcji koniuszkowej dwujamowej. Porównanie zgodności wskaźników odkształcenia mięśnia sercowego w obrębie odpowiadających segmentów przeprowadzono metodą Blanda-Altmana.

Wyniki: Możliwość uzyskania danych ilościowych (ang. *feasibility*) wynosiła 93% dla TDE i 95% dla STE. Spośród 6 segmentów, niedostateczną jakość obrazowania uniemożliwiającą dalszą analizę stwierdzono w obrębie 2 koniuszkowych segmentów ściany bocznej, 2 – ściany dolnej, 1 koniuszkowego segmentu ściany przedniej i 1 – przegrody międzykomorowej. Średnia wartość frakcji wyrzutowej LV (LVEF) była równa 51% (23–65%), u 10 badanych wartość LVEF przekraczała 55%. Średni wymiar końcoworozkurczowy LV wynosił 51 mm, wymiar końcowoskurczowy – 37 mm, wskaźnik masy LV – 133 g/m^2 powierzchni ciała. Współczynnik korelacji wartości odkształcenia analizowanych segmentów koniuszkowych w kierunku podłużnym wynosił 0,7, wykazano również zadowalający poziom zgodności obu technik analizy regionalnej metodą Blanda-Altmana. Dane uzyskiwane za pomocą STE charakteryzowały się tendencją do niższych wartości odkształcenia w porównaniu z TDE (średnie wartości odpowiednio –9 i –14%, p=0,0025). Ponadto stwierdzono zwiększanie się różnicy pomiarów wraz ze wzrostem bezwzględnych wartości odkształcenia ocenianego za pomocą techniki doplerowskiej i algorytmu wykorzystującego obrazy w skali szarości. Średnie wartości odkształcenia podłużnego koniuszkowych segmentów ściany bocznej i przedniej nie różniły się istotnie w zakresie obydwu echokardiograficznych metod oceny ilościowej.

Wnioski: Mimo potencjalnych ograniczeń wynikających z zależności od kąta wiązki ultradźwiękowej w ocenie segmentów koniuszkowych za pomocą TDE, pomiary odkształcenia w kierunku podłużnym charakteryzują się zadowalającym poziomem zgodności w porównaniu z STE.

Słowa kluczowe: tkankowa echokardiografia doplerowska, odkształcenie mięśnia sercowego, śledzenie markerów akustycznych

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