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The Assessment of Left Ventricular Time-Varying Radius Using Tissue Doppler Imaging

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ABSTRACT

Background: Left ventricular twist/torsion is believed to be a sensitive indicator of systolic and diastolic performance. To obtain circumferential rotation using tissue Doppler imaging, we need to estimate the time-varying radius of the left ventricle throughout the cardiac cycle to convert the tangential velocity into angular velocity.
Objective: The aim of this study was to investigate accuracy of measured LV radius using tissue Doppler imaging throughout the cardiac cycle compared to two-dimensional (2D) imaging.
Methods: A total of 35 subjects (47±12 years old) underwent transthoracic echocardiographic standard examinations. Left ventricular radius during complete cardiac cycle measured using tissue Doppler and 2D-imaging at basal and apical short axis levels. For this reason, the 2D-images and velocity-time data derived and transferred to a personal computer for off-line analysis. 2D image frames analyzed via a program written in the MATLAB software. Velocity-time data from anteroseptal at basal level (or anterior wall at apical level) and posterior walls transferred to a spreadsheet Excel program for the radius calculations. Linear correlation and Bland-Altman analysis were calculated to assess the relationships and agreements between the tissue Doppler and 2D-measured radii throughout the cardiac cycle.
Results: There was significant correlation between tissue Doppler and 2D-measured radii and the Pearson correlation coefficients were 0.84 to 0.97 (P<0.05). Bland-Altman analysis by constructing the 95% limits of agreement showed that the good agreements existed between the two methods.
Conclusion: It can be concluded from our experience that the tissue Doppler imaging can reasonably estimate radius of the left ventricle throughout the cardiac cycle.

Implication for health policy/practice/research/medical education:
Estimating the time-varying radius of the LV is required to calculate the tissue Doppler based-LV twist. For this purpose, the tissue Doppler imaging can be used with acceptable accuracy.

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1. Introduction

Developments in echocardiography have provided a powerful tool to quantify LV function. In recent decades, one of the most important advances has been the development of techniques to measure tissue velocity and deformation (1,2). Tissue Doppler imaging (TDI) has fundamentally altered the way echocardiographic approaches characterized global and regional myocardial function (3,4). TDI-based indices of myocardial function have proved to be sensitive measurements (5). In this method only large amplitude echoes with lower frequency shifts are retained and low amplitude echoes with higher frequency shifts are suppressed by low-pass filter, as a result the motion of the tissues can be monitored (6-8).The development of this technique has enabled more accurate assessment of myocardial functional parameters that have been validated by test phantoms, angiographic, sonomicrometry or by magnetic resonance imaging (MRI) studies (9,10).

LV twist or torsion is essential for proper myocardial function. It has an important role in maintaining efficient myocardial function during systole and diastole and may be

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considered as marker for cardiac disease. The importance of measuring LV torsion lies in its ability to provide regional information, its potential for early detection of heart diseases and guiding clinical treatment. Measurements of torsional parameters provide further insight into disease beyond conventional imaging measures such as ejection fraction and Doppler indexes. In papers recently published by Notomi et al., a novel method has been proposed for quantifying LV rotation and torsion in humans using TDI (11-13). To obtain the LV rotation, they estimated the time-varying radius of the LV [R(t)] to convert the tangential velocity of the LV into angular velocity. The aim of this study was to investigate accuracy of LV radius in human subjects measured in short axis using TDI compared to two-dimensional (2D) image frames throughout the cardiac cycle.

2. Materials and Methods

The present study carried out from December 2010 to October 2011. All echocardiography examinations and image processing and analysis were performed in Heshmat Cardiovascular Research Center, Guilan University of Medical Sciences, Rasht, IR, Iran.

2.1. Participants under study

The study group consisted of 9 healthy volunteers who had no cardiac abnormality at clinical, ECG, and Doppler echocardiographic examinations and 26 patients with coronary artery disease (CAD) (in total 24 men, mean age=47±12 years, range 30 to 60 years-old). This study was approved by the local ethical committee and the participants had given written informed consent.

2.2. Echocardiography

Echocardiography studies were performed using a Vivid GE echocardiography system with an ergonomically designed M3S transthoracic multi-frequency transducer (2.5-4 MHz), while the participants rested in the left lateral position.

TDI was performed using Color Doppler myocardial imaging (CDMI) in the standard parasternal short axis view at LV basal and apical levels for accessing myocardial velocities in radial function at the end of expiration according to the guidelines of the American Society of Echocardiography. The sector angle being adjusted and care was taken to keep the anterior and posterior LV wall segments perpendicular to the ultrasound beam to be aligned at, as near zero degrees as possible to radial motion. An appropriate velocity scale was chosen to avoid aliasing. CDMI data recorded throughout at least two cardiac cycles and two-dimensional (2D) invisible color CDMI stored digitally as cine-loop format in the memory of the scanner.

2.3. Off-line Analysis

The stored para-sternal short axis CDMI data sets were processed using the EchoPac quantitative analysis software equipped to obtain regional myocardial velocity. At each level, two 4 mm sample volumes manually placed in the endocardium of anteroseptal wall (AS) at basal level (or anterior wall at apical level) and posterior wall (PW) segments to obtain myocardial velocity-time profiles (Figure 1).

The velocity data exported from the velocity profiles.

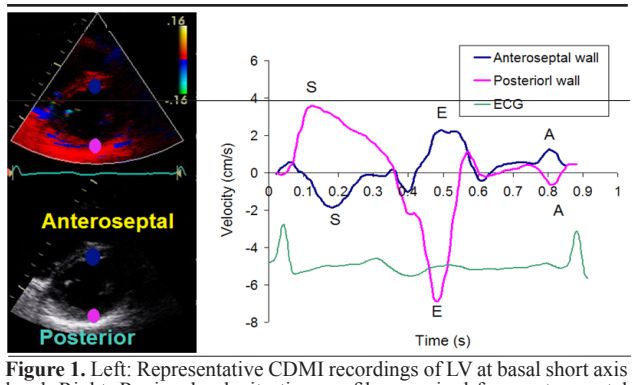

Figure 1. Left: Representative CDMI recordings of LV at basal short axis level. Right: Regional velocity-time profiles acquired from anteroseptal and posterior wall segments at basal level. S=Peak systolic velocity, E=Peak early diastolic velocity, A=Peak late diastolic velocity

Velocity data and stored cine-lope CDMI images transferred to a personal computer.

The 2D images converted to 2D frames, and LV dimension was then measured from AS endocardium edge to PW endocardium edge and the result was divided by two to calculate LV radius using a program written in the Matlab software version 7.04 (Figure 2).

Furthermore, using the velocity data sets, the LV radius was calculated throughout the cardiac cycle as follow:(12)

$$Radius(t) = R_0 + \frac{\left[\int_0^t [V_{Anterior}(t) - V_{Posterior}(t)]dt\right]}{2}$$

Where VAnterior and VPosterior are myocardial velocity at anterior and posterior regions respectively, and R0 is end-diastolic radius.

2.4. Statistical Analysis

All continues data were expressed as mean±SD. The linear correlation was calculated to assess the relationships between the LV radii measured using tissue Doppler and 2D imaging. In addition, Bland-Altman analysis was calculated to assess agreements between the two measurements.(14) All the statistical analyses were performed using the SPSS version 13 software package (SPSS Inc. Chicago, IL, USA).

3. Results

3.1. Clinical and Echocardiographic Characteristic

Clinical characteristics and echocardiographic data of all participants under study are summarized in Table 1.

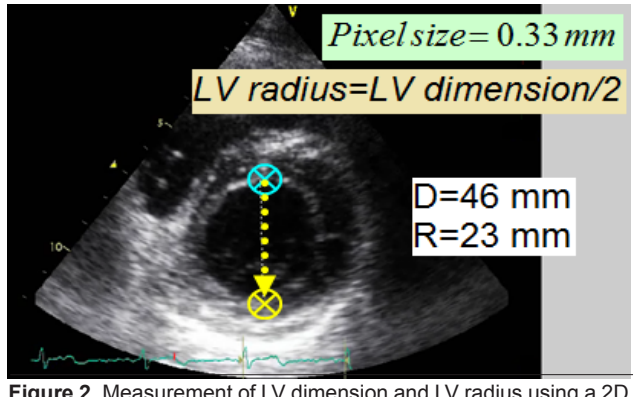

Figure 2. Measurement of LV dimension and LV radius using a 2D short axis image frame. To calculate LV radius, the LV dimension divided by two. In this image, LV dimension and LV radius are 46 mm and 23 mm, respectively. D=LV Dimension, R=LV Radius.

Table 1. Demographic, hemodynamic and echocardiographic characteristics of the participants under study

Variables	Mean±SD
Age (year)	47±12
Total subjects (Male/female)	35(24/11)
SBP (mmHg)	127±14
DBP (mmHg)	84±9
LVEF(%)	48±8
HR (beats/min)	79±11
BMI (kg/m^2)	23±2

SBP=Systolic blood pressure, DBP=Diastolic blood pressure, MI=Body mass index, LVEF=LV, ejection fraction evaluated by Modified biplane Simpson's method

3.2. Correlation study and Bland-Altman analysis

Figure 3 shows the LV radius profiles obtained at the basal level using TDI and 2D methods in a CAD patient throughout the two cardiac cycles. Linear regression analysis and the correlation coefficient were estimated to assess relationships between TDI-measured radiuses and 2D-measured radiuses.

We found significant correlation coefficient in all subjects (range from r=0.84 to r=0.97). For example, Figure 4 shows that TDI-measured radiuses significantly correlated with the 2D-measured radiuses in a patient with CAD throughout the cardiac cycles (r=0.94, P<0.001).

Bland-Altman analysis with 95% limit of agreements (LOA) (i.e., mean difference±1.96SD of the difference) was calculated to assess agreements between TDI-measured and 2D-measured radiuses. The mean difference between all TDI and 2D-measured radiuses was 0.29±0.14 mm. Figure 5 shows the Bland-Altman plots for the patient (mean differences: 0.38±0.64 mm, LOA: ±1.28 mm).

4. Discussion

Current echocardiography scanners have facilitated the regional evaluation of the myocardial systolic and diastolic functions noninvasively. Recently, TDI is used to quantitatively evaluate myocardial velocity, displacement, acceleration, strain/strain rate, and LV torsional parameters (15). It has been proposed that remodeling of the myocardium, degradation of the extracellular matrix, alterations in regional myocardial blood flow or electrical activation may result in altered patterns of LV rotation and torsion in cardiac patients.

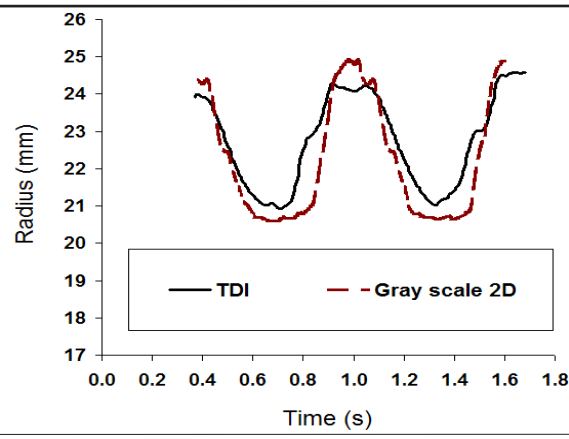

Figure 3. LV radius profiles that obtained at the basal level using TDI and 2D methods in a patient with coronary artery disease (CAD) throughout the 2 cardiac cycles. Black and brown lines indicate results of the TDI and 2D imaging respectively.

Therefore the ability to measure changes in LV torsion may provide further insight into cardiac function (16,17). As an example, the elevated resting torsion in patients with hypertrophic cardiomyopathy was compared with healthy individuals, but the investigators who did this comparison did not observed any augmentation of torsional parameters in exercise. Therefore, the importance of incorporating measures of these parameters into echocardiography may provide clinicians with further insight into cardiac dysfunction (11).

The LV torsion/twist is described by the difference in LV basal and apical rotation (17). To obtain the LV rotation, the time-varying radius of the LV is required to convert LV tangential velocity into LV angular velocity (11-13). The present study sought to assess the accuracy of the estimated time-varying radius of the LV throughout the cardiac cycle using TDI. For this reason, we applied Pearson correlation (Figure 4) and Bland-Altman analysis (Figure 5) to compare TDI-measured radiuses with those measured manually using 2D-images. We found excellent linear correlation, which was confirmed by low mean differences and limits of agreement obtained by Bland-Altman analysis. The principal finding of this study was that LV time-varying radius could be accurately estimated using TDI throughout the cardiac cycle, indicating that these measurements can be utilized for LV

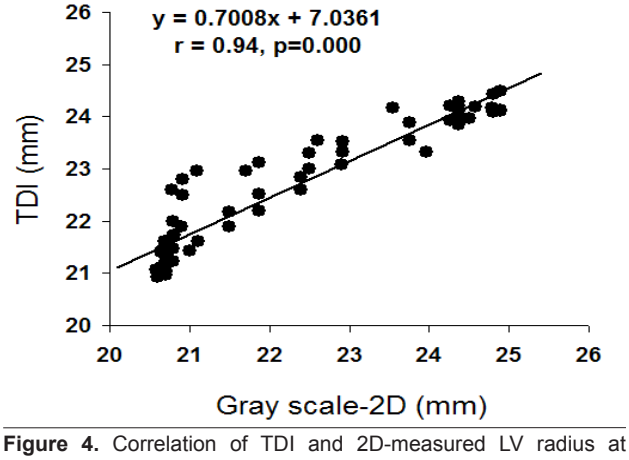

Figure 4. Correlation of TDI and 2D-measured LV radius at the basal level in a patient with coronary artery disease (CAD) throughout the cardiac cycle.

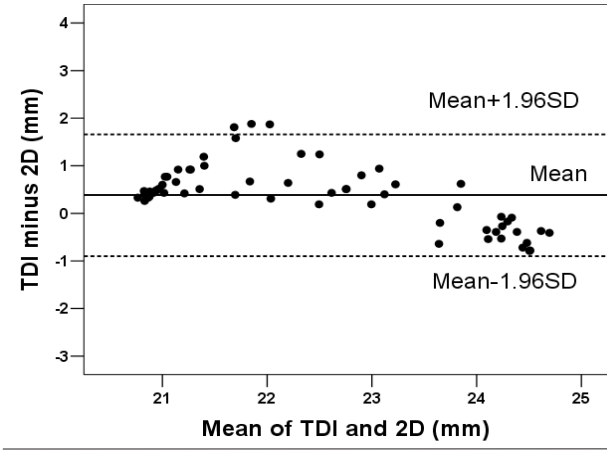

Figure 5. Relative Bland-Altman diagram: the differences between TDI and 2D-measured LV radiuses plotted against the average of both measurements

torsional assessments.

The wringing motion of the LV consists of systolic twisting/twisting rate and diastolic untwisting/untwisting rate. Different methods have been proposed for assessment of this complex motion in clinic, such as MRI tagging and echocardiography(17), but low availability and low temporal resolution of tagged-MRI has remained a major limitation. Echocardiography is wildly available method, more feasible for bedside assessment and therefore growth of interest to development of different modalities such as TDI and speckle tracking imaging (STI) in assessment of LV by echocardiography (18). A close correlation has been reported between those techniques regarding the LV torsional assessment. Ferferieva et al., designed a study to test the influence of the temporal resolution, at which TDI and STI operate, on the accurate assessment of LV peak untwist rate (19). These researchers reported that LV untwist rate values were comparable for both imaging techniques at rest. However, during stress stimulation, these methods cannot be interchanged as STI showed a bias to underestimate untwist rate at high values. In addition, it should be considered that different variables are required to use these methods. For example the TDI method requires the LV time-varying radius data to estimate LV torsional parameters (12). Therefore, in the present study, we assessed the accuracy of TDI method to estimate LV time-varying radius throughout the cardiac cycle. Further study is needed to examine the effect of the LV radius on LV torsional parameters.

Several limitations are to be noted in this study. All Doppler-based methods are angle dependence(20). In this study because of the angular underestimating effect, we only captured the component of velocity parallel to the ultrasound beam direction in the anterior and posterior segments. Additionally, there was a practical limit of the frame rate in 2D imaging (50-80 frames per seconds), so that the 2D frame rate limited the number of data during one cardiac cycle. Finally, artifacts, signal to noise ratio and reverberation were sources of poor image quality, for which we had to eliminate a number of images from the final analyses.

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The authors declare that they have no conflicts of interest.

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