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Evaluation of Left Ventricular Rotation Using Speckle Tracking Technique in Echocardiographic Images of Coronary Artery Stenosis Patients

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ABSTRACT

Introduction: Computed Tomography (CT) is nowadays used widely to differentiate normal brain cranium sutures from abnormal ones in pediatric patients with the aim of early treatment. This study tried to develop a low-dose CT protocol with the acceptable image quality of skull bone in order to evaluate craniosynostosis.

Material and Methods: In this study, 68 men with a mean age of 57± 9 years were enrolled with clinical signs of chest pain. All subjects underwent echocardiography before angiography. LV twist was computed using the speckle tracking algorithm, and LV rotation parameters were obtained from the short-axis view at the base and apex. Based on angiographic findings, the subjects were divided into two groups: 50 individuals with coronary artery stenosis and 18 individuals in the control group who did not have coronary artery stenosis.

Results: The study discovered that patients with coronary artery stenosis had a significantly lower maximum systolic torsion parameter than the control group (11.0 ± 2.6^o vs. 14.1 ± 3.3^o, $p = 0.000$). With a sensitivity of 74% and a specificity of 72%, twist was also a more useful criterion for identifying patients with coronary artery stenosis.

Conclusion: Quantifying the rotational and torsional movement of LV is a non-invasive and useful method for detecting LV dysfunction.

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Introduction

Heart disease is one of the leading causes of death globally. The most frequent cause of cardiac death is coronary artery disease (CAD), which is accompanied by ischemic heart failure and chest pain. Myocardial segments in the left ventricle (LV) do not receive adequate blood flow due to atherosclerotic plaques, vascular occlusions, and reduced perfusion [1]. Diagnostic methods based on clinical symptoms and electrocardiographic results can provide valuable insights, but angiography is the gold standard for the assessment of coronary artery stenosis [2]. The limitations of coronary angiography for patients include high cost, exposure to ionizing radiation, the invasive of the procedure and time required for hospitalization [3]. Therefore, a noninvasive method is important to assess LV function. Research demonstrates that the biomechanical properties of LV function are changed in CAD patients [4, 5]. LV rotation is one of the most important mechanical markers that indicates minor changes in LV dysfunction with normal ejection fraction (EF) [6]. When coronary blood flow is impaired, myocardial fiber contractility is impaired and LV rotation is impaired. Research on left ventricular rotation and torsion changes in CAD patients is limited [7]. The torsion mechanism depends on the architecture of the LV fibers, which spiral from the tip to the base [8]. Two-dimensional speckle tracking echocardiography (2D-STE) is a non-invasive and angle-independent technique that can measure myocardial motion in all directions. This innovative technique has shown a close correlation with cardiac magnetic resonance imaging and has been successfully validated for measuring torsion [9, 10]. Although cardiac magnetic resonance imaging is the gold standard method for assessing LV function, it is less commonly utilized due to longer data acquisition time, lower temporal and spatial resolution, and limited availability to this imaging [11]. This study aims to quantify LV systolic dysfunction with torsion parameters by 2D-STE in CAD patients. The present hypothesis is that this parameter can evaluate the subclinical function of the LV and differentiate patients with coronary artery stenosis from healthy individuals.

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Materials and Methods

In this study, 68 men (57 ± 9 years) with suspected coronary artery stenosis and chest pain were referred to Shahid Rajaei Cardiovascular Hospital from 2020 to 2022. Written informed consent was obtained from all patients or their close companions. The Ethics Committee of Shaheed Rajaie Hospital for Cardiovascular Diseases and Tarbiat Modares University approved this study (approval numbers 1397.070 and 1397.095). Based on the angiographic results, the subjects were divided into two groups: the coronary artery stenosis group (n=50) and the control group (n=18). Before coronary angiography, all participants underwent two-dimensional echocardiography and tissue Doppler imaging. The subjects had no heart disease, heart valve disease, or bypass surgery. Exclusion criteria of the study were previous myocardial infarction (MI), previous coronary artery bypass surgery or percutaneous coronary intervention (PCI), EF<55%, segmental LV wall motion abnormalities, hemodynamic instability, valvular disease, chronic kidney disease, arrhythmia, atrial fibrillation, lung disease, or poor image quality. Subjects who have underlying diseases were excluded from the study.

Long and short-axis B-mode imaging was performed using 2D echocardiography (Philips, Andover, MA, USA) with an S4-2 transducer (2–4 MHz). The images were saved in DICOM and AVI formats for post-processing. Concomitant with electrocardiography (ECG), apical and parasternal short-axis views were acquired at 60 to 90 frames per second for three cardiac cycles. Diastolic and systolic blood pressure were measured using a semiautomatic device (Riester big ben square 0124, Jungingen, Germany, calibrated with a blocking cuff, ±2 mmHg, 30-300 mmHg). Maximum and minimum LV volumes were measured in the postsystolic and end-diastolic phases according to the American Society of Echocardiography (ASE) guidelines [12] using the Simpson biplane method. EF was measured using LV end-diastolic and LV end-systolic values.

24 hours after echocardiography, patients underwent angiography. Angiographic data were evaluated by a highly experienced cardiologist. Coronary artery stenosis was visually estimated in two perpendicular planes. The location of the lesion was identified, and the percentage of stenosis diameter was evaluated according to the American Heart Association classification [13]

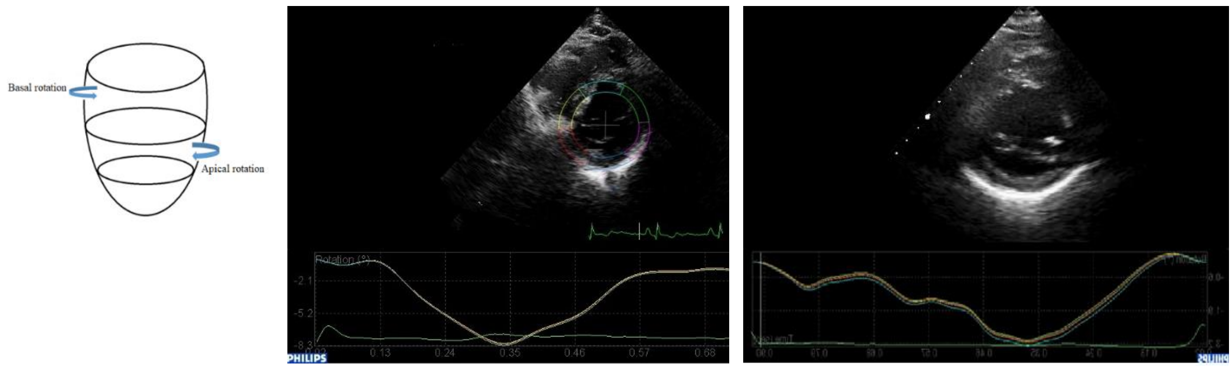
Method theory

The movement of the transverse cross section of the left ventricle around the longitudinal axis at the apex and basal planes is called rotation. The unit of rotation is degrees or radians. Basal and apical planes move clockwise and counterclockwise during the systolic phase, Figure 1a. The difference in the rotation angle of the apex plane (θapex) and the basal plane (θbase) along the long axis of the LV is called twist (θnet) [14].

$$\theta net = \theta apex - \theta base$$

Assessment of rotation and twist using the 2D speckle tracking method

Basal and apical short-axis images were analyzed using the 2D speckle tracking method (QLAB software, Andover, Netherlands) to calculate LV rotation and twist parameters. First, the software automatically created a region of interest (ROI) based on selected basal and apical images to cover the thickness of the LV. Each image is divided into six segments. The ROI is tracked frame by frame and the tracking can be seen in different images. Rotation time curves of each segment were recorded during three cardiac cycles for basal and apical views and saved in PC memory in JPG format. The rotation at basal levels with six segments and their curves for CAD patient and healthy subject are shown in Figure. 1b and 1c, respectively. All measurements were taken during three cardiac cycles.



(a) (b) (c)

Figure 1. a) Left ventricular rotation in the systolic phase, the clockwise movement of the basal plane and the counterclockwise movement of the apex plane are shown with arrows, b) Parametric image of rotation at the basal level for CAD patient and c) at the basal level for normal subjects. Rotation time curves during a cardiac cycle along the short axis are shown. The vertical and horizontal axes show rotation (degrees) and time (s), respectively.

Statistical analysis

Continuous variables were reported as mean and standard deviation. Typically, data distribution was assessed using the Kolmogorov-Smirnov (K-S) test. To statistically compare the control and CAD groups, an independent t-test analysis was used with a confidence level of 95% and a P value of less than 0.05. The sensitivity and specificity of the variables were calculated using discriminant analysis. Statistical analyzes were performed using SPSS software version 23.

Results

Based on the results of angiography, the subjects were divided into a control group (n=18) and a CAD group (n=50). In the CAD group, >70% stenosis was found in LAD, RCA, or LCX vessels. Table 1 shows the hemodynamic characteristics and conventional echocardiographic parameters. Based on these results, the comparison between the two groups showed no significant difference in age, stroke index (SI), and systolic and diastolic blood pressure (P>0.05). There were statistically significant differences in postsystolic volume and EF between the control and CAD groups (P < 0.05), but these were within the normal range and were not clinically significant.

The results of basal and apical rotations in the peak systolic phase of the basal and apical planes and twisting are shown in Figure 2. There are significant differences between rotation and twist angles of the CAD and control groups (P< 0.05).

The discriminant analysis of the rotation and twist parameters with determination of sensitivity and specificity for the control and CAD groups is shown in Table 2. The results showed that the highest correctly classified percentage was related to the twist parameter with 74% sensitivity and 72.2% specificity.

Table 1. Analysis of the mean and standard deviation of baseline clinical characteristics and conventional echocardiographic parameters of the control group and the CAD group

variables	control group (18)	CAD group (50)	P-value
Age (y)	58±10	57±9	0.696
SBP (mmHg)*	131±7	136±9	0.056
DBP (mmHg)*	80±6	84±8	0.065
ESV (ml)*	39.8±4.6	45.5±9.2	0.016
EDV (ml)*	102.0±8.9	111.7±22.0	0.075
EF (%)*	61.0±2.4	59.2±2.3	0.01
SI (ml/m^2)*	62.2±5.6	66.2±13.4	0.221

*SBP, systolic blood pressure; DBP, diastolic blood pressure; ESV, end systolic volume; EDV, end diastolic volume; EF, ejection fraction; SI, stroke index. Bold values mean statistically significant

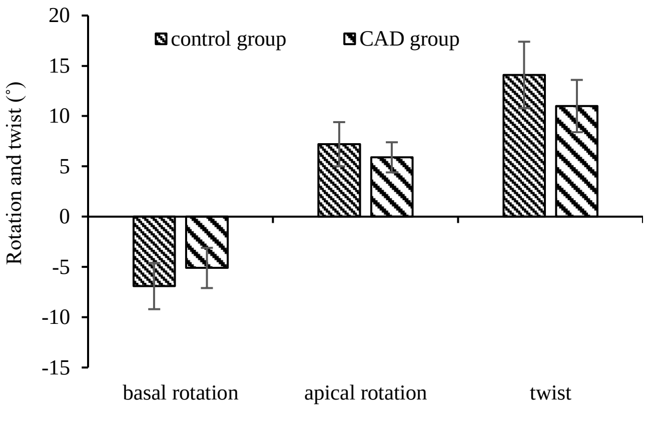


Figure 2. Mean and standard deviation of peak systolic apical and basal rotation and twist of LV. Rotation and twist parameters are significantly decreased in the CAD group compared to the control group

Table 2. Sensitivity and specificity of LV rotation and LV twist parameters

Variables	Sensitivity (%)	Specificity (%)	Correctly classified (%)
Basal rotation (˚)	70.0	61.1	67.6
Apical rotation (˚)	76.0	55.6	70.6
Twist (˚)	74.0	72.2	73.5

Discussion

With the onset of CAD, movement disorders occur in the LV segments. Therefore, ultrasound techniques can assess the local function of the left ventricle due to their ability to analyze motion. Much has been reported about the movement of the heart and changes in the angle of rotation of the left ventricle using speckle tracking echocardiography (STE). The newest and most efficient method for quantitative LV parameters is STE, a combination of B-mode imaging and image processing. This method is angle-independent and indicates the wall movement in the two directions of sound propagation and perpendicular to them. Awadalla et al. [15] investigated LV rotation as a new method to evaluate LV systolic function. 115 patients with acute myocardial infarction (AMI) were imaged with 2D-STE immediately after PCI and six months later. Rotation was significantly less in patients with LV remodeling compared to patients without LV remodeling (7.56 ± 1.95˚ vs. 15.16 ± 4.65, P < 0.005).

Rotation in AMI patients is useful as a diagnostic tool for changes in LV remodeling. Assessment of LV longitudinal torsion in patients with chronic coronary artery stenosis was reported by Jabari et al. [16]. The results were presented on the longitudinal axis. The torsion time and torsion angle for the healthy group were 345 ± 26 ms and 33.26 ± 5.6˚, respectively. In patients with stenosis, the torsion time was significantly increased (358 ± 24 ms) and the torsion angle was significantly decreased (24.15 ±2.16˚) (P<0.05). Mobasheri et al. [17] estimated the wall motion of the intraventricular septum at the three levels of base, middle, and apex using a block matching algorithm and processing sequential echocardiographic images over three cardiac cycles. The three-dimensional path of the heart and the two-dimensional rotation angle were estimated in the short axis and long axis of the interventricular septal wall at the basal plane, respectively (16.33 ± 3.01, 10.61 ± 3.38, 15.11 ± 3.30˚), in the middle level (22.77 ± 4.95, 7.78 ± 2.96, 16.72 ± 2.66˚) and in the apex level (14.6 ± 5.81, 10.37 ± 5.48, 8.79 ± 3.32°). The numerical values obtained for the rotation angle of the LV from the short-axis view in the base and apex segments differed significantly in different studies. In the present study, the rotation and twist angles of the LV were evaluated using STE. The result showed that the basal clockwise segment and the apical counterclockwise segment appeared according to the directional shift of the desired segments in the systolic phase. In addition, the mean value of the maximum rotation angle of the apical segment was larger than that of the basal segment.

The specific position of the fibers and the thickness of the apical segment cause the difference [18]. The rotation results of this study are consistent with Wei et al. agree. [19]. They showed that the value of rotation and basal and apical twists decreased with the STE method in patients with LAD stenosis compared to the normal group. The results of the present study showed that the twist parameter can help distinguish the CAD group from the control group. The reduction in basal and apical rotation angles in CAD patients is due to the increase in stiffness fibers of the inner layer and also to the reduced distance between myofibers. Changes in contractile function shorten the systolic phase and the ejection phase. Therefore, the need for oxygen and wall stress increases in these patients. The most important cause of rotation in the LV is the structure and direction of the fibers in the three layers of the LV and the three-dimensional contraction of the tortuous myofibers [20, 21]. The fibers of the inner layer extend longitudinally at a 90° angle to the middle fibers, the middle fibers at an angle of zero degrees, and the fibers of the outer layer are inclined at an angle of -90° [22]. In fact, LV myofibers have a complicated architecture that is very important in determining LV systolic rotation. When studying the dysfunction of the mechanism, it is reasoned that damage to the epicardial fibers alters the rotation of the myofibers and ultimately disrupts the twist.

Conclusion

The new method of speckle tracking is a powerful and valuable technique for diagnosing CAD patients. LV dysfunction based on segmental analysis can estimated with rotation and twist parameters. The twist parameter determined using the speckle tracking algorithm with a sensitivity of 74% and a specificity of 72% detects LV dysfunction and is useful for patients referred for angiography.

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