Journal of Cardiovascular Disease Research

Journal of Cardiovascular Disease Research, 12 (1)
ISSN: 0975-3583, 0976-2833
DOI: 10.31838/jcdr.2021.12.01.27

RESEARCH ARTICLE

Relation of sphericity index to left ventricular twist in patients with ischemic cardiomyopathy, speckle tracking study

Ahmed Abdelaziz Emara*, Ayman Othman Abdelmonem Hafez, Hend Mohammed Abdo Eldeeb

Cardiology department, Faculty of medicine, Menoufia University

***Corresponding author:** Ahmed Abdelaziz Emara, Cardiology department, Faculty of medicine, Menoufia University.

Received: 2 March 2021; Accepted: 17 April 2021; Published: 08 May 2021

Abstract

Objectives: To assess the relation of sphericity index to left ventricular (LV) twist in patients with ischemic cardiomyopathy (ICM) using speckle tracking imaging.

Background: ICM is the presence of significant LV systolic dysfunction (ejection fraction (EF) ≤ 40%) secondary to coronary artery disease (CAD). LV twist has an important role in determining LV-EF. This twisting deformation depends on the angle between the epicardial and endocardial myofibers which is related to LV sphericity index.

Methods: The study was conducted on 40 patients with ICM, EF less than 50% (patient group) and 20 normal individuals (control group). According to EF, patients were subdivided into 2 subgroups, group 1 included 20 patients with EF 35-50% while group 2 included 20 patients with EF less than 35%. There was a comparison between patient group and control group & also between the 2 patient subgroups regarding the relation of sphericity index to LV twist.

Results: There was a parabolic relation between LV sphericity index and LV twist in control group, while there was a positive linear relation between LV sphericity index and LV twist in patient group. This linear realation remained present in the 2 patient subgroups.

Conclusion: LV twist is significantly influenced by LV remodeling in ICM patients. Therefore, assessment of LV twist may be important in the evaluation and guidance of therapies in ICM.

Keywords: Echocardiography, Ischemic Cardiomyopathy, Left Ventricular Twist, Speckle Tracking, Sphericity Index.

Introduction

The dynamic interaction between subendocardial and subepicardial fiber helices in the left ventricle (LV) leads to a twisting deformation.[1]

This twisting deformation plays an important role in optimizing LV ejection fraction (LV-EF).[2]

Recently, speckle tracking echocardiography (STE) has been introduced as a new method for angle-independent quantification of LV twist.[3,4]

Speckles are natural acoustic markers that occur as small and bright elements in conventional grayscale ultrasound images. The speckles are the result of constructive and destructive interference of ultrasound, back-scattered from structures smaller than a wavelength of ultrasound.[5]

This gives each small area a rather unique speckle pattern that remains relatively constant from one frame to the next. Therefore, a suitable pattern-matching algorithm can identify the frame-to-frame displacement of a speckle pattern, allowing myocardial motion to be followed in two dimensions. Normally, looking at the heart directly from the anterior wall, the LV fiber helix angle varies from approximately –60° at the subendocardium to +60° at the subepicardium, with the mid-wall circumferential fibers at 0°.[6,7]

Shortening of this counterdirectional mantle of muscle fibers results in a wringing movement of the LV that propels blood out of the LV cavity. In a theoretical model by Taber et al.,[8] peak systolic twist approximately doubled with a change in the epicardial/endocardial fiber angles from +90°/–90° to +60°/–60°, underscoring the importance of the arrangement of myocardial fibers for LV twist.

Furthermore, in patients with ischemic cardiomyopathy (ICM), differences in short-axis and long-axis dilatation result in changes in fiber angles that may further impair LV twist and thus cardiac function.[9]

The aim of this study is to assess the relation of sphericity index to LV twist in patients with ICM using speckle tracking imaging.

Methods

This study was conducted on 60 individuals who presented to cardiology departement of faculty of medicine, Menoufia University, Egypt, during the period of 10 months from January 2019 to October 2019. They included 40 patients with ICM, EF less than 50% (patient group), and 20 normal individuals (control group). Among the 40 ICM patients, 20 patients were with EF 35-50% (group 1) and the remaining 20 patients were with EF less than 35% (group 2).

Sampling

The study group was chosen by convenient sample technique.

Data collection

A case record form was used.

All work was performed with the approval of the Menoufia ethics committee. Written informed consent was obtained from all patients and subjects. All patients were subjected to a detailed history taking and clinical examination. A transthoracic echocardiography was performed using a GE Vivid E9 ultrasonographic unit (GE Vingmed, Norway) with an M5S probe (frequency 1.7–3.3 MHz). Subjects assumed the left lateral decubitus position during the echocardiographic examination, and ECG was simultaneously recorded. Left atrial and left ventricular measurements were obtained using 2D guided M-Mode. LV-EF was calculated from LV end diastolic volume (LVEDV) and LV end systolic volume (LVESV) using the modified biplane Simpson method in patients with regional wall motion abnormalities.[10]

LV sphericity index was calculated by dividing the LV maximal long-axis internal dimension by the maximal short-axis internal dimension at end-diastole.[11]

Transmitral Doppler flow velocity was obtained from the apical four-chamber view where peak early filling velocity (E) and peak atrial velocity (A) and the deceleration time (DT) of the E wave were recorded. The E/A ratio was also calculated. Parasternal short-axis images at the LV basal level (showing the tips of the mitral valve leaflets) and LV apical level (just proximal to the level with end-systolic LV luminal obliteration) were obtained. From each short-axis level, three consecutive end-expiratory cardiac cycles were acquired, transferred to a computer (PC) workstation and analysed using analysis software (EchoPAC PC, version 113, GE Healthcare) for assessment of LV twist. To assess LV rotation, six tracking points were placed manually on an end-diastolic frame on the mid-myocardium in each parasternal short-axis image. Tracking points were separated about 60° from each other and placed on 1 (30°, anteroseptal insertion into the LV of the right ventricle), 3 (90°), 5 (150°), 7 (210°), 9 (270°, inferoseptal insertion into the LV of the right ventricle), and 11 (330°) o'clock to fit the total LV circumference. After the tracking points were positioned, the software automatically tracks and accepts segments of good tracking quality and rejects poorly tracked segments, while allowing the observer to manually override its decision based on visual assessments of tracking quality. Rotation (degrees) of LV base and of LV apex was measured. Counterclockwise rotation was marked as a positive value and clockwise rotation as a negative value when viewed from the apex. LV twist was defined as the net difference (degrees) of apical and basal rotation at isochronal time points and was auto-computed by the software from the values of basal and apical rotation.

Statistical analysis

Data were collected and entered to the statistical package for social science (SPSS) version 22

(Armnok, NY: IBM Corp.) for statistical analysis. Quantitative data were presented as mean ± standard deviation (SD). Student's t-test was used for comparison between two groups having quantitative variables. Coefficient of determination (r^2) was used to measure the correlation between two quantitative variables. P-value < 0.05 was considered statistically significant, P-value < 0.001 was considered highly significant and P-value > 0.05 was considered non-significant.

Results

Regarding demographic data, there were 21 males in the patient group (52.5%) and 10 males in the control group (50%), there were 17 smokers in the patient group (42.5%) and 6 smokers in the control group (30%), there were 24 hypertensive patients in the patient group (60%) and there were 21 diabetic patients in the patient group (52.5%) (Table 1).

Regarding echocardiographic data, There was highly statistical significant difference regarding left atrial dimension (4.1 ± 0.4 cm in patient group vs. 3.4 ± 0.3 cm in control group; P-value = 0.001), left ventricular end-diastolic dimension (6.1 ± 0.5 cm in patient group vs. 5 ± 0.3 cm in control group; P-value = 0.001), left ventricular end-systolic dimension (4.9 ± 0.6 cm in patient group vs. 3.3 ± 0.3 cm in control group; P-value = 0.001), left ventricular end-diastolic volume (172.8 ± 34.7 ml in patient group vs. 114 ± 13.1 ml in control group; P-value = 0.001), left ventricular end-systolic volume (113.8 ± 33.3 ml in patient group vs. 42.6 ± 8.3 ml in control group; P-value = 0.001) and E/A ratio (1.9 ± 0.5 in patient group vs. 1.4 ± 0.2 in control group; P-value = 0.005) where they were significantly increased in patient group. Also, there were statistically significant difference regarding LV sphericity index (1.5 ± 0.1 in patient group vs. 1.9 ± 0.2 in control group; P-value = 0.001), LV-EF (35.2 ± 7.1% in patient group vs. 62.4 ± 4.1% in control group; P-value = 0.005) and LV twist (6.1 ± 1.4 degrees in patient group vs. 9.7 ± 2.3 degrees in control group; P-value = 0.001) where they were significantly decreased in patient group. There was no significant difference in deceleration time (169 ± 27.3 ms in patient group vs. 175.6 ± 18.4 ms in control group; P-value = 0.763) (Table 2).

Also between the 2 patient groups, there was statistically significant difference reagarding LV sphericity index (1.6 ± 0.1 in group 1 vs. 1.4 ± 0.1 in group 2; P-value = 0.001) and LV twist (7 ± 0.9 degrees in group 1 vs. 5.1 ± 1.2 degrees in group2; P-value = 0.001) where they were significantly decreased in group 2.

In the total study population, Regression analysis revealed a positive linear relation of LV twist to LV-EF (R^2 = 0.569; P-value = 0.001) (Figure 1). A parabolic relation between LV sphericity index and LV twist (R^2 = 0.468; P-value = 0.001) was identified (Figure 2). In control group, no significant relation could be identified between LV twist and LV-EF. However, the parabolic relation between LV sphericity index and LV twist (R^2 = 0.436; P-value = 0.001) remained present. In patient group, a positive linear relation between LV-EF and LV twist (R^2 = 0.235; P-value = 0.001) was revealed by regression analysis. Also, a positive linear relation between LV sphericity index and LV twist (R^2 = 0.462; P-value = 0.001) could be identified.

In the 2 patient groups, these relationships between LV-EF and LV twist and between LV sphericity index and LV twist remained observable (LV-EF < 35%: R^2 = 0.385 and R^2 = 0.427, respectively; LV-EF 35–50%: R^2 = 0.274 and R^2 = 0.372, respectively; all P-value < 0.05).

Table 1 Distribution of demographic data among study population

		Patients (40)	Control (20)
Age, years	Range	32–54	32–53
	Mean+SD	44.5 ± 5.9	41 ± 6.2
Sex, n	Male	21(52.5%)	10(50%)
	Female	19(47.5%)	10(50%)
Smoking, n	Yes	17(42.5%)	6(30%)
	No	23(57.5%)	14(70%)
HTN, n	Yes	24(60%)	0(0%)
	No	16(40%)	20(100%)
DM, n	Yes	21(52.5)	0(0%)
	No	19(47.5%)	20(100%)

SD: standard deviation, n: number, HTN: hypertension, DM: diabetes mellitus

Discussion

LV twist describes the instantaneous circumferential motion of the apex with respect to the base of the heart and has an important role in determining LV ejection fraction.[1,2]

Table 2 Distribution of echocardiographic data among study population

	Patients (40)	Control (20)	T test	P-Value
LAD, cm	4.1 + 0.4	3.4 + 0.3	4.502	0.001*
IVSd, cm	0.9 + 0.1	1 + 0.1	2.199	.040*
IVSs, cm	1.3 + 0.1	1.5 + 0.2	3.343	0.003*
LVPWd, cm	0.9 + 0.1	1 + 0.1	2.979	0.008*
LVPWs, cm	1.2 + 0.1	1.5 + 0.1	6.970	0.001*
LVEDD, cm	6.1 + 0.5	5 + 0.3	8.318	0.001*
LVESD, cm	4.9 + 0.6	3.3 + 0.3	11.492	0.001*
LVEDV, ml	172.8 + 34.7	114 + 13.1	5.374	0.001*
LVESV, ml	113.8 + 33.3	42.6 + 8.3	11.342	0.001*
LV-EF, %	35.2 + 7.1	62.4 + 4.1	14.637	0.001*
E/A Ratio	1.9 + 0.5	1.4 + 0.2	3.172	0.005*
DT, ms	169 + 27.3	175.6 + 18.4	0.306	0.763
LV Sphericity Index	1.5 + 0.1	1.9 + 0.2	8.637	0.001*
LV Twist, degrees	6.1 + 1.4	9.7 + 2.3	5.210	0.001*

LAD: left atrial diameter, IVSd: interventricular septal wall thickness during diastole, IVSs: interventricular septal wall thickness during systole, LVPWd: left ventricular posterior wall thickness during diastole, LVPWs: left ventricular posterior wall thickness during systole, LVEDD: left ventricular end diastolic diameter, LVESD: left ventricular end systolic diameter, LVEDV: left ventricular end diastolic volume, LVESV: left ventricular end systolic volume, DT: deceleration time, *: significant.

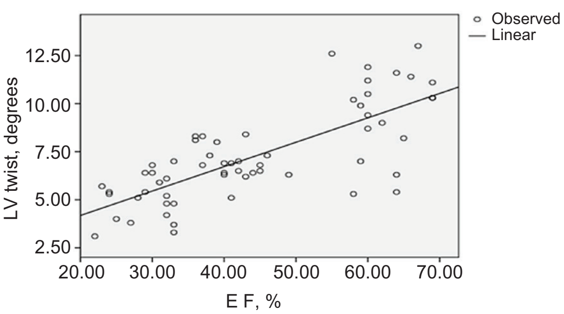

Figure 1 Relation of LV twist to LV-EF in total study population.

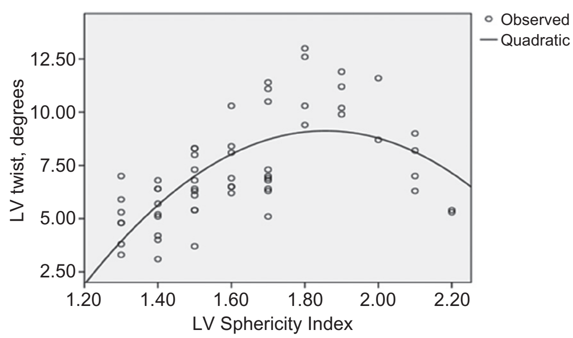

Figure 2 Relation of LV sphericity index to LV twist in total study population.

For the present study, it was hypothesized that the supposedly optimal myofiber helix angle of 60° is related to a certain LV sphericity index and that, therefore, either an increase or decrease in LV sphericity index would result in a decrease in LV twist. Assuming that the LV sphericity index may be related to fiber orientation,[8] a decreased LV sphericity index may be related to decreased LV twist due to a decreased fiber angle, whereas an increased LV sphericity index may be related to decreased LV twist as well due to an increased fiber angle.

This study was conducted to explore the relation between LV sphericity index and LV twist in 20 healthy volunteers and 40 ICM patients arranged into two groups, group 1 contains 20 patients with LV-EF 35–50% and group 2 contains 20 patients with LV-EF <35%.

Our study revealed a positive linear relation between sphericity index and LV twist in patients with ICM and a parabolic relation between sphericity index and LV twist in healthy volunteers. This was in agreement with Floris Kauer et al.,[12] who in 2015 found an independent linear relation between left ventricular sphericity index and peak systolic twist in dilated cardiomyopathy (DCM) patients.

Our study also revealed a positive linear relation between LV-EF and LV twist in total study population and in ICM patients. This was in agreement with Bas M. van Dalen et al.[13] study that resulted in a positive linear relation between LV-EF and LV Twist in total study population and in DCM patients.

Also, our study demonstrated that left atrial dimension, left ventricular end-diastolic dimension, left ventricular end-systolic dimension, left ventricular end-diastolic volume, left ventricular end-systolic volume and E/A ratio were significantly increased whereas LV sphericity index, LV-EF and LV twist were significantly decreased in ICM patients than in healthy volunteers. These results were in agreement with the study done by Bas M. van Dalen et al.[13] in 2009 that was conducted on 45 DCM patients and 60 age- and gender-matched healthy volunteers and demonstrated that LV end-systolic dimension and volume, LV end-diastolic dimension and volume, left atrial size and E-to-A ratio were significantly increased whereas LV sphericity index and LV-EF were significantly decreased in DCM patients compared with healthy volunteers. Also in agreement with our study, Jiabao YIN et al.[14] in 2011 studied thirty-nine patients with DCM and thirty-five controls and demonstrated that LVEDd increased significantly while LV-EF and LV sphericity index decreased significantly in patients with DCM compared with controls.

Study limitations

Our study had some limitations e.g. the small number of the study population, the difficult visualization of the true LV apex and the effect of age on LV twist.

Conclusion

LV twist is significantly influenced by LV remodeling in ICM patients. Prevention of LV remodeling favorably impacts the untoward natural history of heart failure,[15] which may be, at least partly, related to the preservation of LV twist. Therefore, assessment of LV twist may be of importance in the evaluation and guidance of therapies in ICM.

References

1. Ingels NB Jr, Hansen DE, Daughters GT 2nd, Stinson EB, Alderman EL, Miller DC. Relation between longitudinal, circumferential, and oblique shortening and torsional deformation in the left ventricle of the transplanted human heart. Circ Res. 1989; 64: 915–927.
2. Sallin EA. Fiber orientation and ejection fraction in the human left ventricle. Biophys. J. 1969; 9: 954–964.
3. Helle-Valle T, Crosby J, Edvardsen T, Lyseggen E, Amundsen BH, Smith HJ, et al. New noninvasive method for assessment of left ventricular rotation: speckle tracking echocardiography. Circulation. 2005; 112: 3149–3156.
4. Notomi Y, Lysyansky P, Setser RM, Shiota T, Popovic ZB, Martin-Miklovic MG, et al. Measurement of ventricular torsion by two-dimensional ultrasound speckle tracking imaging. J Am Coll Cardiol. 2005; 45: 2034–2041.
5. Bohs LN, Trahey GE. A novel method for angle independent ultrasonic imaging of blood flow and tissue motion. IEEE Trans Biomed Eng. 1991; 38: 280–286.
6. Geerts L, Bovendeerd P, Nicolay K, Arts T. Characterization of the normal cardiac myofiber field in goat measured with MR-diffusion tensor imaging. Am J Physiol Heart Circ Physiol. 2002; 283: H139–H145.
7. Ingels NB Jr. Myocardial fiber architecture and left ventricular function. Technol Health Care. 1997; 5: 45–52.
8. Taber LA, Yang M, Podszus WW. Mechanics of ventricular torsion. J Biomech. 1996; 29: 745–752.
9. Hutchins GM, Bulkley BH, Moore GW, Piasio MA, Lohr FT. Shape of the human cardiac ventricles. Am J Cardiol. 1978; 41: 646–654.
10. Lang RM, Bierig M, Devereux RB, Flachskampf FA, Foster E, Pellikka PA, et al. Recommendations for chamber quantification: a report from the American Society of Echocardiography's Guidelines and Standards Committee and the Chamber Quantification Writing Group, developed in conjunction with the European Association of Echocardiography, a branch of the European Society of Cardiology. J Am Soc Echocardiogr. 2005; 18: 1440–1463.
11. Lowes BD, Gill EA, Abraham WT, Larrain JR, Robertson AD, Bristow MR, et al. Effects of carvedilol on left ventricular mass, chamber geometry, and mitral regurgitation in chronic heart failure. Am J Cardiol. 1999; 83: 1201–1205.
12. Floris Kauer, Marcel Leonard Geleijnse, Bastiaan Martijn van Dalen. Role of left ventricular twist mechanics in cardiomyopathies, dance of the helices. World J Cardiol. 2015; 7(8): 476–482.
13. Bas M. van Dalen, Floris Kauer, Wim B. Vletter, Osama I. I. Soliman, Heleen B. van der Zwaan, Folkert J. ten Cateet al. Influence of cardiac shape on left ventricular twist. Japplphysiol. 2009; 108: 146–151.
14. Jiabao YIN1, Ruiqiang GUO, Jinling CHEN. Relationship between torsion and remodeling or function of left ventricle in patients with dilated cardiomyopathy. Chinese Journal of Ultrasonography. 2011; 20(7): 567–570.
15. Mann DL, Acker MA, Jessup M, Sabbah HN, Starling RC, Kubo SH. Clinical evaluation of the CorCap Cardiac Support Device in patients with dilated cardiomyopathy. Ann Thorac Surg. 2007; 84: 1226–1235.