Age-related Changes in the Left Ventricular Twist

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ABSTRACT

Introduction: Left ventricular (LV) rotation and twist play important roles in LV contraction and relaxation. Systolic function is usually preserved with aging, but diastolic function deteriorates. The aim of this study was to establish a reference value for LV twist and examine the effect of aging on it.

Patients and Methods: We enrolled 75 healthy subjects who were divided into two groups according to age: < 40 and > 40 years. LV rotation and twist were assessed with two-dimensional speckle tracking imaging at the basal and apical levels of the parasternal short axis. LV twist was defined as an apical rotation relative to the baseline. Exclusion criteria included a history of ischemic and valvular disease, arrhythmia, use of a pacemaker, and systolic dysfunction.

Results: Peak A wave velocity (70.6 ± 13.7 vs. 57.7 ± 10.6, p< 0.001) and E/E'ratio (7.7 ± 2.2 vs. 6.1 ± 1.3, p< 0.001) were higher and peak E wave velocity (52.4 ± 16 vs. 76.8 ± 11, p< 0.001) and E/A ratio (0.75 vs. 1.34, p< 0.001) were lower in old patients than in young patients. There was an increase in apical rotation (4.4 ± 2.9° vs. 3.3 ± 2.4°, p= 0.075) and a decrease in basal rotation (–4.1 ± 2.7° vs. –5.2 ± 3.7°, p= 0.185) in old patients, but these changes indicated no significant difference. With aging, the twist increased (8.6 ± 3.3° vs. 8.5 ± 4.1°, p= 0.890), but not significantly. LV apical rotation (5 ± 3.2 vs. 2.4 ± 1.1, p= 0.004) and twist (9.4 ± 3.4 vs. 6.9 ± 2.4, p= 0.64) decreased in the old group with an increasing degree of LV diastolic dysfunction.

Conclusion: LV twist slightly increased with age, but this effect was reversed with increased diastolic dysfunction even in the presence of normal systolic function.

Key Words: Echocardiography; rotation and twist; aging

Sol Ventrikül Bükülme Hareketinde Yaşa Bağlı Değişiklikler

ÖZET

Giriş: Sol ventrikül (LV) rotasyon ve büküm hareketi kasılma ve gevşemede önemli rol oynamaktadır. Yaşlanma ile LV sistolik fonksiyonları korunsada diyastolik fonksiyonlar genellikle bozulur. Bu çalışmanın amacı, LV büküm için bir referans değeri saptamak ve yaşlanmanın büküm üzerinde etkilerini incelemekti.

Hastalar ve Yöntem: Çalışmaya 75 sağlıklı kişi dahil edildi; katılımcılar 40 yaş üstü ve 40 yaş altı olarak iki gruba ayrıldı. LV rotasyon ve büküm parasternal kısa eksen bazal ve apikal seviyelerinde 2D-STI ile değerlendirildi. LV büküm hareketi apikal ve bazal rotasyonun göreceli toplamı olarak tanımlandı. İskemik ve kapak hastalığı, aritmi, kalp pili ve sistolik disfonksiyon öyküsü dışlama kriterleri olarak tanımlandı.

Bulgular: Yaşlılarda gençlere kıyasla pik A dalga hızı (70.6 ± 13.7 vs. 57.7 ± 10.6, p< 0.001), E/E' oranı (7.7 ± 2.23 vs. 6.09 ± 1.3, p< 0.001) daha yüksek, pik E dalga hızı (52.4 ± 16 vs. 76.75 ± 11, p< 0.001), E/A oranı (0.75 vs. 1.34, p< 0.001) daha düşüktü. Yaşlı grupta apikal rotasyonda artış (4.4 ± 2.9° vs. 3.3 ± 2.4°, p= 0.075) ve bazal rotasyonda azalma (-4.1 ± 2.7° vs. 3.7°± -5.2, p= 0.185) izlendi ancak, bu değişiklikler anlamlı değildi. Yaşlanma ile birlikte, büküm önemsiz derecede arttı (8.6 ± 3.3° vs. 8.53 ± 4.1°, p= 0.890). Yaşlı grupta LV diyastolik disfonksiyon derecesi arttıkça apikal rotasyon (5.02 ± 3.2 vs. 2.4 ± 1.1, p= 0.004) ve büküm (9.4 ± 3.4 vs. 6.9 ± 2.4, p= 0.64) azaldı.

Sonuç: Bu çalışma LV bükümün yaşla birlikte hafifçe arttığını, ancak bu etkinin sistolik fonksiyonları normal olsada artmış diyastolik disfonksiyon varlığında tersine döndüğünü gösterdi.

Anahtar Kelimeler: Ekokardiyografi; rotasyon ve büküm; yaşlanma

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INTRODUCTION

The left ventricle has an oblique myocardial fiber orientation that induces rotation around the long axis during contraction[1]. Left ventricular (LV) twist is defined as a wringing motion of the heart caused by the opposite rotation of LV apical and basal segments[1,2]. LV rotation and twist are essential components of cardiac performance[3]. Measurement of LV twist may play an important role in determining LV systolic and diastolic dysfunction[1,4]. Alterations in LV twist have been reported in several pathophysiological conditions, and potential clinical applications of the twist are currently expanding[5-8]. LV systolic function is usually preserved with aging, but diastolic function is not. Evaluation of LV rotation and twist is feasible with two-dimensional speckle tracking imaging (2D-STI)[9,10].

The aim of this study was to establish a reference value of LV twist and examine the effect of aging on LV twist in a group of healthy volunteers.

PATIENTS and METHODS

Patient Selection

Initially, the study population consisted of 102 healthy volunteers, but 27 were excluded because of insufficient image quality, and the remaining 75 subjects (62%) made up the final study group. The study population was divided into two age groups: < 40 years (n= 40) and > 40 years (n= 35). A history of heart disease, such as ischemic and valvular disease, arrhythmia, pacemaker use, or systolic dysfunction were the exclusion criteria. Seventeen older patients received antihypertensive therapy, and their blood pressure was under control. They had normal electrocardiographic findings.

The study was approved by the local institutional ethics committee.

Echocardiography

A standard comprehensive M-mode, 2D echocardiogram, Doppler study were performed with the Philips IE33 system (Philips Medical Systems, Amsterdam, the Netherlands) using an S5-1 transducer. The peak early (E) and late (A) filling velocities and E/A ratio were measured using pulsed-wave Doppler of the mitral inflow. Mitral annulus velocities were achieved from the septal and lateral annulus of the left ventricle by tissue Doppler imaging. Patients were stratified by the grade of diastolic dysfunction that was classified as having impaired relaxation (grade 1), pseudonormal (grade 2), or restrictive patterns of echocardiographic diastolic filling. In addition, all patients with diastolic dysfunction were required to have early diastolic velocity of the septal mitral annulus (E') of < 8 cm/s[11].

After a comprehensive standard echocardiographic examination, apical and basal short axis rotations were measured with 2D-STI. Short axis basal image was defined from the mitral ring level, and the apical image was defined by the LV cavity alone with no visible papillary muscle[12,13]. At each plane, four sequential cardiac cycles were obtained and digitally stored in a hard disk for offline analysis. Using a commercially available 2D strain software, the endocardial border of each short axis plane in the end-systolic frame was manually traced. The software algorithm then automatically segmented the LV short axis plane into six segments and searched speckles in the ROIs on a frame-by-frame basis using the sum of absolute difference algorithm. The software defined the ventricular centroid for the mid-myocardial line on a frame-by-frame basis during one cardiac cycle and calculated the time domain LV rotation and radial displacement profiles for each segment in both short axis planes[14,15]. LV twist was calculated as apical LV rotation relative to basal rotation.

Statistical Analysis

Two independent samples t-test were used to compare continuous data between the two groups according to the parameters assumed. Continuous data were presented as the mean ± standard deviation. Categorical data were compared using chi-square tests. Categorical variables were presented as a count and percentage. Pearson's correlation coefficient was used for the determination of correlation between the LV twist and other parameters. A p-value of < 0.05 was considered significant. Analyses were performed using commercial software (IBM Corp. IBM SPSS Statistics for Windows, Version 16.0. Armonk, NY).

RESULTS

Clinical characteristics and echocardiographic parameters of the two age groups are shown in Table 1. Although left ventricular ejection fraction (LVEF) was preserved in all participants, it was higher in the young group (p= 0.045). The prevalence of diabetes mellitus (p= 0.03), obesity (p= 0.01), and hypertension (p< 0.000) was higher in the elderly group, but blood pressure was under control in these patients. Variables representing the LV diastolic function were found to be distinctly different between the two groups. As expected, Doppler measurements revealed that the peak A wave velocity (70.6 ± 13.7 vs. 57.7 ± 10.6, p< 0.001) and E/E' ratio (7.7 ± 2.2 vs. 6.1 ± 1.3, p< 0.001) increased, and the peak E wave velocity (52.4 ± 16 vs. 76.8 ± 11, p< 0.001), early diastolic mitral annular velocity (E' wave) (7 ± 1.9 vs. 13.1 ± 3.6, p= 0.00), and E/A ratio (0.75 vs. 1.3, p< 0.001) significantly decreased with advancing age. Compared with the young group, there was an increase in the magnitude of peak systolic apical rotation (4.4 ± 2.9° vs. 3.3 ± 2.4°, p= 0.075) and a decrease in basal rotation (-4.1 ± 2.7° vs. -5.2 ± 3.7°, p= 0.185) in the older group, but it was not significant. The peak LV twist insignificantly increased with advancing age; the mean value of peak twist was observed as 8.5 ± 4.1° (range 4.4°–12.6°) for < 40-year-old participants and 8.7 ± 3.3° (range 5.3°-12.9°) for > 40-year-old participants (p= 0.890). In the univariate analysis, LV twist was insignificantly correlated with age (r= 0.081, p= 0.491), BMI (r= 0.047, p= 0.689), diabetes

Table 1. Baseline clinical characteristic values and echocardiographic findings of all subjects

	Young	Older	p value
Age (years)	29 ± 6	64 ± 12	0.001
Patients number (n/M:F)	39/17:22	36/14:22	0.596
Hypertension n (%)	1 (2.6%)	17 (48.6%)	0.000
Diabetes mellitus (%)	1 (2.6%)	6 (17.1%)	0.03
BMI (kg/m^2)	24.5 ± 4.8	29.6 ± 5.2	0.001
LVEF (%)	69.2 ± 7	65.9 ± 7	0.045
E	76.8 ± 11	52.4 ± 16	0.000
A	57.7 ± 10.6	70.6 ± 13.7	0.000
E'	13.1 ± 3.6	7 ± 1.9	0.000
E/A	1.3	0.75	0.000
E/E' ratio	6.1 ± 1.3	7.7 ± 2.2	0.000
Apical rotation (°)	3.3 ± 2.4°	4.4 ± 2.9°	0.075
Basal rotation (°)	-5.2 ± 3.7°	-4.1 ± 2.7°	0.185
Twist (°)	8.5 ± 4.1°	8.7 ± 3.3°	0.890

A: Late mitral inflow velocity, BMI: Body mass index, E: Early mitral inflow velocity, E': Early diastolic mitral annular velocity, LVEF: Left ventricular ejection fraction.

Table 2. Change in rotation and twist with diastolic dysfunction in old group

	Normal(7)	Grade 1 LVDD(23)	Grade 2 LVDD(6)
Apical rotation (°)	4.1 ± 2.5	5.2 ± 3.2	2.4 ± 1.2
Basal rotation (°)	–4.9 ± –3.6	–4.4 ± –2.7	–45 ± –29
Twist	6.9 ± 2.4	9.7 ± 3.2	6.7 ± 3.3

LVDD: Left ventricular diastolic dysfunction.

mellitus (r= 0.050; p= 0.672), and hypertension (r= 0.146; p= 0.212). In addition, basal rotation, apical rotation, and LV twist were not affected by LVEF. LV apical rotation (normal= 4.1 ± 2.5° vs. grade 1= 5.2 ± 3.2°, p= 0.699) and twist (normal= 6.9 ± 2.4° vs. grade 1= 9.7 ± 3.2°, p= 0.084) increased in patients with mild diastolic dysfunction and decreased in those with more advanced diastolic dysfunction (apical rotation in grade 2 was 2.4 ± 1.2°, p= 0.530 vs. the twist in grade 2 which was 6.7 ± 3.3°, p= 0.990) compared with those in normal healthy people (Table 2).

The correlation was not significant between the LV twist and the marker of increased LV end-diastolic pressure: E/A ratio (r= 0.156, p= 0.180) and E/E' (r= 0.135, p= 0.246).

DISCUSSION

This study has investigated the normal reference values of principal LV with parameters and analyzed age-related changes in LV twist. LV rotation and twist increased with age because of increases in apical rotations, but this relationship was not statistically significant. Moreover, an association between LV twist and diastolic dysfunction was shown in this study; the peak LV twist increased in patients with mild or early-stage diastolic dysfunction, and it normalized or decreased with increasing degree of diastolic dysfunction. These findings may provide supplementary information regarding the effect of diastolic dysfunction on LV twist.

Cardiac Motion and Twist

Normally, LV performs a wringing systolic motion with a clockwise rotation in the basal plane and a counterclockwise rotation in the apical plane[14,15]. As shown in Figure 1, viewed from the LV apex, counterclockwise rotation was expressed as a positive value and clockwise rotation as a negative value. Any factor that impoverished LV subendocardial fibers can lead to increased twist. For example, the systolic twist increases in hypertrophic cardiomyopathy or LV hypertrophy caused by aortic stenosis[16-18]. Both conditions lead to a subendocardial dysfunction, causing an increased LV twist[19]. Although the primary pathologic mechanisms for age-related twist changes are not completely known, it has been proposed that the aging process causes subendocardial fibrosis and a decline in subendocardial function[19-21]. Thus, optimization of LV twist is effective to preserve the LVEF in the elderly. Our study showed that LV rotation and twist gradually increased with age, which are consistent with the results of previous studies[19-22]. Evaluation of LV rotation and twist is feasible with 2D-STI. However, LV twist value determined by 2D-STI has significant inter-study discrepancies. For example, Takeuchi et al. and Saygısunar et al. reported a twist value in the range of 6°-7°, which is similar to values in our study (8.5 ± 4.1° vs. 8.7 ± 3.3°)[7,19]. Lee et al. and Sun et al. reported peak twist values in the range of 20°, which was higher than the peak LV twist reported in our study[20,22]. The reasons for this inconsistency may be due to the selection of an apical basal plane and echocardiographic image quality resolution.

LV Twist and Diastolic Dysfunction

Our study showed that LV twist was dependent on the degree of diastolic dysfunction. Consistent with previous study, the peak LV twist increased in patients with mild or early-stage diastolic dysfunction, but it normalized or decreased with an increasing degree of diastolic dysfunction compared with that in normal healthy controls[19]. LV twist also increased in asymptomatic elderly patients, whose diastolic function was generally mildly reduced compared with younger people. This suggests that an increased LV twist is a part of the inherent progression of diastolic dysfunction, and to preserve normal LV filling, it is the first compensation for the decreased function of the myocardium. The increased twist can be used as a marker for early-stage diastolic dysfunction with normal filling pressure, but this requires more investigation.

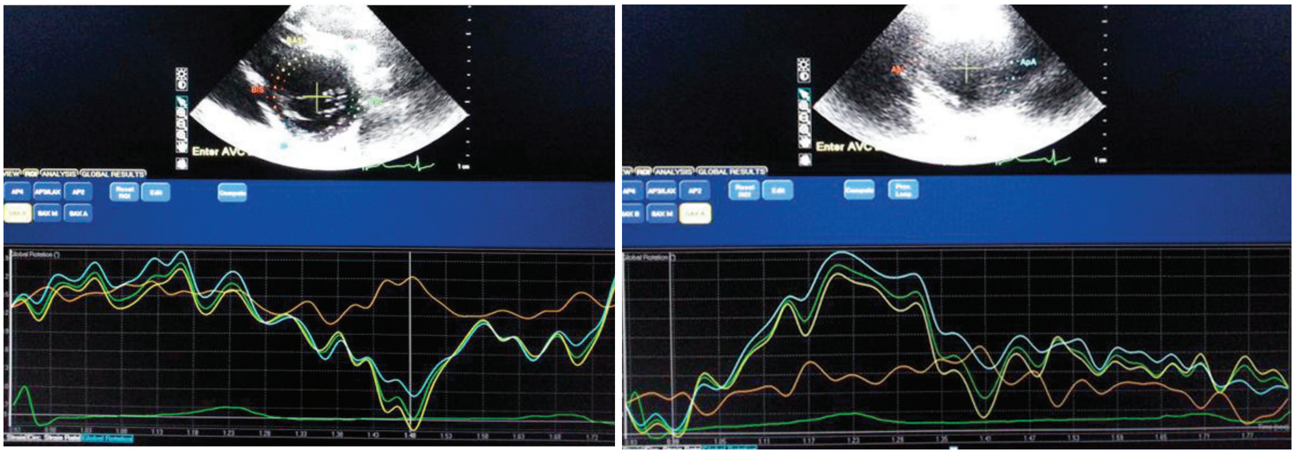

Figure 1. Apical and basal rotation curves. The left ventricle rotates counter clockwise at the apical level and clockwise at the base. Counter clockwise LV rotation as viewed from the apex is expressed as a positive value and clockwise LV rotation is expressed as a negative value.

Limitations of the Study

Our study was limited by the relatively small sample size. Another limitation of this study was the poor quality of some of the 2D images. The selection of optimal imaging planes is quite challenging because of limited acoustic windows and the oblique orientation of the heart in the chest cavity. A small proportion of patients had hypertension, which may have affected LV mechanics. The main purpose of this study was to investigate LV twist characteristics with different grades of diastolic dysfunction; therefore, patients with grade 3 diastolic dysfunction were not included in this study.

CONCLUSION

An evaluation of LV rotation and twist is feasible with 2D-STI. We assessed LV rotation and twist mechanics in young and older people to determine a value for the twist in a normal adult population. This value can serve as a reference for further evaluation of pathological myocardial motions in various cardiovascular and other diseases[23-25]. In addition, our data suggested that this non-invasive parameter can provide helpful information in the assessment of diastolic function. An increased twist can also be used as a marker for early-stage diastolic dysfunction with normal filling pressure, as the twist may decrease with an increasing degree of diastolic dysfunction. We need further studies to determine the most practical and reliable parameters to identify diastolic dysfunction.

CONFLICT of INTEREST

The authors reported no conflict of interest related to this article.

AUTHORSHIP CONTRIBUTIONS

Concept/Design: SY, HK
Analysis/Interpretation: SY, HK, MTA
Data Acquisition: SY, MTP, SD
Writing: SY, HK, EE
Critical Revision: HK, ET
Final Approval: All of authors

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