Decreased Left Ventricular Rotation and Torsion in Hemodialysis Patients Studied by Three-Dimensional Speckle Tracking Imaging

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Abstract

BACKGROUND: Left ventricle (LV) structural change in chronic kidney disease (CKD) patients is due principally to a chronic increase in volume and pressure overload. LV torsion has been shown to be a key factor of evaluating LV function, but has rarely been assessed in CKD by three-dimensional speckle tracking imaging (3D STI). The purpose of this study is to evaluate LV torsion in CKD patients receiving hemodialysis compared with normal healthy subjects.

METHODS: Twenty-seven CKD patients on hemodialysis and 27 healthy volunteers were recruited. 3D STI was performed immediately before hemodialysis in the dialysis room. The rotation, twist, and torsion of the LV were automatically calculated by commercialized software for each segment of the LV.

RESULTS: Body weight (P < 0.01), both systolic and diastolic blood pressure (P < 0.01), end diastolic and end systolic volume (P < 0.05), and ejection fractions (P < 0.01) showed statistically significant differences between the two groups. There were also significant differences in global value of rotation (3.0 ± 2.0 vs. 2.5 ± 1.9 deg P < 0.05), twist (4.6 ± 3.3 vs. 2.7 ± 1.9 deg P < 0.05), basal torsion (1.6 ± 1.1 vs. 0.9 ± 0.6 deg/cm P < 0.05) and regional torsion (1.6 ± 1.2 vs. 0.9 ± 0.8 deg/cm P < 0.05) between healthy volunteers and CKD patients.

CONCLUSION: Assessment of LV torsion by newly developed 3D STI is less laborious and time-consuming. Decrease of LV torsion in CKD patients might be due to the marked disarray of myocardial fibers in a uremic heart that affects LV structure, resulting in non-uniform LV torsion.

KEY WORDS: left ventricle, three-dimensional speckle tracking imaging, chronic kidney disease

Introduction

Cardiovascular disease is the leading cause of death in patients with end-stage renal disease. The prevalence of left ventricle (LV) alterations is high among chronic kidney disease (CKD) patients in all age groups (1-3). LV structural change in CKD patients is due principally to a chronic increase in volume and pressure overload. Cardiac function has been extensively studied by conventional echocardiography, M-mode, Doppler and 2D echocardiography (4-7).

However, the heart is a three-dimensional asymmetric organ; it is sometimes difficult to display the complex structures by one- or two-dimensional imaging. The LV wall motions are complex, involving not only systolic inward motion in the long axis, but also rotation in the short axis. Owing to the spiral architecture of LV myofibers, the rotation of the LV apex is counterclockwise while that of the base is clockwise, as viewed from the LV apex.

Torsional deformation of the LV results from...
Three-dimensional speckle tracking echocardiography showed reconstructing imaging response to the apical 4-chamber (right upper), the apical 2-chamber (right lower), and 3 short-axis views at different levels (middle); the plastic bag 3-dimentional picture of LV (left upper) and doughnuts display of short-axis view (left lower).

Materials and Methods

Twenty-seven patients with CKD, who have been receiving chronic hemodialysis for an average of more than 1 year and 27 healthy volunteers were enrolled. All subjects did not use antihypertensive or antiarrhythmic drugs. Severe valvular heart disease, coronary artery disease, cardiomyopathy and pericardial diseases were excluded by cardiologists with transthoracic echocardiogram. All echocardiograms in hemodialysis patients were performed before dialysis session. This study was approved by the ethics committee and all subjects gave written informed consent.

Three-dimensional speckle tracking real-time imaging was performed from the apical position with a PST-25SX probe (Artida system, Toshiba medical systems, Tokyo, Japan) by the same experienced technician. Apical full-volume acquisition was obtained in all subjects to visualize the entire LV in a volumetric image. To acquire a full-volume data set, a frame rate of 20-30 was used. In the four- and two-chamber views as well as short-axis (mitral, papillary, and apical) views, endocardial and epicardial contours were manually traced. The LV wall was automatically tracked and divided into 16 segment models (6 basal, 6 mid, and 4 apical) according to the American Society of Echocardiography, and each segment was individually analyzed. The software automatically tracked the contour on the subsequent frame in different vectors simultaneously (Fig. 1). Finally, 6 LV basal, 6 mid, and 4 apical segment measurements (total 16) of rotation, twist and basal torsion and regional torsion were calculated. Rotation (degree) is the rotary motion of helical myocardial fibers. This twisting motion has been shown to be a key factor of normal systolic and diastolic myocardial function in both animals and humans (8-13). Assessment of LV torsional deformation seems to be an important approach to quantification of myocardial function. Two- or three-dimensional speckle tracking echocardiography is a unique technique that analyzes a specific area of ultrasound reflex (speckle) of the myocardium, tracking the speckle frame by frame, and ultimately integrating the motion or deformation of the myocardium. It can provide both quantitative and qualitative information of the myocardium function. Newly developed three-dimensional (3D) echocardiography equipped with speckle tracking technique may improve and expand the diagnostic capabilities and accuracy of echocardiography. The purpose of this study is to evaluate LV torsion in CKD patients as compared with normal healthy people by 3D STI.
Decreased LV Rotation and Torsion in Hemodialysis Patients Studied by 3D STI

of the myocardium during contraction; while the apex moves counterclockwise, the base rotates clockwise. Counterclockwise is defined as plus direction. Twist (degree) is the difference between two SAX rotations (difference in angle between red and green circles) of LV; C. Torsion-basal calculation: \((R_i - R_b)/D_i-b \ [\text{deg/cm}]\) \(R_i\) [deg]: rotation values on each short axis (SAX), \(R_b\) [deg]: rotation values on Basal SAX, \(D_i-b\) [cm]: distance between each SAX and Basal SAX; D. Torsion-regional calculation: rotation compared with nearby reference SAX (about 1 cm away), \((R_i - R_j)/D_i-j \ [\text{deg/cm}]\), \(R_i\) [deg]: rotation values on a SAX, \(R_b\) [deg]: rotation values on regional reference SAX, \(D_i-j\) [cm]: distance between these 2 SAX.

Reproducibility

Intraobserver and interobserver variability of the torsion data were evaluated in 10 patients. To assess reproducibility, examinations were repeated by the same observer on the same echocardiographic images at least 1 week apart. Intraobserver and interobserver variabilities were calculated as the absolute difference between the corresponding repeated measurements as a percent of their mean.

Statistical Methods

Data were expressed as means ± SD for continuous variables. Values of different groups of patients were compared using the Student’s t-test. A \(P\) value < 0.05 was considered statistically significant.

Results

Among the 58 subjects who had been initially considered as eligible for the present study, 54 cases (26 males and 28 females) were found to have good quality images for assessment of LV function. Table 1 summarizes the clinical and echocardiographic characteristics of control subjects and CKD patients. Body weight \((P < 0.01)\), both systolic and diastolic blood pressure \((P < 0.01)\), LV end diastolic (LVEDV) and end systolic volume (LVESV) \((P < 0.05)\) and ejection fractions (EF) \((P < 0.01)\) showed statistically significant differences between the two groups. LV inter-ventricular septum (IVS) and posterior wall were higher in the predialysis group than in the normal subjects \((1.2 \pm 0.8 \text{ vs. } 0.8 \pm 0.71 \text{ mm}, P < 0.01; 1.1 \pm 0.7 \text{ vs. } 0.7 \pm 0.28 \text{ mm}, P < 0.01)\). There were also significant differences in the global value of rotation \((3.0 \pm 2.0 \text{ vs. } 2.5 \pm 1.9 \text{ deg}, P < 0.05)\), twist \((4.6 \pm 3.3 \text{ vs. } 2.7 \pm 1.9 \text{ deg}, P < 0.05)\), basal torsion \((1.6 \pm 1.1 \text{ vs. } 0.9 \pm 0.6 \text{ deg/cm}, P < 0.05)\) and regional torsion \((1.6 \pm 1.2 \text{ vs. } 0.9 \pm 0.8 \text{ deg/cm}, P < 0.05)\). There were no significant changes in heart rate (Table 1). The intraobserver variability for the LV torsion
measurement was 10 ± 6%, while the interobserver variability was 12 ± 8%.

**Discussion**

Using the newly developed 3D STI, we observed in this study decrease in global LV rotation, twist and torsion in CKD patients on hemodialysis as compared with normal healthy subjects. LV torsion deformation is due to the complex helical myocardial fiber architecture. The subepicardial fibers are arranged in a left-handed helix pattern. The fibers of the mid wall are circumferentially oriented and the subendocardial fibers are arranged in a right-handed helix pattern (14). It is evident from the other studies that the torsion is complex and closely related to the variations in transmural fiber orientation, irregular shape of the LV, local differences in ventricular morphology (i.e., radii of curvature), wall thickness and load change (15-18). In our CKD patients, the preload (increased LVEDV and LVESV) and afterload (increased BP) and wall thickness were significantly higher than those in the normal controls (Table 1). The changes in afterload and preload on LV torsion gave conflicting results in previous animal and human studies using cineare, MRI, microsonometry and 2D STI (19-23). In animal models, using magnetic resonance imaging (MRI) to track myocardial motion, increased preload (19) and increased afterload (20) both resulted in reduced untwisting. Increased afterload also attenuated the peak torsion (20). Reduced preload (19) and enhanced inotropy with dobutamine (21) augmented the peak torsion. Human studies on the effect of load on LV torsion were undertaken in cardiac allograft recipients with implanted radiographic markers (22, 23). These authors also found that volume loading reduced and delayed untwisting, but in contrast to the findings in animal models, they concluded that torsion was independent of preload and afterload manipulation. Murata’s report showed that the peak systolic strain and ejection remained the same before and after hemodialysis, but the LV functions in the horizontal plane changed. Not only the radial dyssynchrony but also the regional torsion improved after dialysis (5). Weiner et al. revealed that the LV rotation and torsion increased after normal saline infusion in normal subjects (24). We have recently demonstrated that in volume overload uremic patients, decreased preload also increased LV regional torsion after dialysis (25). CKD patients developed a concentric or eccentric LV geometry and LV hypertrophy in response to increased cardiac afterload, followed by progressive myocardial fibrosis. According to Laplace law, increased thickness/radius ratio would increase wall stress and alter LV torsion. In a controversial study on hypertension with LV hypertrophy, 2D speckle tracking-derived longitudinal strains are reduced in hypertension, while torsional mechanics are preserved (26).

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<th>Table 1. Comparison of general data, rotation, twist and torsion of LV in chronic kidney disease patients and controls by 3D STI</th>
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<tr>
<td>Control (N = 27)</td>
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<td>Gender (male/female)</td>
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<td>Age (years)</td>
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<td>Weight (kg)</td>
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<td>Systolic BP (mmHg)</td>
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<td>Diastolic BP (mmHg)</td>
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<td>Heart rate (beats/min)</td>
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<td>Interventricular septum (mm)</td>
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<td>E velocity (cm/s)</td>
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<td>End-diastolic volume (mL)</td>
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<td>Rotation (deg)</td>
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<td>Twist (deg)</td>
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<td>Torsion, R (deg/cm)</td>
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Others have reported that peak systolic twist remains normal while early diastolic LV untwisting velocity during the isovolumic relaxation period is reduced (27). In our study, the LV contractile parameters of CKD patients were significantly reduced. The mechanism was that interstitial fibrosis is a prominent finding in uremic heart disease, and clinical studies have shown that the extent of myocardial fibrosis is more marked in CKD patients than in diabetic patients or essential hypertensive patients with similar LV mass (28, 29). Myocardial fibrosis does not even contribute to the development of LV hypertrophy, a disarray of myocardial fibers in uremic heart disease also affects LV, resulting in non-uniform influence on LV.

This study used the newly developed 3D STI to trace the speckle spatial motion of the myocardium. Torsional motion has been measured by 2D ultrasound speckle tracking image both in animals and humans (30-32).

**Limitations**

There were some limitations of this study. Spatial resolution and full-volume LV data set for 3D STI comprised 4 or 6 sectors, the artifact occurring around the border between sectors may affect speckle tracking quality. Our number of cases was small. There were substantial differences in demographic characteristics among recruited patients.

**Conclusion**

Assessment of LV rotation and torsion by the newly developed 3D STI is less laborious and time-consuming. Our results suggested decreased LV rotation, twist and torsion in chronic hemodialysis patients compared with normal healthy subjects.

**References**

24. Weiner RB, Weyman AE, Khan AM, Reingold IS, Chen-Tournoux AA, Scherrer-Crosbie M, *et al.* Preload dependency of left ven-


