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ORIGINAL ARTICLE

Cardiology

Assessment of Left Ventricle Myocardial Function in Hypertensive Patients Using Three-Dimensional Speckle-Tracking Echocardiography (3D-STE)

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Abstract

Background: Increased myocardial fibrosis in hypertension leads to abnormalities in left ventricular diastolic function. 3D-speckle-tracking imaging (3D-STI) is a primary imaging modality used to detect early changes in the left ventricle (LV). The aim of this study was to assess the left ventricular myocardial function in hypertensive patients using 3D-speckle tracking imaging (3D-STI).

Methods and Results*:* A case control, nonintervention, descriptive study was conducted in the Department of Ultrasound Diagnosis of Union Hospital of Tongji Medical College of Huazhong University of Science and Technology (Wuhan, Hubei, China). The study subjects included 64 patients with hypertension (HT) and, as control group, 44 normotensives. HT patients were divided into HT-I group (SBP of 130-139 mmHg or DBP of 80-89 mmHg, and HT-II group (SBP >140 mmHg or DBP >90 mmHg). In this study, LV geometry and function were assessed using conventional 2D- and 3D-echocardiography in a total of 108 consecutive subjects. LV volumes, global and regional strains were measured using 3D-STI. LV ejection fraction (LVEF) was in normal range in three groups, but in general, it slightly decreased in HT-II patients, compared with control and HT-I groups (62.5±2.1%, 68.0±2.2%, and 67.5±1.3%, respectively, P=0.00). Global systolic strain demonstrated a significant decrease in GLS, GCS, and GRS in the HT-II group, compared with control and HT-I groups. All regional strain parameters (longitudinal, circumferential, and radial) significantly decreased in HT-II patients, compared with control and HT-I groups.

Conclusion: A significant deterioration of global LV systolic functions is found in hypertensive patients with well-preserved LVEF, especially in patients with hypertension stage II.(**International Journal of Biomedicine. 2021;11(4):403-409.**)

Key Words: hypertension • left ventricle • speckle tracking • global strain • regional strain

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Abbreviations

3D-STE, three-dimensional speckle-tracking echocardiography; **3D-STI**, three-dimensional speckle-tracking imaging; **ASE**, American Society of Echocardiography; **BP**, blood pressure; **BSA**, body surface area; **DBP**, diastolic BP; **EDV**, end-diastolic velocity; **GLS**, global longitudinal strain; **GCS**, global circumferential strain; **GRS**, global radial strain; **HT**, hypertension; **IVSd**, interventricular septal thickness; **LAd**, left atrial dimension; **LV**, left ventricle; **LVEF**, left ventricular ejection fraction; **LVEDV**, left ventricular end-diastolic volume; **LVESV**, left ventricular end-systolic volume; **LDEDd**, left ventricular end-diastolic dimension; **LVH**, left ventricular hypertrophy; **LVM**, left ventricular mass; **LVMI**, LVM index; **LVSV**, left ventricular stroke volume; **PWT**, posterior wall thickness; **RWT**, relative wall thickness; **SBP**, systolic BP; **SR**, strain rate; **SSR**, systolic strain rate; **SV**, systolic velocity.

Introduction

According to the 2017 American College of Cardiology (ACC) and the American Heart Association (AHA) guideline, hypertension is defined as SBP ≥130 mmHg or DBP ≥80 mmHg.[1] The prevalence of hypertension rises dramatically with increasing age and is higher in blacks than in whites, Asians, and Hispanic Americans.[1,2]

Early detection of LV dysfunction before the development of LVH is a finding that requires extensive treatment to reduce morbidity and mortality due to cardiovascular disease; therefore, it has to be considered in the evaluation of global cardiovascular risk.[3]

Echocardiography is still the primary imaging modality for assessing cardiac function; The most common index of the myocardial systolic function used in routine clinical practice is LVEF, but conversely, in several studies, LVEF was found to be suboptimal for detecting early myocardial dysfunction, likely due to undetectable wall deformation.[4,5]

3D-STE provides an accurate determination of subclinical myocardial dysfunction and also demonstrates comprehensive information about the cardiac ventricle. In addition, the accuracy and reproducibility of 3D-STE in evaluating the function and structure of the LV has been previously demonstrated.[6,7]

We hypothesize that 3D-STI may provide a reproducible measurement for the evaluation of LV subclinical myocardial changes in patients with primary hypertension.

Materials and Methods

A case control, nonintervention, descriptive study was conducted in the Department of Ultrasound Diagnosis of Union Hospital of Tongji Medical College of Huazhong University of Science and Technology (Wuhan, Hubei, China) during a period from June 2017 to May 2018. In this study, LV geometry and function were assessed using conventional 2D- and 3D-echocardiography in a total of 108 consecutive subjects. The study subjects included 64 HT patients and, as control group, 44 normotensives. HT patients were divided into HT-I group (SBP of 130-139 mmHg or DBP of 80-89 mmHg, and HT-II group (SBP >140 mmHg or DBP >90 mmHg).

Inclusion criteria

Patients aged ≥27 years of different genders with a diagnosis of primary hypertension were included in hypertensive groups. The characteristic features of hypertension patients matched the diagnostic standards of the 2017 ACC/AHA guidelines.[8]

The control group included the participants with no hypertension or diabetes, no use of medication, no cardiac symptoms, and no abnormality detected in the heart in physical examination, electrocardiogram, and echocardiography results.

Exclusion criteria

Any patients with secondary causes of HT, coronary artery diseases, congenital heart disease, severe valvular stenosis or regurgitation, abnormal wall motion, heart failure, arrhythmia, pericardial effusion (moderate or massive) and lung disease were excluded.

Echocardiography image acquisition

The cardiac structure, chamber size, wall thickness, and cardiac function were evaluated by a conventional transthoracic echocardiogram, following the recommendations of the ASE.[9] A commercially available system (IE Elite, Philips Medical Systems, Andover, MA) with an S5-1 broadband phased-array transducer was used. A 3D echocardiographic examination was given to all subjects, using the same system and X5-1 transducer. Images were adjusted to assess the complete LV during a full-volume dataset within the four-chamber apical view. Datasets were acquired with an acquisition setting of four or seven heartbeats. End-expiratory breath holding was done whenever possible. At least four datasets were acquired for each subject, then for offline analysis, three datasets with the best image quality were selected.[10] Datasets that did not include the whole LV, had indefinite endocardial borders, or had obvious stitch artifacts were excluded.

Echocardiographic parameters

The cardiac chamber size, LVM, and LVEF were measured according to the ASE chamber quantification guidelines.[9] IVSd, LVEDd, PWT, and LAd were measured in the parasternal long-axis view. RWT was calculated by dividing myocardial thickness (IVST+PWT) by LVEDd. Trans-mitral peak velocity of early diastole (E) and late diastole (A) was measured by pulse wave Doppler. The ratio of E/A was calculated. For the semi-automatic analysis of LVM, QLAB 3D (Philips Medical Systems) quantification software algorithms were used.

3D speckle-tracking echocardiography (3D-STE)

Offline 3D-STE analysis was obtained with 4D LV-Analysis 3.0 (TomTec Imaging Systems, Unterschleissheim, Germany echocardiographic quantification software). The technique used for measurement is same as Zhang et al.: "Measurements were made using the data set with the best image quality, which was selected by consensus of the two readers. The frame rate of the volumetric image was 15 to 24 frames/sec. The 3D data sets were displayed as multiplanar reconstruction images corresponding to four tiles containing three standard LAX views and a short-axis view, which is orthogonal to the LAX views."[11] The offline analysis method was used. The following strain parameters were assessed during LV strain analysis: GLS (LV peak systolic global longitudinal strain), GRS (LV peak systolic global radial strain), GCS (LV peak systolic global circumferential strain). The three parameters were averaged over the 16 segments: "The peak value of each index was defined as its maximum absolute value with a positive or negative sign. Negative strain values reflect shortening, whereas positive strain values represent lengthening or thickening. All strain values are dimensionless and are expressed as percentages."[11,12]

Statistical analysis was performed using the IBM SPSS Statistics V22.0 (SPSS Inc., Chicago, IL, USA). The normality of distribution of continuous variables was tested by one-sample Kolmogorov-Smirnov test. Continuous variables with normal distribution were presented as mean±standard deviation (SD). Multiple comparisons were performed with one-way ANOVA. Correlation coefficients (R^2) were calculated by linear regression analysis. A probability value of P<0.05 was considered statistically significant.

Results

Clinical characteristics

The demographic characteristics of two hypertensive groups (HT-I, HT-II) and the control group are summarized in Table 1. No significant differences in sex, height, and body surface area between the control, HT-I and HT-II groups were found.

Table 1.

Comparison between the study groups regarding demographic and clinical data

Variables	Control group (n=44)	HT-I group (n=20)	HT-II group (n=44)	*P*-value
Age, yrs	53.5 ±7.9	47.8±10.5*	56.3 ±11.6#	0.01
Gender M/F	30/14	12/8	30/14	0.79
SBP, mmHg	119.3±8.4	135.7±3.9*	153.5±24.7*#	0.00
DBP, mmHg	75.2±9.8	85.8±4.3*	93.5±19.1*	0.00
Height, cm	1.6±0.8	1.6±0.7	1.6±0.1	0.11
Weight, kg	62.7±10.4	67±9.6	69.9±9.4*	0.00
BSA, m^2	1.6±0.1	1.7±0.1	1.7±0.1	0.10

** Compared with control group, P <0.05; # compared with HT-I group, P <0.05.*

2D-echocardiographic analysis

The study found significant differences in RWT between HT groups and normotensive controls (0.4±0.1cm for HT- I group and HT-II respectively, 0.3±0.1cm for the control group, P=0.03). The parameters of diastolic function, such as E/A ratio, show significant differences between the control, HT-I and HT-II groups (1.4±0.9, 0.9±0.3, and 0.8±0.3, respectively, P=0.00). The LVEDd, PWT, LAd and LVM in the HT-II group were significantly higher than those of the control and HT-I groups (Table 2).

3D-STE analysis

The 3D-echocardiography found no significant differences between the control, HT-I and HT-II groups, regarding end-diastolic velocity and systolic velocity (Table 3). A significant difference was found in LVESV among groups: it was higher in the HT-II group than in the control and HT-I groups (42.8±10.7 mL, 35.7±6.7 mL, and 37.2±8.4 mL, respectively, P=0.00). Concerning LVEF, the study revealed that it was in normal range in three groups, but in general, it slightly decreased in HT-II patients, compared with control and HT-I groups (62.5±2.1%, 68.0±2.2%, and 67.5±1.3%, respectively, P=0.00). Global systolic strain demonstrated a significant decrease in GLS, GCS, and GRS in the HT-II group, compared with control and HT-I groups (-15.9±1.6%, -23.5±1.4%, and -20.2±0.9%, respectively, P=0.00; -33.7±1.8%, -37.4±1.7%, and -38.6±1.3%, respectively, P=0.00; and 41.0±2.1%, 51.1±1.7%, and 49.0±1.4%, respectively, P=0.00). Compared with controls, GLS and GRS decreased (P<0.05), but GCS in the HT-I group increased (P<0.05) (Table 3).

Table 2.

Comparison between the study groups by 2D-conventional echocardiography

Variables	Control group (n=44)	HT-I group (n=20)	HT-II group (n=44)	*P*-value
LAd, cm	2.9±0.3	3.5±0.4*	3.9±0.4*#	0.00
LVEDd, cm	4.5±0.3	4.6±0.4	4.8±0.3*#	0.00
IVSd, cm	0.9±0.1	1.0±0.1*	1.1±0.2*#	0.00
PWT, cm	0.8±0.1	0.9±0.2*	1.0±0.2*	0.00
RWT, cm	0.3±0.1	0.4±0.1*	0.4±0.1*	0.03
LVM, g	118.5±23.9	146.0±39.0*	202.7±42.8*#	0.00
E/A	1.4±0.9	0.9±0.3*	0.8 ±0.3*	0.00

*LAd, left atrium diameter; LVEDd, left ventricular end-diastolic dimension; IVSd, interventricular septum thickness; PWT, posterior wall thickness; RWT, relative wall thickness; LVM, left ventricular mass; * compared with control group, P <0.05; # compared with HT-I group, P <0.05.*

Table 3.

Comparison between the study groups by 3D-STE global strain parameters

Variables	Control group (n=44)	HT-I group (n=20)	HT-II group (n=44)	*P*-value
LVEDV, mL	111.3±18.3	113.8±26.6	113.7±25.4	0.87
LVESV, mL	35.7±6.7	37.2±8.4	42.8±10.7*#	0.00
LVSV, mL	75.6±12.2	76.6±18.3	70.9±15.0	0.21
LVEF, %	68.0±2.2	67.5±1.3	62.5±2.1*#	0.00
GCS, %	-37.4±1.7	-38.6±1.3*	-33.7±1.8*#	0.00
GLS, %	-23.5±1.4	-20.2±0.9*	-15.9±1.6*#	0.00
GRS, %	51.1±1.7	49.0±1.4*	41.0±2.1*#	0.00

EDV, end-diastolic volume; ESV, end-systolic volume; SV, stroke volume; LVEF, left ventricular ejection fraction; GLS, global longitudinal strain; GCS, global circumferential strain; GRS, global radial strain. compared with control group, P<0.05; #compared with HT-I group, P<0.05.*

In 3D-STE of regional strain parameters, significant differences were demonstrated in this study in the longitudinal, circumferential, and radial (basal, middle and apical strains) strains among three groups. All regional strain parameters (longitudinal, circumferential, and radial) significantly decreased in HT-II patients, compared with control and HT-I groups (Table 4, Fig.1-3).

Table 4.

Comparison between the study groups by 3D-STE regional strain parameters

Variables	Control group (n=44)	HT-I group (n=20)	HT-II group (n=44)	*P*-value
CS/B, %	-31.8±3.6	-32.2±3.1	-29.5±3.1*#	0.01
CS/M,%	-39.9±3.2	-41.5±2.1	-37.2±2.8*#	0.00
CS/A,%	-45.1±3.5	-47.1±4.0*	-39.1±4.7*#	0.00
RS/B,%	45.2±4.1	41.6±2.8*	38.5±3.1*#	0.00
RS/M,%	50.9±4.5	53.1±5.2	41.8±3.3*#	0.00
RSA,%	61.6±5.6	59.0±4.0*	47.0±5.5*#	0.00
LS/B,%	-23.2±3.4	-18.0±2.0*	-17.1±3.0*	0.00
LS/M,%	-21.1±3.3	-19.8±2.4	-13.9±2.7*#	0.00
LS/A,%	-27.9±4.7	-24.6±2.6*	-17.7±3.5*#	0.00

*CS/B, basal circumferential strain; CS/M, middle circumferential strain; CS/A, apical circumferential strain; RS/B, basal radial strain; RS/M, middle radial strain; RS/A apical radial strain; LS/B, basal longitudinal strain; L/M, middle longitudinal strain; LS/A, apical longitudinal strain. *Compared with control group, P<0.01; # compared with HT-I group, P<0.01.*

Regarding the HT-I group, compared with control group, the basal radial strain (RS/B), apical radial stain (RS/A), basal longitudinal strain (LS/B), and apical longitudinal strain (LS/A) decreased while the apical circumferential strain (CS/A) increased. Among the patients of the HT-II group, a significant negative linear relationship was found between LVEF and global strain parameters [LVEF and GLS (R^2=0.12, P<0.05), LVEF and GCS (R^2=0.34, P<0.05), and LVEF and GRS (R^2=0.27, P<0.05), GCS was more relevant to LVEF (Fig.4).

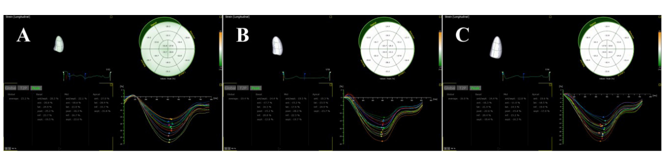

Fig.1. *The LV longitudinal strain of HT-I and HT-II patients was lower than that of normotensive individual. The LV longitudinal strain of HT-II patient was the lowest. A - normotensive individual; B - HT-I patient; C - HT-II patient. (These patients were all male patients of similar age).*

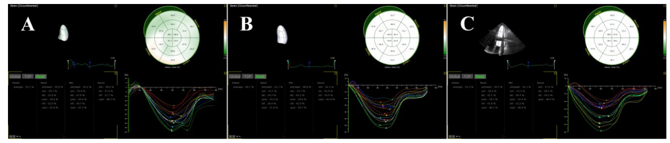

Fig.2. *The LV circumferential strain of HT-II patient was lower than that of normotensive individual and HT-I patient. The LV circumferential strain of normotensive individual and HT-I patient was similar. A - normotensive individual; B - HT-I patient; C - HT-II patient. (The same patients as in Figure 1).*

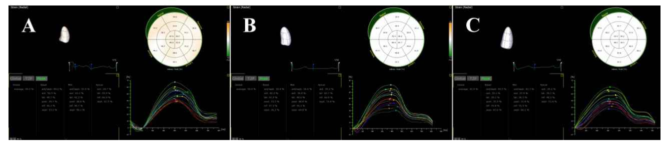

Fig.3. *The LV radial strain of HT-II patient was lower than that of normotensive individual and HT-I patient. The LV radial strain of normotensive individual and HT-I patient was similar. A - normotensive individual; B - HT-I patient; C - HT-II patient. (The same patients as in Figures 1 and 2).*

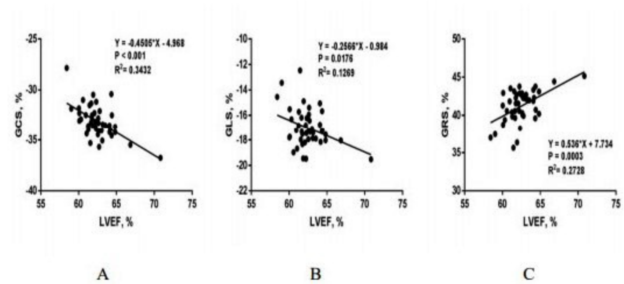

Fig.4. *Relationship of LVEF with global systolic function in patients of HT-II group. A - GCS; B -GLS; C - GRS.*

Discussion

The heart is a vital organ that sustains human life. In the late stage, systemic hypertension is one of the most frequent causes of heart failure.[5] Hypertension now accounts for the largest proportion of cardiovascular mortality worldwide. Cardiac hypertrophy occurs in hypertensive patients due to hemodynamic pressure overload, leading to increased wall thickness and LV remodeling. Echocardiography is the primary preferred imaging technique for assessing LV geometry and cardiac function for risk stratification.[13,14]

In this study, LV structure, mass, and E/A ratio were obtained from trans-mitral inflow Doppler. LV volumes, global and regional strains in longitudinal, circumferential, and radial directions were measured in primary diagnosed HT patients, using RT 3D-STE.

In 2D conventional echocardiography, in this study, the RWT was significantly increased in the hypertensive patients, compared to normotensive individuals; diastolic function parameters such as E/A ratio were significantly different between the control group, HT-I, and HT-II groups (decreased gradually from the control group to HT-1 and HT-II), but LVEDd, PWT, LAd and LVM were significantly higher in the HT-II than in the HT-1 and control groups. Compared to the present study, Ikonomidis et al.[15] found that in 2D conventional echocardiography there was a non-significant difference in ejection fraction, LVEDV and LVESV between hypertensive and control groups; however, a significant difference was shown in LVMI, RWT, and the left atrial volume between the two groups; all these parameters were higher in a hypertensive group than in control group. Galderisi M. et al.[16] also demonstrate the same results: Hypertensive patients have higher LVM and wall thickness and a significant difference in diastolic parameters, compared to control, but no significant difference in ejection fraction in conventional 2D echocardiography. No significant differences were found in this study in 3D-echocardiography between control, HT-I, and HT-II groups regarding EDV and SV. LVESV was slightly more in the HT-II group than in the control and HT-I groups. LVEF significantly decreased in HT-II, compared to HT-I and control groups, but was in the normal range. Furthermore, GCS, GLS, GRS showed significant differences between HT groups and control (significantly decreased in HT-II compared to HT- I and control groups).

Longitudinal basal, middle strain, apical strain, circumferential basal, middle and apical strain, radial basal, middle, and apical strain were decreased in patients of the HT-II group, compared to control and HT-I groups. Regarding the HT-I group, compared with control, CS/A increased, RS/B, RS/A, LS/B, and LS/A decreased. Among the patients of the HT-II group, a significant negative correlation was found between EF and each parameter of GLS, and GCS, with GCS being more relevant to LVEF. According to Galderisi et al.,[16] there was no significant difference in LV volumes, EF, or sphericity index determined by RT 3DE between the hypertensive and control groups, but LVMI was more in the hypertensive groups than in the control group. GAS and GLS were significantly decreased in hypertensive patients, but GCS did not vary significantly between hypertensive and control patients; in general, our results were close to theirs, except for GCS, as this study shows a significant difference in the control, HT-I and HT-II groups.[16]

The results of this study are also similar to those of Yao et al.;[17] they found that GAS, GLS, GCS, and GRS in hypertensive patients were significantly decreased, as was LVEF, compared to controls. Our study clarified that GAS can detect early changes in LV global systolic function in hypertensive patients with normal ventricular geometry; in our study, GCS is more relevant to LVEF. Haque et al. found that the global left ventricular, longitudinal, systolic strain, radial strain and area strain by RT3DSTE were significantly reduced (P<0.001) in groups of hypertensive patients with presence or absence of LVH by 2D-echo-cardiography, compared to the control group.[18]

In contrast to other studies conducted using 2D-STE to assess global and regional strains in hypertensive patients, El-Noamany et al.[19] found that global peak systolic strain was significantly lower in the hypertensive group, compared to the control group. Global early diastolic SR was reduced in hypertensive patients, compared to controls (P=0.001). Meanwhile, global late diastolic SR was higher in hypertensives than in the control group (P=0.001). No significant differences in LVEF values and LV systolic function assessed by conventional echocardiography between hypertensives and control patients were noted. However, highly significant reductions in LV systolic strain and SR values were noted between control and hypertensive patients.[19] Hamed et al.[20] stated that the early diastolic SR was significantly decreased in hypertensive groups, compared with the control group, possibly due to increased myocardial fibrosis in hypertensive patients, leading to abnormalities in diastolic function and myocardial stiffness. GLS (global longitudinal strain) and SSR (systolic strain rate) were impaired in hypertensive patients, but the radial and circumferential strains showed insignificant differences between the control and hypertensive groups in a study done by Ikonomidis et al.[15] This is because the longitudinal subendocardial fibers of the myocardium are most vulnerable to adverse influences, such as hypo-perfusion and age-related interstitial fibrosis, so impaired longitudinal function, which is decreased in hypertensive disease, is an early sign of myocardial dysfunction.[21]

Conclusion

This study concludes that 3D-STE allows early diagnosis of abnormal LV myocardial systolic function, even in the subclinical stage. There was a significant reduction of myocardial systolic function in HT-II patients, compared with HT-I patients and the control group. The basal, middle, and apical segments strains significantly decreased in hypertensive patients, compared to the control group. GCS (global circumferential strain) may play a more important role in maintaining LVEF (left ventricular ejection fraction) than GLS (global longitudinal strain) and GRS (global radial strain).

Ethical Clearance

The ethical clearance was obtained from the Department of Ultrasound Diagnosis of Union Hospital of Tongji Medical College of Huazhong University of Science and Technology, Wuhan, Hubei, China. All the study participants were informed that all information would be used for research purposes only, then the result of the examination formed a part of this study.

All specific information relating to the participants' identities was protected, as was other medical data collected as routine case management. Participants were informed about the procedure and purpose of the study. Additional informed consent was obtained from all individual participants for whom identifying information is included in this article. Ultrasound and echocardiography scanning formed a part of routine management of the study cases.

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Competing Interests

The authors declare that they have no competing interests.

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