Evaluation of left ventricular hypertrophy in hypertensive patients with echocardiographic myocardial videodensitometry normalized by displacement

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Abstract

Left ventricular hypertrophy (LVH) is an important predictor of cardiovascular morbidity and mortality. To investigate the feasibility of the myocardial grayscale intensity (GI) normalized by displacement (d) to discriminate between healthy and hypertrophic myocardium in hypertensive patients, sixty hypertensive patients and sixty age and sex-matched healthy volunteers were involved in this study. The peak d and the maximal GI [GI(max)] and minimal GI [GI(min)] for the middle interventricular septal (IVS) and the middle posterior wall (PW) at the level of papillary muscle were obtained from the standard parasternal long axis views using tissue tracking (TT) and videodensitometric analysis, respectively. The GI and the cyclic variation of GI (CVGI) normalized by d were calculated. The results showed that the d both for IVS and PW, the amplitude of CVGI for IVS in hypertensive patients with LVH were smaller than the ones without LVH and the normal subjects. But, the CVGI/d both for IVS and PW in hypertensive patients with LVH were all greater than the ones without LVH and the normal subjects. Moreover, the parameter, CVGI/d correlated positively with left ventricular mass index (LVMI). So, the method employed in this study, videodensitometric analysis in combination with TT allow objective and accurate determination of LVH and CVGI/d is a sensitive indicator for hypertensive patients with LVH.

KEY WORDS: myocardial tissue characterization, tissue tracking, grayscale intensity, displacement, left ventricular hypertrophy, hypertension

Introduction

Left ventricular hypertrophy (LVH) is a common adaptation mechanism of the heart in response to a chronic pressure overload of the left ventricle in hypertensive patients, which is an important predictor of cardiovascular morbidity and mortality, such as diastolic dysfunction, sudden death and so on. [1-7]. So, it is important to regress the LVH by antihypertensive therapy [7]. Echocardiography is a common approach to assess the myocardial structure and function, which can provide a quantitative evaluation of LV muscle mass and the values are near to those found at necropsy [4,8]. Recently, myocardial tissue characterization (MTC), which is based on the hypothesis that pathological changes of myocardial structure and function result in alterations of the interaction of ultrasound with tissue [9], have been exploited to characterize various abnormal pathological states, in particular to ischemic [10], dilated [11], and hypertrophic cardiomyopathy [12,13]. There are two methods available for the assessment of MTC now: the analysis of the radiofrequency signal and the videodensitometry [9-13]. They allow integration of the conventional echocardiographic evaluation, and obtain specific acoustic properties parameters that reflect the myocardial ultrastructural texture. The analysis of the radiofrequency signal is considered as gold standard which direct analyze of the raw radiofrequency signal from the transducer while videodensitometric analysis exploits methods of statistical quantification of the normal echocardiographic images to determine mean gray levels of a selected region of interest (ROI) [9]. However, they have some common deficiencies, such as variable attenuation effects because of different distances between transducer and myocardial region through the chest wall [14], different backscattered signal from blood as normalized reference due to the different resolution of the sensor and the blood components [15]. To date, neither is extensively diffused in clinical practice. The appearance of a new echocardiographic technique integrating the analysis of regional myocardial motion, deformation and tissue characterization parameters, such as velocity, displacement, strain rate, strain and grayscale intensity, maybe change this situation, which facilitate a fast, simple, accu-

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rate measurement of the myocardial structural and mechanical properties at the same site and in the same cardiac cycle. In this study, we took displacement as a reference, and normalized the myocardial grayscale intensity with displacement in order to obtain an intrinsic myocardial tissue characterization parameters that are less susceptible to other factors, for example, the attenuation effects, the different reference, the different site and cardiac cycle. We aimed to investigate the feasibility of the myocardial grayscale intensity normalized by displacement to discriminate between healthy and hypertrophic myocardium in patients with hypertension.

Materials and Methods

Study population

The study population consisted of 60 hypertensive patients (30 males and 30 females, mean age: 45.8±17.3 years, range: 32–80 years) who did not suffer from aortic disease, diabetes, renal disease, known coronary artery disease, previous stroke, chronic obstructive pulmonary disease. Meanwhile, 60 age and sex-matched normal subjects (30 males and 30 females, mean age: 44.9±16.4 years, range: 30–80 years) were recruited as the control group who were absence of clinical, biochemical detection, X-ray, electrocardiographic and echocardiographic evidence of various disease. The study was approved by the local human research ethics committee and free informed consent was obtained from all the study patients. The blood pressure that is greater than or equal to 140/90 mmHg is diagnosed as hypertension based on the guidelines of the seventh report of the Joint National Committee on Prevention, Detection, Evaluation, and Treatment of High Blood Pressure (JNC-7) [16].

Echocardiographic study

The echocardiographic study was performed in all the subjects lying in left lateral decubitus position with the electrocardiography recorded simultaneously. The echocardiographic data were acquired using a commercially available ultrasonic system (Vivid 7; General Electric Medical Systems, Milwaukee, WI, USA) and a harmonic 1.7-3.4 MHz variable frequency phased array transducer. This ultrasonic system was equipped with a Q-analyze quantitative analysis software for the analysis of displacement (d), grayscale intensity(GI) and so on at the same site and in the same cardiac cycle (Figure 1). First of all, the standard parasternal long axis view was obtained. An M-mode tracing (100mm/s) was recorded for the subsequent measurements: diastolic interventricular septal thickness (DIVST), diastolic posterior wall thickness (DPWT), left ventricular end-diastolic diameter (LVEDD), left ventricular end-sistolic diameter (LVESD), left atrial end-sistolic diameter (LAESD). The left ventricular fractional shorting (LVFS) and left ventricular ejection-fraction (LVEF) were automatically calculated by the ultrasonic system. The left ventricular mass (LVM) was calculated according to the definition of the American Society of Echocardiography: LVM= 1.05×[(LVEDD+ DVST+ DPWT)3 -LVEDD3)] [17]. The LVM indexed for body surface area (LVMI) was calculated according to the recommendations of Devereux [18,19]. Left ventricular hypertrophy (LVH) was defined as LVMI above 134 g/m2 in men and 110 g/m2 in women. Secondly, the tissue velocity imaging (TVI) function was

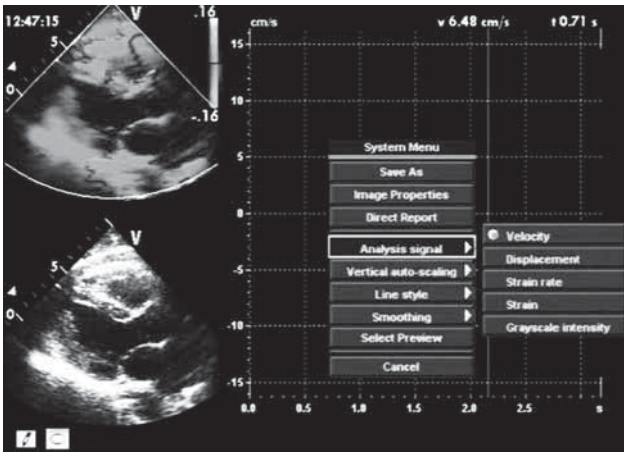

FIGURE 1. Regional myocardial motion, deformation parameters and grayscale intensity measured by the ultrasonic system (Vivid 7; General Electric Medical Systems), including velocity, displacement, strain rate, strain and grayscale intensity using tissue velocity imaging, tissue tracking, strain rate imaging and videodensitometric analysis.

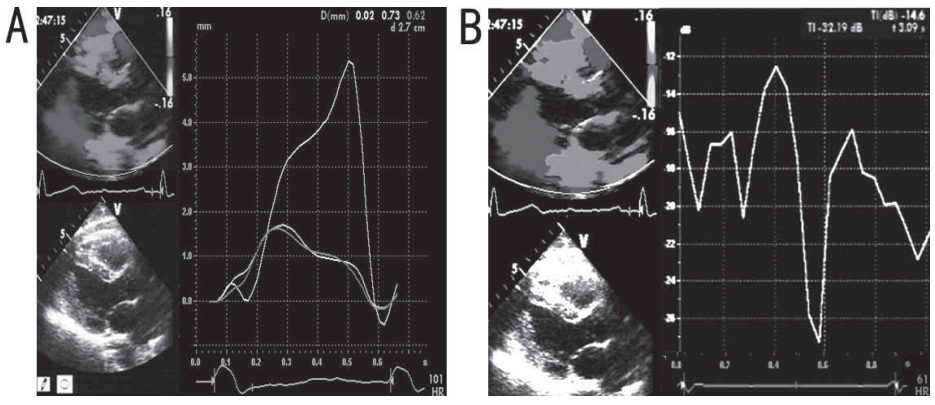

FIGURE 2. Measurement methods of regional myocardial displacement and grayscale intensity. The image was obtained from the parasternal long-axis view of the heart in a normal subject. A. peak displacement determined by displacement curve using tissue tracking; B. maximal and minimal grayscale intensity in the cardiac cycle determined by grayscale intensity curve using videodensitometric analysis.

activated and the TVI of five cardiac cycles in the standard parasternal long axis view was stored at a frame rate of 100 frames per second for subsequent analysis. In this process, gains were adjusted at the minimal optimal level to minimize noise, and the filter settings were kept low (50 Hz). Finally, a region of interest was placed at the middle interventricular septal (IVS) and the middle posterior wall (PW) at the level of papillary muscle for measurements of displacement (d) and grayscale intensity (GI). Adequate tracking of IVS or PW was verified and, if necessary, adjusted. The peak displacement, the maximal GI [GI(max)] and minimal GI [GI(min)] were obtained using tissue tracking (TT) and videodensitometric analysis, respectively (Figure 2), and the cyclic variation of GI (CVGI) and the CVGI normalized by displacement were calculated. All values for each parameter were obtained by averaging measurements from three successive cardiac cycles.

Reproducibility

Intraobserver variability was assessed in 30 patients (15 in normal subjects and 15 hypertensive patients) by repeating the measurements on two occasions (5 days apart) under the same basal conditions. To test the interobserver variability, the measurements were performed offline from video recordings by a second observer who was unaware of the results of the first examination. Variability was calculated as the mean percentage error, derived as the difference between the two sets of measurements.

Statistical analysis

The values were expressed as the mean ± SD. Differences between the mean values of the two groups were analyzed by the one-way analysis of variance (ANOVA). The linear correlation analysis was used for determining the significance of correlations between variables. Differences were considered significant at $p<0.05$. SPSS version 13 (SPSS, Chicago, IL, USA) was used for all statistical analysis.

Results

Cinical characteristics of hypertensive patients

As shown in Table 1, age, sex, body surface area, body mass index (BMI), heart rate, LVEDD, LVESD, LVFS and LVEF did not differ between the hypertensive patients and the normal subjects. The SBP, DBP, DIVST, DPWT, LVM, LVMI and LAESD

TABLE 1. Clinical and echocardiographic characteristics of hypertensive patients and normal subjects

	N, mean (SD)	HP, mean (SD)	*P*-value
Clinical parameters			
Age (years)	44.9 (16.4)	45.8 (17.3)	0.76
Sex (female/male)	30/30	30/30	
Body surface area(m^2)	1.79 (0.13)	1.82 (0.14)	0.68
BMI (kg/m^2)	20.73 (1.73)	22.64 (2.29)	0.63
Heart rate (min^{-1})	71.25 (5.66)	74.49 (6.18)	0.72
SBP (mmHg)	119.94 (13.26)	157.63 (18.98)	0.0015
DBP (mmHg)	72.62 (11.92)	89.65 (14.53)	0.037
Echocardiographic parameters			
LVEDD (mm)	49.32 (0.67)	51.3 (0.52)	0.73
LVESD (mm)	30.29 (3.42)	31.34 (4.61)	0.71
DIVST (mm)	9.14 (0.72)	12.76 (1.53)	0.017
DPWT (mm)	9.06 (0.37)	11.82 (1.39)	0.023
LVM (g)	209.56 (18.77)	264.95 (38.62)	0.026
LVMI (g/m^2)	109.78 (13.69)	149.54 (25.39)	0.009
LAESD (mm)	34.89 (2.08)	43.57 (4.76)	0.014
LVFS (%)	32.79 (5.99)	33.86 (7.12)	0.69
LVEF (%)	69.85 (9.33)	71.64 (10.47)	0.53

Legend: N, normal subjects; HP, hypertensive patients; BMI, body mass index; SBP, systolic blood pressure; DBP, diastolic blood pressure; LVEDD, left ventricular end-diastolic diameter; LVESD, left ventricular end-sistolic diameter; DIVST, diastolic interventricular septal thickness; DPWT, diastolic posterior wall thickness; LVM, left ventricular mass; LVMI, left ventricular mass index; LAESD, left atrial end-sistolic diameter; LVFS, left ventricular fractional shorting; LVEF, left ventricular ejection-fraction

TABLE 2. Comparison of the displacement and grayscale intensity between hypertensive patients and normal subjects

Variables	N (A), mean (SD)	HP–LVH (B), mean (SD)	HP+LVH (C), mean (SD)	P-value A vs. B	P-value A vs. C	P-value B vs. C
IVS						
d (mm)	4.02 (2.17)	4.29 (2.69)	2.07 (0.68)	0.81	0.02	0.03
GI(max) (dB)	28.75 (7.86)	31.90 (4.71)	38.42 (6.69)	0.73	0.14	0.19
GI(min) (dB)	23.25 (5.46)	27.52 (5.58)	35.03 (7.86)	0.86	0.46	0.49
CVGI (dB)	5.81(2.09)	5.58 (2.13)	4.39 (1.56)	0.82	0.019	0.021
CVGI/d (dB/mm)	1.37 (0.71)	1.34 (0.58)	2.18 (0.97)	0.79	0.0014	0.0016
PW						
d (mm)	4.44 (2.95)	5.35 (2.74)	3.55 (1.85)	0.76	0.042	0.035
GI(max)(dB)	30.47 (6.61)	31.57 (4.51)	36.05 (5.21)	0.91	0.52	0.86
GI(min)(dB)	23.36 (6.29)	25.19 (6.31)	29.68 (5.67)	0.87	0.58	0.86
CVGI (dB)	6.10 (3.71)	6.38 (3.38)	7.37 (3.46)	0.88	0.74	0.87
CVGI/d (dB/mm)	1.14 (0.59)	1.42 (0.48)	2.37 (0.86)	0.77	0.0009	0.0013

Legend: N, normal subjects; HP-LVH, hypertensive patients without left ventricular hypertrophy; HP+LVH, hypertensive patients with left ventricular hypertrophy; IVS, interventricular septum; PW, posterior wall; d, peak displacement; GI (max), the maximal grayscale intensity in the cardiac cycle; GI (min), the minimal grayscale intensity in the cardiac cycle; CVGI, the cyclic variation of grayscale intensity.

TABLE 3. Relation of CVGI/d to DIVST, DPWT, LVM, LVMI, LAESD

Variables	CVGI/d, r (p)	
	IVS	PW
DIVST	0.19 (0.63)	0.23 (0.32)
DPWT	0.13 (0.69)	0.16 (0.68)
LVM	0.42 (0.52)	0.37 (0.58)
LVMI	0.68 (0.011)	0.72 (0.008)
LAESD	0.24 (0.35)	0.26 (0.39)

IVS, interventricular septum; PW, posterior wall; CVGI, the cyclic variation of grayscale intensity; d, peak displacement; DIVST, diastolic interventricular septal thickness; DPWT, diastolic posterior wall thickness; LVM, left ventricular mass; LVMI, left ventricular mass index; LAESD, left atrial end-sistolic diameter; r, pearson correlation coefficient; p, p-value calculated by t test

of the hypertensive patients were greater than those of the normal subjects.

Comparison of the displacement and grayscale intensity between hypertensive patients and normal subjects

Table 2 displays that hypertensive patients without LVH and the normal subjects did not differ in d, GI (max), GI (min), CVGI and CVGI/d both at IVS and PW. The hypertensive patients with LVH had a smaller d for IVS and PW and a smaller amplitude of CVGI for IVS than did the ones without LVH and the normal subjects while the CVGI/d both for IVS and PW in hypertensive patients with LVH were all greater than the ones without LVH and the normal subjects.

Relation of CVGI/d to DIVST, DPWT,LVM,LVMI,LAESD

Due to a significant difference of CVGI/d for IVS and PW among the hypertensive patients with and without LVH and the normal subjects, a linear correlation analysis was used for determining the significance of correlations between CVGI/d and DIVST, DPWT, LVM, LVMI, LAESD. As shown in Table 3, only CVGI/d for IVS and PW correlated positively with LVMI while there were no significant correlation between CVGI/d and DIVST, DPWT, LVM and LAESD.

Reproducibility

Intraobserver and interobserver variability for LVEDD, LVESD, DIVST, DPWT, LVM, LVMI and LAESD ranged from 3.2% to 7.6%. Intraobserver and interobserver variability for the d were 5.6%±2.2%, 6.4%±3.2%, respectively. Intraobserver and interobserver variability for the GI were 6.3%±2.3% and 6.9%±1.9%, respectively.

Discussion

To obtain the acoustic properties of myocardium which reflect its ultrastructural texture, MTC has been widely used in scientific research and clinical practice since about 25 years ago. Now, with the advances in digital signal processing, the clinical used equipments have allowed the MTC integrate other technical parameters, such as motion and deformation mentioned above for better assessment of myocardial structure and function. Usually, MTC may provide two types of information: one is static and consists of the absolute myocardial echo intensity that reflects the ultrastructural myocardial changes in different diseases; the other is dynamic and is related to the variations of echo intensity during the cardiac cycle which is linked to the intrinsic myocardial contractility [20]. For the first one, there are currently no uniform standards for the discrimination of different diseases because of many factors, such as the different instruments used, the different attenuation effects, the different reference chosen, the different site and so on. In this study, hypertensive patients with and without LVH and the normal subjects did not differ in GI (max), GI (min) both at IVS and PW, so it is difficult to discriminate the hypertensive patients with or without LVH and the normal subjects according the absolute myocardial echo intensity. For the second one, it seems to be feasible to identify the characteristics of various diseases, because of its relative independence, objectivity and fewer influencing factors. It is similar to Masuyama's report [21] that hypertensive patients with LVH had a smaller amplitude of CVGI for IVS than did the ones without LVH and the normal subjects in this study, but such a decrease in CVGI was not observed in the posterior wall in these patients. There are several possible factors for explaining this finding: The effect of regional differences in the systolic wall stress, the regional differences in the structural changes and the asymmetric septal hypertrophy. Each factor can possible lead to the phenomenon mentioned above. In other words, CVGI alone did not always qualify for distinguishing abnormal and normal pathological states as previous study [9,21,22]. The d originating from myocardial cyclical movement, as one of indicators of intrinsic myocardial contractility, can be fast, simple, reproducible measured. This study showed that hypertensive patients with LVH had a smaller d for IVS and PW than did the ones without LVH and the normal subjects. When CVGI was normalized by d, the CVGI/d means the changes of CVGI per unit displacement, which provide more precise integration of information about myocardial ultrastructure and intrinsic contractility. The results showed that hypertensive patients with LVH had a bigger amplitude of CVGI/d for IVS and PW than did the ones without LVH and the normal subjects. Moreover, this parameter was significantly correlated with LVMI. This demonstrates that CVGI/d is a sensitive indicator for hypertensive patients with LVH. The exact mechanism for a increase in CVGI/d in hypertensive patients with LVH is not completely known. Tanaka et a1 found the percent area of fibrosis correlated with heart weight [23], and Ciulla et al also found that collagen

content appears to be the major determinant of regional echo intensity [24]. The structural changes of an increase in fibrosis of the myocardium in hypertensive patients with LVH may result in a decrease in CVGI and an insufficient contractility. A smaller d for IVS and PW in hypertensive patients with LVH was an illustration for the attenuated myocardial contractility. Although the magnitude of CVGI also decreased at IVS (not seen at PW) in hypertensive patients in this study, the value of CVGI/d seems to be no influenced, so CVGI/d is a valuable parameter for the assessment of left ventricular hypertrophy in hypertensive patients.

Conclusion

Our study demonstrate that videodensitometric analysis in combination with TT allow objective and accurate determination of LVH by providing more precise integration of information about myocardial ultrastructure and intrinsic contractility and CVGI/d is a sensitive indicator for hypertensive patients with LVH.

Acknowledgments

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Declaration of Interest

The authors have no conflict of interest to declare.

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