ORIGINAL ARTICLE

Left Ventricular Geometric Patterns in Newly Diagnosed Hypertension: An Echocardiographic Study

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Objective: To investigate patterns of left ventricular (LV) geometric patterns in patients diagnosed with new-onset hypertension using transthoracic echocardiography. The LV diastolic function was also evaluated in these patients.

Materials and Methods: The present study was a cross-sectional study that clinically evaluated patients diagnosed with new-onset hypertension at Burapha University Hospital. To classify LV geometric patterns, electrocardiogram, and transthoracic echocardiography to measure LV mass index and relative wall thickness were performed. Other relevant assessments were also conducted, including the diastolic function.

Results: Fifty-five patients diagnosed with new-onset hypertension were enrolled, their mean age was 55.3 years, with a standard deviation of 11.8 years. Of all participants, 70.9% (95% CI 57.1 to 82.4) had concentric remodeling, 16.4% (95% CI 7.8 to 28.8) had concentric hypertrophy, 10.9% (95% CI 4.1 to 22.3) had normal geometry and 1.8% (95% CI 0.1 to 9.7) had eccentric hypertrophy. Of all participants, 81.8% were detected to have abnormal LV diastolic dysfunction. Abnormal relaxation pattern was the most common format.

Conclusion: In the present study, approximately 10.9% of patients diagnosed with new-onset hypertension had normal LV geometry, whereas 89.1% had abnormal geometry in different patterns. Concentric remodeling was found to be the predominant abnormal geometrical format. Understanding LV geometric patterns helps clinicians stratify risk, predict prognosis, and make informed decisions about treatment strategies for these patients.

Keywords: Hypertension; Left ventricular geometric pattern; Diastolic dysfunction

Received 19 December 2022 | Revised 17 August 2023 | Accepted 12 September 2023

J Med Assoc Thai 2023;106(10):980-7

Website: http://www.jmatonline.com

At present, the number of patients with high blood pressure in Thailand is increasing. As reported by the sixth National Health Examination Survey in 2020, 25.4% of Thai adults were hypertensive with 26.7% in men and 24.2% in women[1]. Hypertension is a silent disease because it is a risk factor that causes other diseases such as heart failure, cerebrovascular disease, and chronic kidney disease. Hypertension is also a major risk factor that causes cardiovascular morbidity and mortality worldwide[2]. Hypertension causes a change in the structure of the heart at the cellular level, abnormal heart cell growth, and accumulation of collagen fibers leading to myocardial fibrosis, cardiomyopathy, and eventually heart failure[3-5]. Before progressing to heart failure, abnormal filling of blood volume occurs in the left ventricle, which is also known as diastolic dysfunction[6]. Previous studies[7,8] have shown that patients with hypertension can develop four types of the left ventricular (LV) geometric patterns, normal geometry, concentric remodeling, concentric hypertrophy, and eccentric hypertrophy. The normal geometric pattern is the most common feature in the four groups. Concentric hypertrophy pattern does not always develop in patients with high blood pressure. Previous studies had found these changes take many forms, but none have examined the LV geometric pattern in Thai patients. There were studies demonstrating demographic factors including ethnicity influence geometrical property of the LV[9,10]. In addition, little information is known

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How to cite this article:

Koowattanatianchai S, Sukonthanit A, Rangsrisaeneepitak V, Kanjanaampol C, Kaladee A. Left Ventricular Geometric Patterns in Newly Diagnosed Hypertension: An Echocardiographic Study. J Med Assoc Thai 2023;106:980-7.

DOI: 10.35755/jmedassocthai.2023.10.13905

regarding the LV geometric patterns in Thais, which might have different distributions from those seen in other ethnicities. Therefore, the present study aimed to describe the type and prevalence of LV geometric patterns in Thai patients diagnosed with new-onset hypertension.

Materials and Methods

Sample size calculation

The sample size was calculated based on a previous study published in 1992[7], where in a cohort of 50 patients diagnosed with hypertension, they found a normal LV geometric pattern in approximately 54% when using echocardiogram. With a test power of 80% and a significance level of 5% (two-sided test), a sufficient sample size should include 43 patients.

Population and samples

The present study enrolled adult patients diagnosed with new-onset hypertension in the Burapha University Hospital, Thailand, between August 2021 and August 2022. These patients were screened for eligibility for the present study. The inclusion criteria were 1) aged older than 35 years, 2) had systolic blood pressure (SBP) of 140 mmHg or greater and/or a diastolic blood pressure (DBP) of 90 mmHg or greater, according to the 2019 Thai Guidelines on the Treatment of Hypertension[11], and 3) had never received antihypertensive drugs. The blood pressure was measured twice (at the outpatient department and before echocardiography) at the hospital. All patients had a recent history of hypertension when they were measured at home by staff from primary health care unit or village health volunteers. The exclusion criteria were 1) documented secondary hypertension, 2) documented cardiovascular diseases, including coronary artery disease, and moderate-to-severe valvular heart disease, 3) serum creatinine greater than 2 mg/dL, and 4) aged older than 74 years. Patients who met the inclusion criteria underwent transthoracic echocardiography by a cardiologist. Mostly, patients were free of the investigating cost depending on their medical benefit scheme and assessment program. In addition, after the echocardiography, they were informed of the obtained information, which provided indirect benefit for caring health.

The present study was approved by the Burapha University Institutional Review Board (HS043/2564). All patients provided written informed consent.

Transthoracic echocardiography parameters

Patients diagnosed with new-onset hypertension underwent transthoracic echocardiography by a cardiologist (SK). The American Society of Echocardiography Guidelines and Recommendations[12,13] were used to assess and measure these parameters. The cardiologist performed all examinations using a diagnostic ultrasound system (Philips EPIQ CVx with a Philips X5-1 MHz Phased Array Probe). In the current analysis, parameters used included LV end-systolic and diastolic diameters (LVESd and LVEDd, respectively), posterior wall thickness at end diastole (PWTd), septal wall thickness at end diastole (SWTd), LV mass index (LVMi), relative wall thickness (RWT), LV ejection fraction (LVEF) by modified Simpson's method, LV diastolic function, mitral annular diastolic velocity e' and E/e', right ventricular systolic function (tricuspid annular plane systolic excursion and peak S'), mean pulmonary arterial pressure by Abbas's formula, right ventricular systolic pressure, and right atrial pressure.

Specifically, RWT = (2 × PWTd) / LVEDd; LV mass = $0.8\times\{1.04\ [(LVEDd + PWTd + SWTd)^3 - (LVEDd)^3]\} + 0.6$ g; LVMi = LV mass/body surface area (BSA). LVMi greater than 115 g/m² for men and greater than 95 g/m² for women were defined as LV hypertrophy. Based on the RWT value of less or equal to 0.42 or greater than 0.42 and LVMi, LV geometry was classified into four, normal geometry as LVMi of less or equal to 95 g/m² in women and less or equal to 115 g/m² in men and RWT or less or equal to 0.42, concentric hypertrophy as LVMi greater than 95 in women and greater than 115 in men and RWT greater than 0.42, eccentric hypertrophy as LVMi greater than 95 in women and greater than 115 in men and RWT smaller or equal to 0.42, and concentric remodeling as LVMi smaller or equal to 95 in women and smaller or equal to 115 in men and RWT greater than 0.42, respectively, as shown in Figure 1.

Blood pressure measurement

Blood pressure measurements were obtained according to the Thai Hypertension Guidelines. Blood pressure[11] was measured using a sphygmomanometer. In brief, the cuff was placed around the arm and above the elbow and inflated with a pump until the circulation was cutoff. A small valve was turned to slowly deflate the cuff, and the physician measured blood pressure using a stethoscope, placed over your arm, to listen for the sound of blood pulsing through the arteries. The first sound of rushing blood refers to the SBP. Once the sound faded, the second

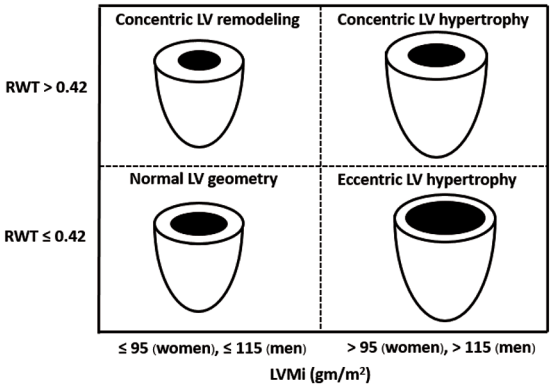

Figure 1. Determination of left ventricular geometric patterns using left ventricular mass index and relative wall thickness.

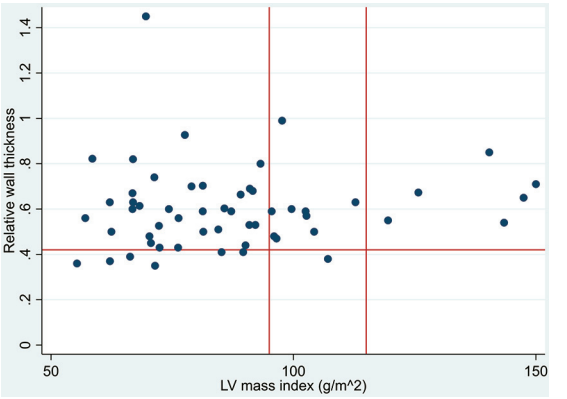

Figure 2. Distribution of the left ventricular geometric pattern.

number indicated the DBP. The blood pressure of the patient was measured at least twice, in the outpatient department and before echocardiography. Blood pressure was measured in millimeters of mercury (mmHg) and recorded with the systolic number first, followed by the diastolic number.

Data collection

A structured case record form was used to collect data at baseline. Data, which included demographics (age and gender), anthropometrics (body weight and height), comorbidities (smoking, obesity, dyslipidemia, diabetes mellitus, and obstructive sleep apnea), laboratories (renal function and electrolyte), 12-leads electrocardiogram, and medications used, were collected by two independent investigators. The body mass index (BMI) was calculated as weight/height^2, and BMI equal or greater than 28 kg/m^2 was defined as obesity for Thai populations, and BSA was calculated as (weight 0.425 × height 0.725) × 0.007184.

Inter-observer variability of RWT and LVMi measurement

To access the inter-observer variation of the RWT and LVMi measurement by echocardiography, forty-five patients were randomly selected to measure LVEDd, PWTd, and SWTd for calculating RWT and LVMi by two independent observers. Variation was expressed as a concordance correlation coefficient (CCC) and mean difference in measurements between the two observations. The limits of agreement were made by Bland-Altman Method.

Statistical analysis

For the descriptive analysis, continuous variables were presented as mean ± standard deviation (SD) and minimum and maximum for normally distributed variables. Categorical variables were presented as number (percentage) and frequency. The difference among the four groups of LV geometric patterns were tested by one-way analysis of variance, using the Bonferroni correction for making multiple comparisons. Comparisons of the performance between each observer for analyzing inter-observer variability were made by paired t-test. A p-value less than 0.05 was considered statistically significant.

Results

Fifty-five patients were enrolled in the present study. The mean age was 55.3±11.8 years, and men accounted for 58.2% of the study population. The youngest and oldest patients were 36 and 74 years old, respectively. General information and baseline characteristics of all participants in the four groups are presented in Table 1. All patients had normal renal function and electrolyte levels, especially potassium, indicating that the patients were unlikely to have secondary hypertension. Laboratory profiles including electrocardiographic findings are shown in Table 2.

In the study population, LV geometric patterns were found to be normal geometry in six patients (10.9%) and abnormal in 49 (89.1%). The abnormal features were classified into concentric remodeling in 39 patients (70.9%), concentric hypertrophy in nine patients (16.4%), and eccentric hypertrophy in one patient (1.8%). The distribution of the LV geometric pattern is shown in Figure 2.

Data from echocardiographic parameters are shown in Table 3. The four population groups had a normal heart size, LV contraction, and right

Table 1. Baseline characteristics

Characteristics	Normal geometry	Concentric hypertrophy	Eccentric hypertrophy	Concentric remodeling	p-value
Prevalence; n (%)	6 (10.9)	9 (16.4)	1 (1.8)	39 (70.9)	-
95% CI	4.1 to 22.3	7.8 to 28.8	0.1 to 9.7	57.1 to 82.4	
Male; n (%)	2 (33.3)	4 (44.4)	0 (0.0)	26 (66.7)	0.177
Age (years); mean±SD	55.7±12.6	59.0±12.0	67±0	53.9±10.9	0.449
BMI (kg/m^2); mean±SD	26.7±4.1	24.2±1.5	30.7±0	27.1±4.2	0.176
BSA (m^2); mean±SD	1.7±0.2	1.6±0.2	1.6±0	1.8±0.2	0.076
SBP (mmHg); mean±SD	165.0±22.8	169.7±24.7	169.0±0	159±15.3	0.432
DBP (mmHg); mean±SD	95.2±7.4	87.1±18.4	88.0±0	93.5±9.8	0.429
Heart rate (bpm); mean±SD	86.8±7.4	73.7±11.8	83.0±0	87.9±14.3	0.071
Diabetes; n (%)	1 (16.7)	1 (11.1)	0 (0.0)	7 (18.0)	1.000
Dyslipidemia; n (%)	2 (33.3)	2 (22.2)	1 (100)	23 (59.0)	0.096
Smoking; n (%)	2 (33.3)	0 (0.0)	0 (0.0)	5 (12.8)	0.285
Alcohol; n (%)	1 (16.7)	1 (16.7)	0 (0.0)	10 (25.6)	0.896

CI=confidence interval; SD=standard deviation; BMI=body mass index; BSA=body surface area; SBP=systolic blood pressure; DBP=diastolic blood pressure

Table 2. Laboratory values and electrocardiogram of the studied patients with hypertension

Laboratory values	Normal geometry (n=6)	Concentric hypertrophy (n=9)	Eccentric hypertrophy (n=1)	Concentric remodeling (n=39)	p-value
Creatinine (mg/dL); mean±SD	0.9±0.2	1.0±0.4	0.7±0	0.9±0.3	0.788
GFR (mL/minute/1.73 m^2); mean±SD	88.6±26.0	79.1±26.9	86.9±0	87.8±19.1	0.730
Sodium (mEq/L); mean±SD	140.3±2.7	139.2±3.4	142.0±0	140.3±2.5	0.652
Potassium (mEq/L); mean±SD	4.1±0.2	4.0±0.2	4.6±0	4.1±0.3	0.274
Chloride (mEq/L); mean±SD	106.2±3.1	104.4±3.7	110.0±0	105.3±2.9	0.343
Bicarbonate (mEq/L); mean±SD	24.7±1.6	24.1±3.7	22.0±0	24.8±2.2	0.623
Sinus rhythm; n (%)	6 (100)	9 (100)	1 (100)	39 (100)	-
ECG show LVH; n (%)	0 (0.0)	2 (22.2)	0 (0.0)	6 (15.4)	0.639

SD=standard deviation; GFR=glomerular filtration rate; ECG=electrocardiography; LVH=left ventricular hypertrophy

ventricular systolic function.

The normal geometry group had mostly abnormal relaxation patterns and normal mean of left atrial volume index. The concentric hypertrophy group had mostly abnormal relaxation pattern and large mean left atrial volume index. The concentric remodeling group, which was the most common type, had an abnormal relaxation pattern and normal mean left atrial volume index. Only one patient in the eccentric hypertrophy group had an abnormal relaxation pattern and normal mean left atrial volume index.

Inter-observer variability of RWT and LVMi measurement

There was no difference in the magnitude of differences found between the observers. The CCC for the RWT measurement was calculated to be 0.51 (95% CI 0.32 to 0.71, p<0.001), suggesting that the degree of agreement was poor. However, the mean difference between the inter-observer measurements was only 0.002, with 95% limits of agreement ranging from –0.31 to 0.32 (Figure 3). For the LVMi measurement, the CCC was calculated to be 0.95 (95% CI 0.92 to 0.98, p<0.001), suggesting that the degree of agreement was substantial. The mean difference in measurements between the inter-observer observations was 0.71, with 95% limits of agreement ranging from –12.61 to 14.03 (Figure 4).

Discussion

The present study illustrates that concentric remodeling is the most common LV geometrical pattern in patients diagnosed with new-onset hypertension. This phenomenon is consistent with the previous study conducted by Sha et al. (2017)[14] who investigated patterns of LV geometry in Chinese population and found that among 2,290 patients with hypertension, LVMi and RWT are normal in 47.7%, whereas 51.9% have increased RWT with normal LV mass as concentric remodeling. From that study,

Table 3. Echocardiographic parameters

Cardiac geometry	Normal geometry (n=6)	Concentric hypertrophy (n=9)	Eccentric hypertrophy (n=1)	Concentric remodeling (n=39)	p-value
Septal wall thickness at end diastole (mm); mean±SD	8.1±1.3	12.1±2.5[a,d]	9.4±0	9.9±2.1	0.005
Posterior wall thickness at end diastole (mm); mean±SD	8.6±1.1	13.3±2.1[a]	10.0±0	12.2±1.8[b]	0.001
Left ventricular end-diastolic dimension (mm); mean±SD	44.6±4.3	40.8±5.6	52.0±0	39.9±5.1	0.024
Left ventricular mass index (g/m^2); mean±SD	71.7±13.3	116.5±22.4[a,d]	107.1±0	82.3±18.3	<0.001
Relative wall thickness; mean±SD	0.4±0.1	0.7±0.2[a]	0.4±0	0.6±0.2[b]	0.006
Diastolic function; n (%)					0.886
Grade 0	1 (16.7)	1 (11.1)	0 (0.0)	8 (20.5)	
Grade I	5 (83.3)	6 (66.7)	1 (100)	27 (69.2)	
Grade II	0 (0.0)	2 (22.2)	0 (0.0)	4 (10.3)	
TAPSE (mm); mean±SD	24.4±3.2	24.3±2.7	26.2±0	25.7±3.9	0.694
Peak S' (cm/sec); mean±SD	13.1±2.3	12.7±1.6	12.8±0	13.0±2.1	0.976
Left atrial volume index (mL/m^2); mean±SD	31.0±4.4	44.4±10.0[a,d]	44.0±0	31.8±8.2	<0.001
LVEF (%); mean±SD	64.3±4.7	72.3±8.2[c]	51.4±0	66.8±6.5	0.014
MPAP (mmHg); mean±SD	24.1±2.8	23.1±3.8	0	21.9±3.9	0.520
RVSP (mmHg); mean±SD	30.7±6.2	42.3±14.3	28.7±0	33.0±6.7	0.205
RAP (mmHg); mean±SD	7.5±0.9	8.2±1.2	7.6±0	8.0±1.3	0.738
E wave; mean±SD	69.9±22.4	74.9±18.0	62.7±0	70.7±17.0	0.876
A wave; mean±SD	85.8±16.5	82.9±28.6	82.3±0	79.7±14.5	0.886
Decelation time; mean±SD	187.0±32.5	175.1±48.6	243±0	182.8±43.8	0.530
e'; mean±SD	8.7±2.1	7.1±1.7	4.9±0	7.4±1.8	0.181
E/e'; mean±SD	8.4±3.3	10.9±3.1	12.7±0	9.9±2.4	0.218

SD=standard deviation; TAPSE=tricuspid annular plane systolic excursion; LVEF=left ventricular ejection fraction; MPAP=mean pulmonary arterial pressure; RVSP=right ventricular systolic pressure; RAP=right atrial pressure; e'=mitral annular diastolic velocity e'

[a] p<0.05 vs. normal geometry, [b] p<0.05 vs. normal geometry, [c] p<0.05 vs. eccentric hypertrophy, [d] p<0.05 vs. concentric remodeling

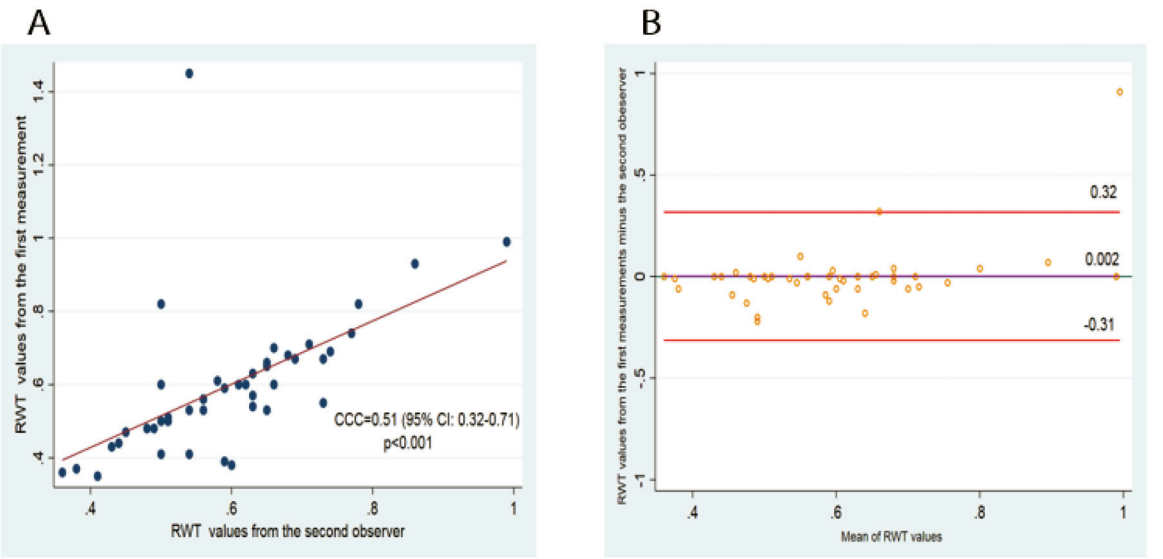

Figure 3. Inter-observer variability of RWT measurement. A for Concordance correlation coefficient and B for Bland-Altman plot.

RWT: relative wall thickness, CCC: concordance correlation coefficient

Sha et al. further found that large waist circumference and neck circumference are the most predominant factors that give rise to the concentric remodeling pattern. The present study findings and those by

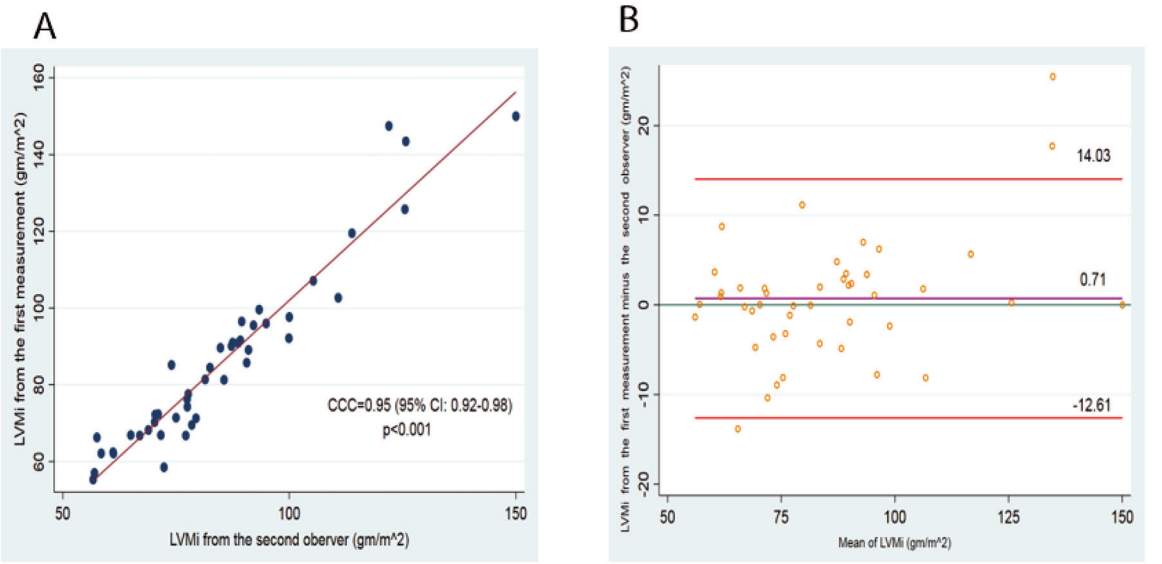

Figure 4. Inter-observer variability of LVMi measurement. A for Concordance correlation coefficient and B for Bland-Altman plot.

LVMi: left ventricular mass index, CCC: concordance correlation coefficient

Sha et al. are unique relative to those advocated by previous studies[7,15-17]. Specifically, Ganau et al. (1992), Ganau et al. (1990), Aje et al. (2006), and Karaye & Habib (2013) have observed that the normal geometry pattern is more common than other geometry patterns. This may be due to differences in race, gender, and age[10]. Many authors reported that concentric remodeling is the most common pattern in hypertensive African-Americans. Whereas in African-European group the concentric hypertrophy is found to be the most common pattern[9]. In addition, remodeling patterns also appear to be different in Hispanic subgroups and whites[18]. What is more, different races have known different genetic characteristics. Influenced by genetic factors, the adaptive response to LV pressure overload could be different among populations[18].

The present study also reveals the sophistication in the mechanism of LV geometric adaptation during hypertension. Several factors that were identified to affect the adaptation include blood pressure, peripheral vascular resistance, stroke volume, BMI, age, and gender[19]. A hemodynamic profile can also be used as an explanatory variable for LV geometric adaptation during hypertension. Specifically, patients' pressure load and volume load should be examined for their prevalence[7,20]. The pressure load of patients diagnosed with new-onset hypertension persists, causing thickening of cardiac muscles, without enlarging the left ventricle. This condition ultimately results in concentric remodeling. Three cross-sectional studies[21-23] have showed higher prevalence of cerebrovascular disease and worse prognosis in patients with LV concentric remodeling than in those with normal LV geometry.

When the LV mass computational equation is considered, factors that lead to increased LV mass are LV end-diastolic dimensions. As shown in Table 3, the mean LV end-diastolic dimension is the smallest for the concentric remodeling group. Furthermore, this group can be seen to have greater increments in the peripheral arterial tone or peripheral resistance, but lower cardiac index than other groups. These disparities lead to a reduction in the stroke volume and ventricular chamber size, causing structural adaptation of the left ventricle to increase its contraction capability to satisfy a high afterload. The concentric remodeling geometrical pattern occurs following this adaptation[24]. Meanwhile, eccentric hypertrophy is observed during the final state of disease progression, causing LV expansion. Considering the present study, a patient in the eccentric hypertrophy group had higher, but not significant, age and BMI than other groups. These factors can create dissimilar forms of the LV geometry[25]. Besides that, intrinsic factors including duration of hypertension, level of blood pressure including hemodynamic and left ventricular loading also affect the LV geometry[26].

LV geometric adaptation to concentric

remodeling in patients diagnosed with new-onset hypertension is clinically important because previous studies[27] have indicated that this geometrical pattern increases the risk of cardiovascular events, including acute myocardial infarction, heart failure, paralysis, and fatally heart attack, compared with the normal geometrical pattern.

Limitation

One limitation of the present study is the small sample size with only 55 patients enrolled. The results may not represent the larger population of patients with new-onset hypertension. A larger sample size would provide more robust and generalizable findings. Another limitation is the cross-sectional design of the present study. Cross-sectional studies can only provide a snapshot of data at a specific point in time and cannot establish causal relationships or determine the temporal sequence of events. Longitudinal studies would be valuable in understanding the progression and changes in LV geometric patterns over time in patients with new-onset hypertension. Additionally, the present study only used transthoracic echocardiography to assess LV geometric patterns and diastolic function. While echocardiography is a widely used and valuable tool, it has its limitations. Other imaging modalities, such as cardiac magnetic resonance imaging (MRI), could provide more detailed and accurate information about LV geometry and function. Furthermore, the present study did not provide information on the comorbidities or risk factors associated with new-onset hypertension in the enrolled patients. Understanding these factors could provide important context and help identify potential confounders or modifiers of the relationship between hypertension and LV geometry. Lastly, the present study did not investigate the long-term outcomes or clinical implications of the observed LV geometric patterns. Future research could explore the association of different LV geometric patterns with cardiovascular events, mortality, or response to antihypertensive therapies. In conclusion, while this study provides insights into LV geometric patterns in patients with new-onset hypertension, its limitations, including small sample size, cross-sectional design, reliance on echocardiography alone, lack of information on comorbidities, and limited clinical implications, should be considered when interpreting the results. Further research with larger sample sizes, longitudinal designs, and multi-modal imaging approaches is warranted to enhance our understanding of LV geometry in patients with hypertension.

Conclusion

In the present study, concentric remodeling was found to be the predominant abnormal geometrical format in patients with new-onset hypertension. Approximately 81.8% of patients diagnosed with new-onset hypertension were detected to have abnormal LV diastolic dysfunction. Abnormal relaxation pattern was the most common format. Understanding LV geometric patterns helps clinicians stratify risk, predict prognosis, and make informed decisions about treatment strategies for these patients.

What is already known on this topic?

The pattern of LV geometric adaptation to hypertension can develop in many forms. Concentric hypertrophy is not necessarily the typical format.

What does this study add?

Further from ambulatory and home blood pressure monitoring, echocardiography may be useful for enhancing the diagnostic process of identifying patients with new onset hypertension, especially those who cannot be clearly determined as having high blood pressure. Moreover, echocardiography can provide reliable information about left ventricular geometric patterns that further increase the capability of identifying potential risks, treatment plan, and prognosis of patients with hypertension.

Acknowledgement

English proofreading certification: Enago, the editing brand of Crimson Interactive Inc. under Copyediting.

Conflicts of interest

The authors declare no conflict of interest.

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