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Echocardiographic Assessment of Left Ventricular Geometric Patterns in Hypertensive Patients in Nigeria

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Abstract: Left ventricular (LV) hypertrophy is an important predictor of morbidity and mortality in hypertensive patients, and its geometric pattern is a useful determinant of severity and prognosis of heart disease. Studies on LV geometric pattern involving large number of Nigerian hypertensive patients are limited. We examined the LV geometric pattern in hypertensive patients seen in our echocardiographic laboratory. A two-dimensional, pulsed, continuous and color flow Doppler echocardiographic evaluation of 1020 consecutive hypertensive patients aged between 18 and 91 years was conducted over an 8-year period. LV geometric patterns were determined using the relationship between the relative wall thickness and LV mass index. Four patterns of LV geometry were found: 237 (23.2%) patients had concentric hypertrophy, 109 (10.7%) had eccentric hypertrophy, 488 (47.8%) had concentric remodeling, and 186 (18.2%) had normal geometry. Patients with concentric hypertrophy were significantly older in age, and had significantly higher systolic blood pressure (BP), diastolic BP, and pulse pressure than those with normal geometry. Systolic function index in patients with eccentric hypertrophy was significantly lower than in other geometric patterns. Doppler echocardiographic parameters showed some diastolic dysfunction in hypertensive patients with abnormal LV geometry. Concentric remodeling was the most common LV geometric pattern observed in our hypertensive patients, followed by concentric hypertrophy and eccentric hypertrophy. Patients with concentric hypertrophy were older than those with other geometric patterns. LV systolic function was significantly lower in patients with eccentric hypertrophy and some degree of diastolic dysfunction were present in patients with abnormal LV geometry.

Keywords: echocardiography, hypertension, geometric pattern, systolic, diastolic, Nigeria

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Introduction

One of the most important individual risk factors for cardiovascular disease (CVD) is hypertension.¹ Left ventricular hypertrophy (LVH), which is defined as an abnormal increase in left ventricular (LV) mass, is one of the organic processes resulting from hypertension.¹ LVH has been widely documented to be an independent cardiac risk factor in hypertensive patients,^{2,3} and the structural classification of LV geometry also provides useful and additional prognostic information.^{4,5} Some authors^{6,7} have observed that age significantly affects LV structure and geometric patterns.

The LV adaptation to hypertension takes four different geometric patterns using the combinations of left ventricular mass index (LVMI) and relative wall thickness (RWT). The heart may adapt to hypertension by developing concentric hypertrophy (CH) with increased LVMI and RWT, eccentric hypertrophy (EH) with increased LVMI and normal RWT, concentric remodeling (CR) with normal LVMI and increased RWT, or by retaining normal geometry (NG) with both normal LVMI and RWT. Each geometric pattern is associated with a distinct combination of pressure and volume stimuli, contractile efficiency (reduced in those with concentric hypertrophy and concentric remodeling), and prognosis (worst with concentric hypertrophy and best with normal geometry).^{8,9}

In Nigeria, studies on LV geometric patterns^{10–13} involving large number of hypertensive patients are limited and there is little information regarding the association between age and geometric patterns in hypertensive Nigerians. We therefore present an eight-year echocardiographic study of LV geometric patterns of 1020 consecutive hypertensive patients seen at the Cardiac Care Unit of Obafemi Awolowo University Teaching Hospitals Complex (OAUTHC) Ile-Ife, a tertiary hospital in Southwest Nigeria. This study will further help define the pattern of LV geometry in hypertensive subjects in our environment, as well as add to the national and global database.

Materials and Methods

Two-dimensional, pulsed, continuous, and color flow Doppler transthoracic echocardiography was performed on 1020 consecutive hypertensive patients between 2002 and 2010 with Siemens Sonoline G 60s using standard procedures.^{14,15} The left ventricular

mass was derived using the Devereux modified ASE cube formula:¹⁶

$$\text{Estimated LVMI (g/m}^2\text{)} = 0.80 [1.04 (\text{LVIDd} + \text{PWT} + \text{IVSD})^3 - (\text{LVIDd})^3] + 0.6 \text{ g/BSA}$$

Upper normal limits for LV mass index were 134 and 110 g/m² in men and women respectively.^{13,17} Relative wall thickness ($2 \times$ posterior wall thickness/LV diastolic diameter) was calculated. A partition value of 0.45 for relative wall thickness was used for men and women.^{13,18}

Demographic parameters of patients were recorded. Weight was measured using a standard weighing scale, while height was measured using a stadiometer. The body mass index was derived by dividing the weight (in kilograms) by the square of the height (in meters).

Patients were considered hypertensive if they had a resting systolic blood pressure (SBP) \geq 140 mmHg and/or diastolic blood pressure (DBP) \geq 90 mmHg measured after at least 15 minutes of rest in the sitting position with an Accosson mercury sphygmomanometer and adapted cuff at the brachial artery or if they were on antihypertensive therapy.¹⁹ Korotkoff phase 1 was used for SBP and phase 5 for DBP. Three consecutive measurements were performed at 5-min intervals and the mean values for SBP and DBP were noted. Hypertensive patients with heart failure, myocardial infarction, renal failure, and cerebrovascular diseases were excluded from this study. The patients gave their informed consent before participating in this study and ethical clearance was obtained for the study from OAUTHC Ethics and Research Committee.

Statistical analysis

SPSS software version 16.0 (SPSS Inc., Chicago, IL, USA) was used for statistical analysis. Categorical variables were expressed as proportions and percentages, while continuous variables were expressed as mean \pm SD. Categorical variables were compared using chi square. Analysis of variance (ANOVA) was used to determine the significant differences of the studied parameters among the four groups of LV geometric pattern. Multiple comparisons between the 4 groups were performed by one—way analysis of variance with the Duncan post hoc test. The level of statistical significance was $P \leq 0.05$.



Table 1. Demographic characteristics of hypertensive patients.

Variable	Hypertensive (n = 1020)
Age (years)	57.78 ± 12.87
Sex	
Male	568
Female	452
Weight (Kg)	72.93 ± 15.28
Height (m)	1.64 ± 0.08
BMI (kg/m ²)	27.03 ± 5.34
Systolic (mmHg)	143.74 ± 21.94
Diastolic (mmHg)	87.98 ± 12.80
BSA (g/m ²)	1.82 ± 5.48
PP (mmHg)	55.77 ± 16.78
MAP (mmHg)	106.56 ± 14.32

Notes: Unless otherwise stated, values are expressed as mean ± standard deviation. *Expressed in proportion (percentage).

Abbreviations: BMI, body mass index; BSA, body surface area; SBP, systolic blood pressure; DBP, diastolic blood pressure; PP, pulse pressure; MAP, mean arterial pressure.

Results

Of the 1020 hypertensive patients seen, 568 (55.7%) were male and 452 (44.3%) were female, with a male to female ratio of 1.3:1. The mean age was 57.78 ± 12.87 years (range 18 to 91 years). The demographic characteristics of hypertensive patients are shown in Table 1. The average body mass index (BMI) of the patients was 27.03 ± 5.34 with the mean systolic and diastolic blood pressure of 143.74 ± 21.94 and 87.98 ± 12.80 respectively.

Table 2 shows the demographic characteristics of different LV geometric patterns in hypertensive subjects. 237 (23.2%) patients had concentric

hypertrophy, 109 (10.7%) had eccentric hypertrophy, 488 (47.8%) had concentric remodeling, and 186 (18.2%) had normal geometry. Patients with concentric hypertrophy were older than those with other geometric pattern. They also had significantly higher SBP, DBP, mean arterial pressure, and pulse pressure than those with normal geometry.

Table 3 shows the echocardiographic parameters of different LV geometric patterns in the patients. The mean LV internal diameter in diastole was significantly higher in patients with eccentric hypertrophy compared to other geometric patterns. The left atrial dimension was significantly higher among those with concentric and eccentric hypertrophy compared to those with normal geometry. Patients with eccentric hypertrophy had statistically significant lowest indices of systolic function (ejection fraction and fractional shortening) compared to other geometric patterns. The Doppler echocardiographic parameters showed some degree of diastolic dysfunction in hypertensive patients with abnormal LV geometric patterns. Such parameters included the E/A ratio, deceleration time (DT), and isovolumic relaxation time (IVRT), and patients with concentric hypertrophy showed significant differences in all these three parameters compared with those with normal geometry.

Discussion

With hypertension, the cardiovascular system adapts to neuro-humoral and hemodynamic variations, which may lead to the development of different LV geometric patterns, each carrying a different risk profile for major adverse cardiovascular events.²⁰

Table 2. Demographic characteristics of the different left ventricular geometric patterns.

Variable	Concentric hypertrophy (n = 237)	Eccentric hypertrophy (n = 109)	Concentric remodeling (n = 488)	Normal (n = 186)	P-value (overall)
Age (years)	60.11 ± 12.87 [†]	59.43 ± 12.14 [†]	57.14 ± 12.38	55.48 ± 12.68	0.001 [†]
Height (m)	1.63 ± 0.08	1.64 ± 0.08	1.64 ± 0.08	1.65 ± 0.09	0.397
Weight (Kg)	69.51 ± 15.64 [‡]	70.09 ± 15.86 [‡]	74.55 ± 14.28	74.70 ± 16.16	0.0001 [‡]
BMI (Kg/m ²)	25.97 ± 5.31 [‡]	25.96 ± 5.58 [‡]	27.57 ± 4.98	27.58 ± 5.83	0.0001 [‡]
SBP (mmHg)	149.59 ± 21.71 [‡]	140.81 ± 21.47	142.76 ± 21.89	140.58 ± 21.38	0.0001 [‡]
DBP (mmHg)	90.08 ± 13.55 [*]	87.03 ± 12.37	87.79 ± 12.71	86.33 ± 12.02	0.017 [*]
PP (mmHg)	59.51 ± 16.89 [†]	53.78 ± 16.89	54.97 ± 16.61	54.25 ± 16.20	0.001 [†]
MAP (mmHg)	109.92 ± 14.70 [†]	104.95 ± 13.86	106.12 ± 14.36	104.41 ± 13.74	0.0001 [†]

Notes: Unless otherwise stated, values are expressed as mean ± standard deviation, ANOVA used to test differences between geometrical patterns with Duncan post hoc pair wise comparisons, statistically significant (^{*}P-value < 0.05; [†]P-value < 0.01; [‡]P-value < 0.001 vs. normal geometry).

Abbreviations: BMI, body mass index; SBP, systolic blood pressure; DBP, diastolic blood pressure; PP, pulse pressure; MAP, mean arterial pressure.



Table 3. Two-dimensional and Doppler echocardiographic characteristics of different geometric patterns in hypertensive subjects.

Variable	Concentric hypertrophy (n = 237)	Eccentric hypertrophy (n = 109)	Concentric remodeling (n = 488)	Normal (n = 186)	P-value (overall)
IVSD (mm)	14.07 ± 2.82 [‡]	11.71 ± 2.08 [†]	12.09 ± 2.04 [†]	11.10 ± 2.21	0.0001 [‡]
LVIDd (mm)	47.43 ± 6.49	57.65 ± 7.83 [‡]	41.54 ± 5.20	47.35 ± 5.05	0.0001 [‡]
LVPWD (mm)	14.36 ± 8.99 [‡]	10.75 ± 1.62 [*]	12.07 ± 1.45 [†]	8.98 ± 1.37	0.0001 [‡]
LAD (mm)	39.04 ± 18.32 [†]	38.56 ± 8.13 [†]	35.46 ± 17.27	34.84 ± 5.74	0.005 [†]
EF (%)	68.05 ± 12.91	57.89 ± 18.34 [*]	70.48 ± 11.14	67.11 ± 12.57	0.0001 [‡]
FS (%)	33.87 ± 11.72	27.77 ± 11.08 [*]	35.00 ± 8.25	32.54 ± 9.14	0.0001 [‡]
RWT	0.62 ± 0.39 [‡]	0.38 ± 0.06	0.59 ± 0.11 [†]	0.38 ± 0.05	0.0001 [‡]
E _m -waves (ms)	66.44 ± 18.90	73.88 ± 25.72 [*]	63.32 ± 16.93	68.69 ± 21.07	0.0001 [‡]
A _m -waves (ms)	75.05 ± 19.66 [*]	70.25 ± 25.71	71.39 ± 17.33	68.86 ± 16.71	0.006 [†]
E/A	0.94 ± 0.38 [*]	1.24 ± 0.79 [*]	0.93 ± 0.31 [*]	1.05 ± 0.44	0.0001 [‡]
DT (ms)	213.71 ± 53.75 [*]	195.35 ± 60.58	211.64 ± 48.22	202.38 ± 50.77	0.003 [†]
IVRT (ms)	106.97 ± 31.54 [*]	107.03 ± 31.85 [*]	99.27 ± 24.89	94.22 ± 26.80	0.0001 [‡]
A-DUR (ms)	141.14 ± 39.09	147.13 ± 45.82	140.37 ± 61.21	141.44 ± 33.62	0.677
AVV _{max} (mmHg)	1.27 ± 0.35 [*]	1.18 ± 0.40	1.19 ± 0.28	1.17 ± 0.26	0.002 [†]
AVV _{mean} (mmHg)	0.82 ± 0.25 [*]	0.80 ± 0.25	0.78 ± 0.16	0.77 ± 0.18	0.022
AVVTI (mmHg)	23.79 ± 9.89	22.30 ± 8.34	22.38 ± 5.24	22.32 ± 5.74	0.055
AVPG _{max} (mmHg)	7.28 ± 6.57	7.45 ± 9.90 [*]	6.37 ± 5.51	6.00 ± 3.95	0.064
AVPG _{mean} (mmHg)	2.88 ± 1.92 [*]	2.96 ± 3.10 [†]	2.56 ± 1.10	2.45 ± 1.09	0.007 [†]
LVET Dop (sec)	281.10 ± 44.77	269.04 ± 56.46 [†]	276.15 ± 41.17	289.28 ± 46.11	0.001 [†]
LVPEP (sec)	97.19 ± 33.90 [*]	103.43 ± 27.62 [†]	90.08 ± 27.26	89.70 ± 20.66	0.0001 [‡]
LVSTI (sec)	1.14 ± 11.71	1.03 ± 6.30	0.74 ± 6.24	0.32 ± 0.10	0.740

Notes: Unless otherwise stated, values are expressed as mean ± standard deviation, ANOVA used to test differences between geometrical patterns with Duncan post hoc pair wise comparisons, statistically significant (**P*-value < 0.05; †*P*-value < 0.01; ‡*P*-value < 0.001 vs. normal geometry).

Abbreviations: IVSD, interventricular septal thickness in diastole; LVIDd, left ventricular internal diameter in diastole; LVPWD, left ventricular posterior wall thickness in diastole; LAD, left atrial diameter; EF, ejection fraction; FS, fractional shortening; RWT, relative wall thickness; E_m-waves, peak mitral E-waves; A_m-waves, Peak Mitral A-waves; E/A, E/A ratio; DT, Deceleration time; IVRT, Isovolumic relaxation time; A-DUR, Mitral-A duration; AVV_{max}, maximum aortic valve pressure; AVV_{mean}, mean aortic valve pressure; AVVTI, velocity time interval of aortic valve; AVPG_{max}, maximum aortic valve pressure gradient; AVPG_{mean}, mean aortic valve pressure gradient; LVET Dop, left ventricular ejection time with Doppler; LVPEP, left ventricular pre-ejection pressure time; LVSTI, left ventricular stroke-time interval gradient.

LV hypertrophy is a powerful independent predictor of morbidity and mortality in hypertensive patients.²¹ Our results showed that concentric remodeling was the most common LV geometric pattern, followed by concentric hypertrophy, which agrees with the findings of Wang et al²² and Fox et al.²³ Akintunde et al^{24,25} and Adamu et al¹² also reported that concentric remodeling and concentric hypertrophy were the predominant LV geometric patterns among their studied population of Nigerian hypertensives.

In a study in Texas, USA, eccentric hypertrophy was the most common LV geometric pattern in hypertensive patients with LVH and with or without clinical evidence of coronary artery disease.²⁶ The least common LV geometric pattern found in our study was eccentric hypertrophy, which agreed with the findings of other studies conducted within^{11,12} and outside of^{22,23} Nigeria. Environmental factors, ethnic differences, and genetic variability may have contributed

to the differences in geometric patterns.¹⁰ The link between genetics, ethnicity, and hypertension may therefore involve environmental factors.^{27–29}

According to the paradigm of compensatory ventricular response to a chronic pressure overload, ventricular wall thickness should increase proportionally to blood pressure level to maintain normal wall stress.³⁰ However, LV adaptation to hypertension has been shown to be more complex than expected.³¹ Concentric hypertrophy, one of the patterns of remodeling, is thought to ultimately progress to left ventricular dilatation and failure in hypertensive. It portends poor prognosis and the greatest risk of cardiovascular events.⁴ Concentric hypertrophy was also associated with the highest mortality in hypertensive patients²³ and carried the greatest stroke risk, followed by eccentric hypertrophy.³² Milani et al³³ in the Ochsner studies reported an increased cardiovascular risk associated with concentric hypertrophy and



concentric remodeling. Concentric remodeling and concentric hypertrophy may predominate in “early” and “intermediate” hypertensives due to the predominating pressure overload whereas eccentric hypertrophy progressively takes over with increased LV mass due to increases in volume overload.³¹

In our study, patients with concentric hypertrophy were significantly older than those with normal geometry, which is similar to the findings of previous studies.^{6,7,34} We also found that systolic function was significantly lower in patients with eccentric hypertrophy compared to those with normal geometry and concentric hypertrophy, which was similar to other findings.^{11,23,35}

We also observed enhanced longitudinal LV function and augmented EF with increasing degrees of concentric remodeling as earlier reported in London by Chahal et al.³⁵ The hemodynamic changes seen in eccentric hypertrophy are associated with increased in LV end diastolic and systolic volume due to LV volume overload, hence heralding the development of heart failure in hypertensive patients. Studies have shown that severe systolic dysfunction is observed more frequently in hypertensive patients with eccentric hypertrophy than concentric hypertrophy.^{36,37}

The Doppler echocardiographic parameters showed some degree of diastolic dysfunction in our hypertensive patients with abnormal LV geometric patterns. Other studies have also demonstrated that hypertensive patients may have diastolic dysfunction, regardless of the differences in their structural geometries.^{12,25,38–40} In addition, the degree of impairment of cardiac diastolic function differed between hypertensive patients with different LV geometric patterns,^{12,39,40} which was worst in those with concentric geometry.¹² Diastolic dysfunction was observed in incipient stages of hypertensive heart disease, and thus its early detection may help in the risk stratification of hypertensive patients.³⁸ Karaye et al recently assessed right ventricular (RV) systolic and diastolic dysfunction (RVSD and RVDD, respectively) in Nigerian hypertensives, stratified by LV geometric patterns. The study revealed that approximately two-thirds of the hypertensives had RVDD, while about one-third had RVSD. Subjects with eccentric hypertrophy had the highest prevalence of RVSD, while RVDD was common across all groups.⁴¹ Since studies have shown that prompt diagnosis and treatment

of hypertension could reverse or retard the LV hypertrophy in hypertensive patients,^{42,43} these should be among the main goals in such patients.

Conclusions

Concentric remodeling was the most common LV geometric pattern in our hypertensive patients. This was followed by concentric hypertrophy and eccentric hypertrophy. Patients with concentric hypertrophy were older than those with other geometric patterns. LV systolic function was significantly lower in patients with eccentric hypertrophy and some degree of diastolic dysfunction were present in hypertensive patients with abnormal LV geometry.

Author Contributions

Conceived and designed the experiments: RAA, MOB, AOA. Analyzed the data: RAA, OJB, VOA, LAB, TOM, EAA, OOA. Wrote the first draft of the manuscript: RAA, OJB. Contributed to the writing of the manuscript: RAA, OJB, MOB, AOA, VOA, LAB, TOM, EAA, OOA. Agree with manuscript results and conclusions: RAA, OJB, MOB, AOA, VOA, LAB, TOM, EAA, OOA. Jointly developed the structure and arguments for the paper: RAA, OJB, MOB, AOA, VOA, LAB, TOM, EAA, OOA. Made critical revisions and approved final version: RAA, OJB, MOB, AOA, VOA, LAB, TOM, EAA, OOA. All authors reviewed and approved of the final manuscript.

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Competing Interests

Author(s) disclose no potential conflicts of interest.

Disclosures and Ethics

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References

- Tovillas-Morán FJ, Zabaleta-del-Olmo E, Dalfó-Baqué A, Vilaplana-Coscolluela M, Galcerán JM, Coca A. Cardiovascular morbidity and mortality and left ventricular geometric patterns in hypertensive patients treated in primary care. *Rev Esp Cardiol*. 2009;62(3):246–54.
- Levy D, Garrison RJ, Savage DD, Kannel WP, Castelli WP. Prognostic implications of echocardiography determined left ventricular mass in the Framingham Heart Study. *N Engl J Med*. 1990;322(22):1561–6.
- Ghali JK, Liao Y, Simmons B, Castaner A, Cao G, Cooper RS. The prognostic role of left ventricular hypertrophy in patients with or without coronary artery disease. *Ann Intern Med*. 1992;117(10):826–31.
- Koren MJ, Devereux RB, Casale PN, Savage DD, Laragh JH. Relation of left ventricular mass and geometry to morbidity and mortality in men and women with essential hypertension. *Ann Intern Med*. 1991;114(2):345–52.
- Verdecchia P, Schillaci G, Borgioni C, et al. Adverse prognostic significance of concentric remodeling of the left ventricle in hypertensive patients with normal left ventricular mass. *J Am Coll Cardiol*. 1995;25(4):871–8.
- Shipilova T, Pshenichnikov I, Kaik J, et al. Echocardiographic assessment of the different left ventricular geometric patterns in middle-aged men and women in Tallinn. *Blood Press*. 2003;12(5–6):284–90.
- de Simone G, Daniels SR, Kimball TR, et al. Evaluation of concentric left ventricular geometry in humans: evidence for age-related systematic underestimation. *Hypertension*. 2005;45(1):64–8.
- Devereux RB, Roman MJ. Left ventricular hypertrophy in hypertension: stimuli, patterns, and consequences. *Hypertens Res*. 1999;22(1):1–9.
- Krumholz HM, Larson M, Levy D. Prognosis of left ventricular geometric patterns in the Framingham Heart Study. *J Am Coll Cardiol*. 1995;25(4): 879–84.
- Aje A, Adebisi AA, Oladapo OO, et al. Left ventricular geometric patterns in newly presenting Nigerian hypertensives: an echocardiographic study. *BMC Cardiovasc Disord*. 2006;6:4.
- Akintunde A, Akinwusi O, Opadijo G. Left ventricular hypertrophy, geometric patterns and clinical correlates among treated hypertensive Nigerians. *Pan Afr Med J*. 2010;4:8.
- Adamu UG, Kolo PM, Katibi IA, Opadijo GO, Omotosho AB, Araoye MA. Relationship between left ventricular diastolic function and geometric patterns in Nigerians with newly diagnosed systemic hypertension. *Cardiovasc J Afr*. 2009;20(3):173–7.
- Ajayi OE, Ajayi EA, Akintomide AO, et al. Ambulatory blood pressure profile and left ventricular geometry in Nigerian hypertensives. *J Cardiovasc Dis Res*. 2011;2(3):164–71.
- Schiller NB, Crawford M. Recommendations for quantitation of the left ventricle by two-dimensional echocardiography: American Society of Echocardiography Committee on Standards, Subcommittee on Quantitation of Two-Dimensional Echocardiogram. *J Am Soc Echocardiogr*. 1989;2(5): 358–67.
- Quiñones MA, Otto CM, Stoddard M, Waggoner A, Zoghbi WA; Doppler Quantification Task Force of the Nomenclature and Standards Committee of the American Society of Echocardiography. Recommendations for quantification of Doppler echocardiography: a report from the Doppler Quantification Task Force of the Nomenclature and Standards Committee of the American Society of Echocardiography. *J Am Soc Echocardiogr*. 2002;15(2):167–84.
- Devereux RB, Alonso DR, Lutas EM, et al. Echocardiographic assessment of left ventricular hypertrophy: comparison to necropsy findings. *Am J Cardiol*. 1986;57(6):450–8.
- Levy D, Savage DD, Garrison RJ, Anderson KM, Kannel WB, Castelli WP. Echocardiographic criteria for left ventricular hypertrophy: The Framingham Heart Study. *Am J Cardiol*. 1987;59(9):956–60.
- Reichek N, Devereux RB. Reliable estimation of peak left ventricular systolic pressure by M-mode echographic-determined end-diastolic relative wall thickness: identification of severe valvular aortic stenosis in adult patients. *Am Heart J*. 1982;103(2):202–3.
- Chobanian AV, Bakris GL, Black HR, et al; National Heart, Lung, and Blood Institute Joint National Committee on Prevention, Detection, Evaluation, and Treatment of High Blood Pressure; National High Blood Pressure Education Program Coordinating Committee. The Seventh Report of the Joint National Committee on Prevention, Detection, Evaluation, and Treatment of High Blood Pressure: the JNC 7 report. *JAMA*. 2003;289(19):2560–72.
- Silangei LK, Maro VP, Diefenthal H, et al. Assessment of left ventricular geometrical patterns and function among hypertensive patients at a tertiary hospital, Northern Tanzania. *BMC Cardiovasc Disord*. 2012;12:109.
- Takasaki K, Miyata M, Imamura M, et al. Left ventricular dysfunction assessed by cardiac time interval analysis among different geometric patterns in untreated hypertension. *Circ J*. 2012;76(6):1409–14.
- Wang SX, Xue H, Zou YB, et al. Prevalence and risk factors for left ventricular hypertrophy and left ventricular geometric abnormality in the patients with hypertension among Han Chinese. *Chin Med J (Engl)*. 2012;125(1):21–6.
- Fox ER, Taylor J, Taylor H, et al. Left ventricular geometric patterns in the Jackson cohort of the Atherosclerotic Risk in Communities (ARIC) Study: clinical correlates and influences on systolic and diastolic dysfunction. *Am Heart J*. 2007;153(2):238–44.
- Akintunde AA, Familoni OB, Akinwusi PO, Opadijo OG. Relationship between left ventricular geometric pattern and systolic and diastolic function in treated Nigerian hypertensives. *Cardiovasc J Afr*. 2010;21(1):21–5.
- Akintunde AA, Akinwusi PO, Opadijo GO. Relationship between Tei index of myocardial performance and left ventricular geometry in Nigerians with systemic hypertension. *Cardiovasc J Afr*. 2011;22(3):124–7.
- Zabalgoitia M, Berning J, Koren MJ, et al. LIFE Study Investigators. Impact of coronary artery disease on left ventricular systolic function and geometry in hypertensive patients with left ventricular hypertrophy (the LIFE study). *Am J Cardiol*. 2001;88(6):646–50.
- Kato N. Ethnic differences in genetic predisposition to hypertension. *Hypertens Res*. 2012;35(6):574–81.
- Lohmueller KE, Wong LJ, Mauney MM, et al. Patterns of genetic variation in the hypertension candidate gene GRK4: ethnic variation and haplotype structure. *Ann Hum Genet*. 2006;70(Pt 1):27–41.
- Kaplan NM, Victor RG. Mechanisms of Primary (Essential) Hypertension. In: Braunwald's Heart Disease: A Textbook of Cardiovascular Medicine. Libby P, Bonow RO, Mann DL, Zipes DP, editors. 8th ed. Philadelphia: Saunders Elsevier; 2008.
- Grossman W, Ioner D, McLaurin LP. Wall stress and patterns of hypertrophy in the human left ventricle. *J Clin Invest*. 1975;56(1):56–64.
- Ganau A, Devereux RB, Roman MJ, et al. Patterns of left ventricular hypertrophy and geometric remodeling in essential hypertension. *J Am Coll Cardiol*. 1992;19(7):1550–8.
- Di Tullio MR, Zwas DR, Sacco RL, Sciacca RR, Homma S. Left ventricular mass and geometry and the risk of ischemic stroke. *Stroke*. 2003;34(10): 2380–4.
- Milani RV, Lavie CJ, Mehra MR, Ventura HO, Kurtz JD, Messerli FH. Left ventricular geometry and survival in patients with normal left ventricular ejection fraction. *Am J Cardiol*. 2006;97(7):959–63.
- Sumimoto T, Mukai M, Murakami E, et al. Effect of age on left ventricular geometric patterns in hypertensive patients. *J Hypertens*. 1995;13(12 Pt 2): 1813–7.
- Chahal NS, Lim TK, Jain P, Chambers JC, Kooner JS, Senior R. New insights into the relationship of left ventricular geometry and left ventricular mass with cardiac function: a population study of hypertensive subjects. *Eur Heart J*. 2010;31(5):588–94.
- Devereux RB, Bella JN, Palmieri V, et al; Hypertension Genetic Epidemiology Network Study Group. Left ventricular systolic dysfunction in a biracial sample of hypertensive adults: The Hypertension Genetic Epidemiology Network (HyperGEN) Study. *Hypertension*. 2001;38(3):417–23.
- Wachtell K, Rokkedal J, Bella JN, et al. Effect of electrocardiographic left ventricular hypertrophy on left ventricular systolic function in systemic hypertension (The LIFE Study). Losartan Intervention For Endpoint. *Am J Cardiol*. 2001;87(1):54–60.



38. Rosa EC, Moysés VA, Rivera I, et al. Left ventricular diastolic function in essential hypertensive patients: influence of age and left ventricular geometry. *Arq Bras Cardiol.* 2002;78(5):466–77. Portugese.
39. Qu P, Ding Y, Xia D, Wang H, Tian X. Variations in cardiac diastolic function in hypertensive patients with different left ventricular geometric patterns. *Hypertens Res.* 2001;24(5):601–4.
40. Oda S, Yoshiyama M, Ichiba N, et al. The relationship between left ventricular geometric remodeling and cardiac function in essential hypertension. *Osaka City Med J.* 2004;50(2):69–77.
41. Karaye KM, Sai'du H, Shehu MN. Right ventricular dysfunction in a hypertensive population stratified by patterns of left ventricular geometry. *Cardiovasc J Afr.* 2012;23(9):478–82.
42. Schmieder RE, Martus P, Klingbeil A. Reversal of left ventricular hypertrophy in essential hypertension. A meta-analysis of randomized double-blind studies. *JAMA.* 1996;275(19):1507–13.
43. MacMahon SW, Wilcken DE, Macdonald GJ. The effect of weight reduction on left ventricular mass. A randomized controlled trial in young, overweight hypertensive patients. *N Engl J Med.* 1986;314(6):334–9.