LEFT VENTRICULAR GEOMETRY IN UNTREATED HYPERTENSIVE PATIENTS PRESENTING TO A TERTIARY HOSPITAL IN NORTH EASTERN NIGERIA

MA TALLE*

BN OKEAHIALAM**

B BAKKI*

CO ANJORIN*

MM BABA*

BW GONI*

H YUSUF*

ABSTRACT

***Background*:** With the increasing prevalence of hypertension, an increase in burden of diseases due to hypertensive changes in left ventricular (LV) geometry is eminent. Assessment of LV geometric pattern identifies hypertensive patients with increased risk of cardiovascular mortality and morbidity.

Methods: This was a cross-sectional study in which LV geometric patterns were evaluated in treatment naïve adult hypertensive patients. Blood pressure (BP) and anthropometric parameters were determined using standard protocols. Echocardiographic LV indices were obtained using American Society of Echocardiography (ASE) guidelines. Spot urine sample was collected for determination of urine albumin-creatinine ratio (ACR). Data was analyzed using SPSS Version 16 for windows and a *p* value of =0.05 considered significant.

Results: One hundred and thirty six patients (made of 66 males and 70 females) with a mean of 44.82 (10.51) years were studied. Abnormal LV geometry was observed in 80.88%. Concentric remodeling was seen in 44.12%. Concentric left ventricular hypertrophy (LVH) was present in 24.26% while 12.50% had eccentric LVH, giving an overall prevalence of 36.77% for LVH. LVH is commoner among the obese and those with stage II hypertension. Ejection fraction (EF) and fractional shortening (FS) were significantly lower in eccentric hypertrophy but did not differ in other geometric patterns. Systolic blood pressure, pulse rate and ACR independently predicts LVH.

Conclusions: There is a high prevalence of abnormal LV geometry and LVH in newly presenting untreated hypertensive patients. Eccentric hypertrophy is associated with lower systolic function compared to other geometric patterns.

Author Affiliations: *Department of Medicine, College of Medical Sciences, University of Maiduguri; **Department of Internal Medicine, University of Jos/Jos University Teaching Hospital, Nigeria.

Corresponding Author: Dr Mohammed Abdullahi Talle, Division of Cardiovascular Medicine, Department of Medicine, College of Medical Sciences, University of Maiduguri, PMB 1069, Maiduguri. Nigeria.

E-mail: abdultalle@yahoo.com

Keywords: Hypertension;Echocardiography;left ventricular geometry

INTRODUCTION

Despite tremendous progress in the understanding and management of hypertension, control of elevated blood pressure (BP) in the general hypertensive population remains unsatisfactory, with only an approximate one third of patients achieving the recommended BP goals.[1] Consequently, cardiovascular risk as a result of target organ damage, notably in the heart, kidneys and brain remain high among majority of hypertensive patients, whether treated or not.[1,2]

The prevalence of hypertension continues to rise in both developed and developing societies and is currently among the leading cause of morbidity and mortality in the world.[3] Hypertension remain the most common non-communicable disease in our community.[4]

Left ventricular hypertrophy (LVH) is an important preclinical manifestation of cardiovascular disease and predicts future cardiovascular events in hypertensive patients.[5] The adverse prognostic impact of altered left ventricular (LV) geometry in hypertensive patients have been documented by a number of studies.[6,7] Concentric LVH was reported to have the highest risk of mortality, followed by eccentric LVH and concentric remodeling in that order.[6] However, Krumholz et al., revealed that the association between cardiac geometry and prognosis is largely attenuated by adjustment for baseline differences in LV mass index.[8]

A population based study involving hypertensive patients revealed an independent association between hypertrophic LV remodeling and impaired systolic and diastolic function.[9] Similarly, Concentric remodeling with normal LV mass has been associated with worse prognosis compared with normal LV geometry.[10]

We sought to establish the prevalence of the different LV geometric patterns and LVH in patients presenting with newly

diagnosed hypertension at the University of Maiduguri Teaching Hospital (UMTH).

Materials and Methods

One hundred and eighty six newly diagnosed, treatment naïve adult hypertensive patients were consecutively referred to the cardiology clinic of the UMTH between June 2007 and February 2008. The following were excluded from the study: chronic kidney disease, congestive heart failure, valvular heart disease, diabetes mellitus/elevated blood glucose, proteinuria on dipstick urinalysis, poor image quality, athletic background and refusal of consent.

An informed consent was obtained from each of the participating patients and approval granted by the Research and Ethics committee of the UMTH. The Helsinki declaration was adhered to.

Complete medical history was obtained and physical examination carried out. Blood pressure was measured using a mercury sphygmomanometer in sitting position following standard guidelines.[11,12] Hypertension was defined as an average BP of =140 mmHg systolic and /or =90 mmHg diastolic, and classified according to the JNC VII guideline.[11] Weight (in kilograms) was measured with the patients light-clothed and height determined (in metres) without shoes or head gear. Body mass index (BMI) was calculated as BMI=weight (kg)/height^2 (m^2) and body surface area (BSA) determined using the formula of Dubois and Dubois. Body mass index was classified in accordance with the international diabetes federation (IDF) guideline.[13] Routine investigations including serum electrolytes, urea, creatinine, fasting blood sugar, haematocrit, serum cholesterol and resting ECG were carried out. Urine albumin and creatinine concentrations were determined from a single spot-urine sample and albumin-creatinine ratio (ACR) computed.

Echocardiographic examination was carried out on all patients that satisfied the inclusion criteria using a scanner 250 (PIE Medical, Japan). A 2-D guided M-mode echocardiographic LV measurements were carried out at the tips of the mitral valve leaf-lets. Thicknesses of the interventricular septum and the left ventricular posterior wall (PWT) were measured in diastole and systole using the leading-edge to leading-edge convention. Left ventricular internal dimension in diastole (LVIDD) and left ventricular end-systolic diameter (LVESD) were measured using similar convention at the tips of the mitral valve leaflets. Left ventricular mass (LVM) was obtained using the American Society of Echocardiography (ASE) formula whilst left ventricular mass index (LVMI) was determined by dividing LVM by body surface area (BSA).[14] Relative wall thickness (RWT) was determined as RWT = 2xPWT / LVIDD.

Left ventricular hypertrophy was defined according to ASE guideline as LVMI of >115g/m^2 in males and >95g/m^2 in females. Concentric LVH was defined as LVH with RWT >0.42 while eccentric LVH was defined as LVH with RWT<=0.42. Normal LVMI with RWT of >0.42 considered as concentric remodeling, while normal geometry was defined as normal LVMI with RWT <=0.4.[14]

The data was analyzed using SPSS version 16 for windows (SPSS, Ill, Chicago, USA). Students't-test was used in comparing mean values of the different geometric patterns and results expressed as mean ± standard deviation (SD). P value of =0.05 was considered significant.

Results

We studied 136 newly diagnosed hypertensive patients comprising 66 (48.53%) males and 70(51.47%) females with a mean age of 44.82±10.51 years. Clinical and laboratory profile of the patients stratified according to left ventricular geometric pattern is illustrated in table 1.

Patients with concentric left ventricular remodeling were significantly older than those with other geometric pattern. Mean BMI was 25.67±4.66 kg/m^2 and did not differ significantly in males and females. However, those with concentric remodeling had a higher BMI compared to other geometric patterns ($p<0.05$). Overweight was observed in 35.29% of the patients while 17.65% were obese.

Systolic blood pressure (SBP) was significantly higher in those with abnormal geometric pattern ($p<0.005$), but only those with concentric remodeling had higher diastolic blood pressure (DBP) ($p<0.05$). Blood pressure did not differ significantly in males and females. Stage II hypertension was observed in 55.15% while stage I hypertension was seen in 43.38% of all patients. Isolated systolic hypertension was observed in 6.62% while isolated diastolic hypertension was seen in 3.68%. Combined systolic and diastolic hypertension was recorded in 89.70%.

Abnormal LV geometry was observed in 80.88% with concentric LV remodeling being the most prevalent (44.12%). Concentric LVH was present in 24.26% while 12.50% had eccentric LVH, giving an overall prevalence of 36.77% for LVH. Interventricular septum and left ventricular wall thicknesses as well as LVM and LVMI were significantly higher in those with abnormal geometry. Relative wall thickness was also higher in concentric remodeling and concentric hypertrophy but not in eccentric hypertrophy. Ejection fraction and fractional shortening (FS) were significantly lower in eccentric hypertrophy compared to other geometric patterns. Echocardiographic profile of the different geometric patterns is illustrated in table 2. Overall, LVH was more prevalent in females (42.86%) compared to males (30.30%) (figure 1).

The prevalence of LVH was higher in patients with obesity (85.71%)

Table 1: Clinical and laboratory characteristics stratified by left ventricular geometric patterns

	Left ventricular geometric patterns			
	Normal geometry	**Concentric remodeling**	**Concentric hypertrophy**	**Eccentric hypertrophy**
N(%)	26(19.12)	60(44.12)	33(24.26)	17(12.50)
M/F	11/15	35/25	12/21	8/9
Age(Years)	41.31±11.99	44.61±8.58	48.03±10.15*	44.24±13.74
BMI (Kg/m2)	24.54±5.48	25.35±4.07	27.99±4.45*	23.90±4.42
WC(cm)	84.52±11.32	88.42±10.11	92.62±11.03*	81.88±11.70
BSA(m2)	1.78±0.18	1.81±0.22	1.74±0.38	1.68±0.22
SBP(mmHg)	148.08±15.13	161.02±15.38*	173.58±20.35†	159.18±18.00*
DBP(mmHg)	94.69±6.69	99.02±8.70*	99.58±12.38	97.06±12.87
PR(bpm)	82.81±15.57	82.02±10.29	86.88±14.59	89.59±14.63
PP(mmHg)	53.38±14.81	62.03±13.99*	73.39±16.04†	62.12±22.53
MAP(mmHg)	112.5±7.58	119.15±9.97†	123.72±13.09†	117.76±10.27
ACR(mg/g)	40.19±11.12	28.90±2.69	62.70±8.99	80.27±16.36*
TC(mmol/L)	4.79±0.93	4.56±0.92	4.71±1.09	4.28±1.09
LDL(mmol/L)	3.29±0.78	2.97±0.95	3.06±1.26	2.78±1.03
HDL(mmol/L)	0.91±0.37	1.11±0.28*	1.12±0.26*	0.95±0.28
TG(mmol/L)	1.62±0.63	1.42±0.46	1.51±0.62	1.33±0.43
FBS(mmol/L	4.59±0.88	4.77±0.83	4.51±0.85	4.10±0.92

N=Number; M/F=Male/Female; BMI=body mass index; WC=waist circumference; BSA=body surface area; SBP=systolic blood pressure; DBP=diastolic blood pressure; PR=pulse rate; PP=pulse pressure; MAP=mean arterial pressure; ACR=albumin-craetinine ratio; TC=total cholesterol; LDL=low density lipoprotein cholesterol; HDL=high density lipoprotein cholesterol; TG=triglyceride; FBS=fasting blood sugar; *mean (± standard error of mean); *P<0.05, †P<0.001 versus normal geometry

Table 2: Echocardiographic profiles characterized by left ventricular geometric patterns

	Left ventricular geometric patterns			
	Normal geometry	**Concentric remodeling**	**Concentric hypertrophy**	**Eccentric hypertrophy**
N(%)	26(19.12)	60(44.12)	33(24.26)	17(12.50)
M/F	11/15	35/25	12/21	8/9
Age(Years)	41.31±11.99	44.61±8.58	48.03±10.15	44.24±13.74
LVIDD(mm)	42.77±5.79	39.32±4.56†	44.94±5.45	52.53±5.42†
LVESD(mm)	34.23±5.27	29.51±5.37†	33.39±5.01	42.29±5.94†
IVSTD(mm)	10.42±2.97	11.98±1.79*	13.91±2.14†	11.76±1.60
PWTD(mm)	7.35±1.50	11.19±1.94†	13.48±1.81†	10.12±1.54†
Ao(mm)	30.92±5.47	29.61±5.28	30.94±4.92	29.00±5.79
LA(mm)	34.12±4.51	34.10±4.84	33.15±4.64	34.88±6.04
LVM(g)	123.42±42.29	157.83±41.14†	243.64±59.80†	26.12±55.58†
LVMI(g/m2)	68.75±21.25	86.32±17.00†	133.56±27.19†	33.06±24.97†
RWT	0.34±0.06	0.62±0.23†	0.62±0.12†	0.38±0.40
EF(%)	61.08±8.42	59.46±7.12	60.79±7.23	56.06±5.17*
FS(%)	28.13±5.75	26.51±4.60	26.67±4.67	24.00±2.60*

N=Number; M/F=Male/Female; IVSTD=interventricular septal thickness in diastole; PWTD=posterior wall thickness in diastole; LVIDD=left ventricular internal diameter in diastole; LVESD=left ventricular end-systolic diameter; Ao=Aorta; LA=left atrium; LVM=left ventricular mass; LVMI=left ventricular mass index; RWT=relative wall thickness; FS=fractional shortening; EF=ejection fraction; *P<0.05, †P<0.001 versus normal geometry

compared to those with overweight (43.75%), and in patients with stage II (48%) than stage I (23.21%) hypertension. Multiple linear regression analysis revealed SBP, pulse rate (PR) and ACR to be significant independent predictors of increased LVM and LVMI (table 3).

Discussions

One of the early target organ damage observed in hypertensive patients is alteration in LV geometry and LVH. We report a prevalence of 80.88% for abnormal LV geometry in untreated hypertensive patients at UMTH. This is similar to what was reported in newly presenting hypertensive patients in other parts of Nigeria.[15,16,17,18]

The prevalence of the different geometric patterns observed differs from that reported by Adebiyi *et al.,* in Ibadan.[17] This variation could partly be explained by the fact that our patients are much younger, and whereas we used the ASE chamber quantification guideline of 2005, they defined abnormal geometry using the Framingham study template of 1987.[14,19] In addition, SBP, PR and mean arterial pressure (MAP) observed to be independent predictors of LVH in this study were higher than that reported in the Ibadan study.

Several studies have documented LVH as a harbinger of mortality and morbidity in hypertensive patients.[20,21,22] The prognostic value of echocardiographically detected LVH has been unequivocally demonstrated by the Framingham Heart Study in which echocardiographic LVH identifies a population at high risk for cardiovascular disease.[20] The relative risk of developing cardiovascular disease and death has been demonstrated to be higher in those with increased LVM even after adjustment for other major cardiovascular risk factors.[11]

There are a number of conflicting reports regarding the prognostic usefulness of LV geometric pattern in patients with systemic hypertension. Koren *et al.,* found concentric LVH to

Table 3: Regression analysis for the predictors of LVH

Variable	B (SE)	Wald	P Value	Exp (B)	95% CI for Exp (B)	
					Lower	Upper
Ht	-0.0889(0.032)	7.642	0.006*	0.916	0.860	0.975
SBP	0.043(0.012)	12.378	0.000*	1.044	1.019	1.069
PR	0.040(0.017)	5.203	0.023*	1.040	1.006	1.076
ACR	0.022(0.005)	16.322	0.000*	1.022	1.011	1.032

* P value is significant; Ht height; SBP systolic blood pressure; PR pulse rate; ACR albumin-to-creatinine ratio

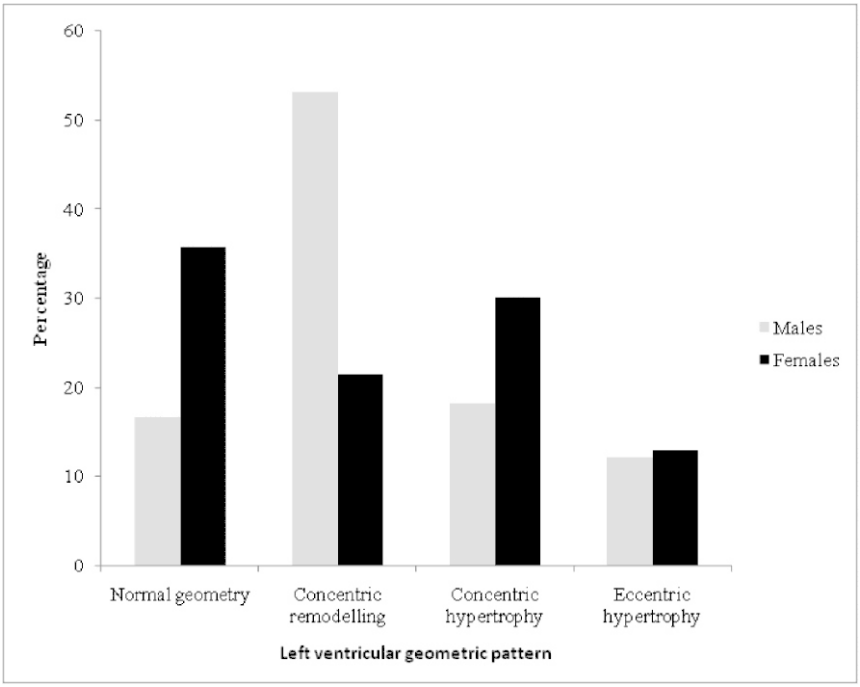

Figure 1: Prevalence of the different left ventricular geometric patterns

have the highest risk of mortality, followed by eccentric LVH and concentric remodeling in that order.[6] The adverse prognostic significance of concentric remodeling was confirmed in a large prospective study by Verdecchia *et al.*[23] However, a population based sample survey by Krumholz *et al.,* revealed that the association between cardiac geometry and prognosis is largely attenuated by adjustment for baseline differences in LVMI.[8] The heightened cardiovascular event risk in patients with concentric hypertrophy may be related to greater myocardial oxygen demand and low coronary flow reserve resulting in myocardial ischemia and decreased contractility.[24,25] The contrasting reports on the prognostic value of concentric remodeling notwithstanding, this geometric pattern identifies patients with the highest likelihood of progressing to LVH, thus providing an opportunity to halt the progression if identified early.

Our study shows lower systolic function in patients with eccentric hypertrophy compared to other geometric patterns. This finding concur with the report of other workers showing impaired systolic function in eccentric hypertrophy .[9,26] Eccentric hypertrophy is typically associated with states of volume overload. However, it may represent an early cardiomyopathic process in hypertension without an intervening concentric hypertrophy.[9]

Multiple regression analysis identified SBP, ACR and PR to be the most significant predictors of LVH. However, only SBP was significantly related to LVH in the cohort studied by Salako *et al.*[17] a finding similar to that of Rayner and Becker among hypertensive patients in South Africa.[27] Studies have shown LVM to be more closely related to SBP whereas LV thickness correlates better with DBP. However, Missault and colleagues found that all parameters of hypertrophy are more closely related to SBP than to DBP or mean blood pressure.[28] Pressure overload from elevated SBP results in increased wall stress leading to addition of myofibrils in parallel and thickening of ventricular wall, thereby restoring wall stress to normal or near normal.[29] The higher prevalence of LVH in stage II than stage I hypertension is perhaps a reflection of the continuous, consistent and independent relation between blood pressure and other cardiovascular risks.[11]

Obesity is associated with higher prevalence of LVH compared to overweight and normal BMI. This is similar to report of other workers.[30, 31]Obesity is a potent and independent stimulus for LV growth and in combination with elevated blood pressure, are more consistently associated with LVH than either stimulus.[32]

The high prevalence of abnormal LV geometry observed in this study has important implications in the management of the increasing number of hypertensive patients. In addition to being important in risk stratification, it also has a bearing on the choice of antihypertensive medication.[1,11,12]Studies have shown the use of ACE inhibitors and ARB to be associated with regression of LVH and improved survival.[7, 33] Among the cohorts of the LIFE study group, concentric hypertrophy was virtually eliminated after 4 years of antihypertensive therapy in spite of a somewhat suboptimal systolic blood

pressure control.[33]

With the prevalence of hypertension steadily on the rise in the general population, the use of risk stratification is becoming increasingly recognized as part of the initial work up, not only as a guide for therapeutic strategies, but also to reduce cardiovascular morbidity and mortality. Aggressive treatment of the large number of patients with abnormal LV geometry is imperative in order to avert the adverse cardiovascular consequences of the altered LV geometry.

Our study has some limitations. Being a cross sectional study, prognostic implications of the different geometric patterns could not be ascertained. Long term follow up will be required to establish causal relationship between abnormal geometry and cardiovascular events. Secondly, LV filling pressure could not be assessed due to lack of tissue Doppler.

Conclusion

There is a high prevalence of abnormal LV geometry amongst newly presenting untreated hypertensive patients at the University of Maiduguri Teaching Hospital. Systolic function is noted to be significantly lower in patients with eccentric hypertrophy compared to other geometric patterns.

Acknowledgment

We thank Mrs Rhoda Yathba for assisting with biochemical analysis of the samples and Mr Seth Williams for arranging echocardiography. A great deal of appreciation is due to Prof. Dann Nel of the Stellenbosch University for his advice on statistical analysis.

REFERENCES

1. Mancia G, De Backer G, Dominiczak A, Cifkova R, Fagard R, Germano G *et al.,* Guidelines for the Management of Arterial Hypertension: The Task Force for the Management of Arterial Hypertension of the European Society of Hypertension (ESH) and of the European Society of Cardiology (ESC). Journal of Hypertension 2007, 25: 1113 1124

2. Kaplan NM. Systemic Hypertension: Mechanisms and Diagnosis. In: Zipes DP, Libby P, Bonow RO, Braunwald E (Eds.); Braunwald's Heart Disease, A Textbook of Cardiovascular Medicine 7th Edition, Elsevier Saunders; Philadelphia, Pennsylvania U.S.A 2005. Pp959

3. Srinath RK. Cardiovascular diseases in the developing countries: Dimensions, determinants, dynamics, and direction for public health action. Public Health Nutrition, 2001; 5: 231-237

4. Akinkugbe OO. Non-Communicable Diseases in Nigeria-Final Report of a National Survey. Lagos: Federal Ministry of Health-National Expert Committee on NCD, 1997:1-12

5. Levy. D, Garrison RJ, Savage DD, Kannel WB, Castelli WP. Prognostic implications of echocardiographically determined left ventricular mass in the Framingham Heart Study. N Engl J Med 1990; 322:1561-1566

6. Koren MJ, Devereux RB, Casale PN, Savage DD, Laragh JH. Relation of left ventricular mass and geometry to morbidity and mortality in uncomplicated essential hypertension. *Ann Intern Med* 1991; 114: 345352

7. Gerdts E, Cramariuc D, De Simone G, Wachtell K, Dahlo¨f B, and Devereux RB. Impact of left ventricular geometry on prognosis in hypertensive patients with left ventricular hypertrophy (the LIFE study). Eur J Echocardiogr 2008; 9: 809815

8. Krumholz HM, Larson M, Levy D. Prognosis of left ventricular geometric patterns in the Framingham Heart Study. *J Am Coll Cardiol* 1995; 25: 879884

9. Chahal NS, Lim TK, Jain P, Chambers JC, Kooner JS, and 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: 588594

10. Pierdomenico SD, Lapenna D, Bucci A, Manente BM, Cuccurullo F, and Mezzetti A. Prognostic Value of Left Ventricular Concentric Remodeling in Uncomplicated Mild Hypertension. *AJH 2004; 17:10351039*

11. Aram VC, George LB, Henry RB, William CC, Lee AG, Joseph Li Jr, *et al*., 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: 2560-2572.

12. Williams B, Poulter NR, Brown MJ, Devis M, Mclnnes GT, Potter JF *et al.,* British hypertension SocietyGuidelines for hypertension management 2004 (BHS-IV): Summary. BMJ 2004; 328: 634 640

13. Zimmet P, Alberty G, Shaw J. A new IDF worldwide definition of metabolic syndrome. Diabetes Voice 2005; 50: 31-33

14. Lang RM, Bierig M, Devereux RB, Flachskampf FA, Foster E, Pellikka PA *et al.,* Recommendations for chamber quantification: a report from the American Society of Echocardiography's Guidelines and Standards Committee and the Chamber Quantification Writing Group, developed in conjunction with the European Association of Echocardiography, a branch of the European Society of Cardiology. J Am Soc Echocardiogr 2005; 18: 1440 1463

15. Katibi IA, Adenle AD. Comparison between various electrocardiographic criteria for the diagnosis of left ventricular hypertrophy and echocardiogram in adult hypertensive Nigerians. Nig Med Pract 2003; 43: 3-6

16. Adebiyi AA, Ogah OS, Aje A, Ojji DB, Adebayo AK, Oladapo OO *et al.,* Echocardiographic partition values and prevalence of left ventricular hypertrophy in hypertensive Nigerians. BMC Medical Imaging, 2006; 10

17. Salako BL, Ogah OS, Adebiyi AA, Adedapo KS, Bekibele CO, Oluleye TS *et al.,* Unexpectedly high prevalence of target organ damage in newly diagnosed Nigerians with hypertension. Cardiovascular Journal of South Africa 2007; 18: 77 83

18. Karaye KM, Okeahialam BN, Wali SS. Cardiovascular risk factors in Nigerians with systemic hypertension. Niger J Med. 2007; 16: 119-24

19. Savage DD, Garrison RJ, Kannel WB, Levy D, Anderson SJ, Stokes J *et al*: The spectrum of left ventricular hypertrophy in a general population sample: the Framingham Study. Circulation 1987; 75: I26-33.

20. Levy D, Murabito JM, Anderson KM, Christiansen JC, Castelli WP: Echocardiographic left ventricular hypertrophy: clinical characteristics: the Framingham Heart Study. Clin Exp Hypertens. 1992; 14: 8597

21. Frohlich ED: Risk mechanism in hypertensive heart disease. Hypertension 1999; 34: 782 789

22. Enrico AR, Maria LM, Massimo S. Evaluation of sub-clinical target organ damage for risk assessment and treatment in the hypertensive patient: left ventricular hypertrophy. J Am Soc Nephrol 2006; 15: S104 S108

23. Verdecchia P, Schillaci G, Borgioni C, Ciucci A, Gattobigio R, Zampi I *et al.,* Prognostic value of left ventricular mass and geometry in systemic hypertension with left ventricular hypertrophy. Am J Cardiol 1996; 78: 197 202

24. Devereux RB, Roman MJ, Palmieri V, Okin PM, Boman K, Gerdts E *et al.,* Left ventricular wall stresses and wall stress-mass-heart rate products in hypertensive patients with electrocardiographic left ventricular hypertrophy: the LIFE study. Losartan Intervention for Endpoint reduction in hypertension. J Hypertens 2000; 18: 112938.

25. De Simone G, Devereux RB, Roman MJ, Ganau A, Saba PS, Alderman MH *et al.,* Assessment of left ventricular function by midwall fractional shortening/ end-systolic stress relation in human hypertension. J Am Coll Cardiol 1994; 23: 144451.

26. Devereux RB, Bella JN, Palmieri V, Oberman A, Kitzman DW, Hopkins PN *et al.,* Left ventricular systolic dysfunction in a biracial sample of hypertensive adults: the Hypertension Genetic Epidemiology Network (HyperGEN) Study. Hypertension 2001;38:417423.

27. Rayner B, Becker P: The prevalence of microalbuminuria and ECG left ventricular hypertrophy in hypertensive patients in private practices in South Africa. Cardiovascular Journal of South Africa 2006; 17(5): 245 249

28. Missault LH, De Buyzere ML, De Bacquer DD, Duprez DD, Clement DL. Relationship between left ventricular mass and blood pressure in treated hypertension. J Hum Hypertens 2002; 16: 61 66

29. Frohlich ED, Apstein C, Chobanian AV, Devereux RB, Dustan HP, Dzau V *et al*: The heart in hypertension. N Engl J Med 1992; 327: 998 1008.

30. Lauer MS, Anderson KM, Kannel WB, Levy D. The impact of obesity on left ventricular mass and geometry: the Framingham Heart Study. JAMA 1991; 2666:231-236

31. Garavaglia GE, Messerli FH, Nunez BD, Schmieder RE, Grossman E. Myocardial contractility and left ventricular function in obese patients with essential hypertension. Am J CardioL 1988;62:594-597

32. De Simone G, Devereux RB, Roman MJ, Alderman MH, Laragh JH. Relation of Obesity and Gender to Left Ventricular Hypertrophy in Normotensive and Hypertensive Adults. Hypertension 1994;23:600-606

33. Gerdts E, Roman MJ, Palmieri V, Wachtell K, Smith G, Nieminen MS *et al.,* Impact of age on Left ventricular hypertrophy regression during antihypertensive treatment with losartan or atenolol (the LIFE study) Journal of Human Hypertension 2004; 18: 417 422