Cardiovascular Topics

Echocardiographic left atrial remodelling and determinants of left atrial size in the early phase of high blood pressure: a comparative cross-sectional study in Douala, Cameroon

Armelle Corrine Simo Gounoue, Anastase Dzudie Tamdja, Simeon-Pierre Choukem, Hamadou Ba, Sidick Mouliom Aboubakar, Archange Nzali, Marie Patrice Halle, Clovis Nkoke, Benjamin Momo Kadia, Martin Hongieh Abanda, Chris Nadege Nganou, Marcel Kenfack Abzabji, Samuel Kingue

Abstract

Background: Left atrial remodelling (LAR) has been described in Western populations with chronic hypertension and is associated with a higher risk of adverse cardiovascular events. Although hypertension tends to occur earlier and is more severe in sub-Saharan Africa than in more developed nations, LAR and its associated factors in these African hypertensive subjects have been poorly elucidated.

Objectives: To assess left atrial structural remodelling in black hypertensive patients and determine factors associated with left atrial size.

Methods: This was a cross-sectional, comparative study carried out in two tertiary hospitals in Douala, Cameroon over a period of three months. Fifty-two patients, either newly diagnosed with hypertension or known hypertensives treated for less than a year, were consecutively recruited. These patients were matched (unpaired matching) for age and gender to 40 randomly selected healthy subjects. The posterior–anterior diameter indexed to body surface area (BSA), volume indexed to BSA, and longitudinal and transverse diameters of the left atrium (LA) were measured using transthoracic echocardiography, in accordance with the American Society of Echocardiography guidelines. LAR was defined as increase in LA size, characterised by LA volume ≥ 34 ml/m^2. Early morning urine was analysed for microalbuminuria using urine strips to obtain spot albumin/creatinine ratio. Data were analysed using SPSS version 23 and statistical significance was set at $p < 0.05$.

Results: The gender distribution and mean age were similar between the two groups. Hypertensive patients had significantly higher mean body mass index, left ventricular mass and an altered diastolic function. They also had significantly higher LA longitudinal diameter (50.0 vs 47.4 mm; $p = 0.045$), surface area (17.9 vs 15.5 cm^2; $p = 0.003$) and volume (52.4 vs 43.8 ml; $p = 0.002$) compared to the non-hypertensive counterparts. Fourteen patients (26.9%) had LA enlargement compared to one (2.5%) in the non-hypertensive group (odds ratio = 9.78, CI: 2.67–35.8, $p < 0.0001$). Diastolic dysfunction ($p = 0.008$) was the only independent predictor of LA size in the hypertensive subjects. Microalbuminuria did not significantly correlate with LA size.

Conclusion: Our study shows evidence of LAR in newly diagnosed black African patients with hypertension, characterised by an increase in the LA length, surface area and volume. Future studies are warranted to better elucidate the biological mechanisms underlying the link between the early phase of hypertension and LAR, as well as its prognostic implications in our population.

Faculty of Health Sciences, University of Buea, Buea, Cameroon
Armelle Corrine Simo Gounoue, MD, corrine_simo@yahoo.com
Anastase Dzudie Tamdja, MD, PhD, FESC
Simeon-Pierre Choukem, MD, PU-PH (Paris)

Faculty of Medicine and Biomedical Sciences, University of Yaoundé I, Yaoundé, Cameroon
Anastase Dzudie Tamdja, MD, PhD, FESC
Hamadou Ba, MD
Chris Nadege Nganou, MD
Marcel Kenfack Abzabji, MD
Samuel Kingue, MD

Douala General Hospital, Douala, Cameroon
Anastase Dzudie Tamdja, MD, PhD, FESC
Simeon-Pierre Choukem, MD, PU-PH (Paris)
Sidick Mouliom Aboubakar, MD
Marie Patrice Halle, MD, DU, DES (Nephology)

Clinical Research Education, Networking and Consultancy, Douala, Cameroon
Anastase Dzudie Tamdja, MD, PhD, FESC
Archange Nzali, MD, DU (Cardiology)
Armelle Corrine Simo Gounoue, MD, corrine_simo@yahoo.com
Martin Hongieh Abanda, MD

Deido District Hospital, Douala, Cameroon
Archange Nzali, MD, DU (Cardiology)

Buea Regional Hospital, Buea, Cameroon
Clovis Nkoke, MD

Faculty of Epidemiology and Population Health and Centre for Evaluation, London School of Hygiene and Tropical Medicine, London, UK
Benjamin Momo Kadia, MD

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Hypertension is an important public health challenge worldwide.[1] In sub-Saharan African populations, hypertension tends to occur at an earlier age than in more developed nations, is frequently under-diagnosed, and is often severe and complicated at the time of diagnosis.[2-4]

Systemic hypertension causes well-recognised structural and functional changes in the heart, which are known as cardiac remodelling. The spectrum of hypertensive heart disease is characterised by left ventricular hypertrophy (LVH), atrial remodelling and heterogeneity of atrial conduction, and fibrosis, all of which can result in atrial fibrillation.[5] Although the effect of hypertension on the left ventricle has been extensively studied, its effect on the left atrium is less well defined.[6]

Left atrial (LA) size has rapidly gained interest over the years as some studies have shown its role in predicting cardiovascular events.[7] Evidence suggests that LA remodelling (LAR) occurs even before the development and detection of LVH and is therefore an early sign of hypertensive heart disease.[8] LA remodelling, characterised by LA enlargement, has been associated with an increased risk of developing atrial fibrillation and stroke.[9] Variables known to affect LA size are age, obesity, race, body surface area and left ventricular mass.[10,11] The burden of chronically elevated blood pressure on LA size, as demonstrated by an increasing size, has been shown in studies on Caucasians and Asians.[12,13] Few studies have been conducted in black hypertensive patients in sub-Saharan Africa.

The paucity of studies on LAR in black hypertensive patients in the early phase of hypertension is a real concern. The objectives of our study were three-fold: first, to determine the difference in LA size between hypertensive and non-hypertensive individuals, second, to determine the proportion of hypertensive patients with LA enlargement, and third, to determine the predictors of LA size in hypertensive patients.

Methods

This study was a cross-sectional, comparative study conducted at the out-patient cardiology units of two hospitals in Douala, Cameroon, namely the Douala General Hospital (DGH) and Deido District Hospital (DDH), over a period of three months from January to March 2017. These hospitals are among the busiest hospitals in Douala, the economic capital of Cameroon, which has a population of about three million people. Each of these hospitals has a cardiology unit with an equipped examination room and expert cardiologists.

Hypertensive patients (cases) were enrolled consecutively while a non-hypertensive group (controls) was enrolled conveniently and consisted of volunteers from hospital staff and patient carers attending the DGH and DDH (all native Africans). Cases were matched by age and gender to non-hypertensive control subjects.

Hypertensive patients were native African adults who fulfilled the following inclusion criteria: aged 18 years and above, diagnosed with hypertension for less than a year to the period of recruitment (drug naïve or treated), and with mild to moderate hypertension. Patients with evidence (medical records) of coronary heart disease, heart failure, valvular heart disease, diabetes mellitus, co-existing cardiomyopathy or arrhythmia were excluded. Controls were non-hypertensive patients with no cardiovascular or renal diseases.

Ethical approval was obtained from the institutional review board of the Faculty of Health Sciences of the University of Buea. Written informed consent was obtained from all study participants before their enrolment into the study. The study was carried out in conformity to the Declaration of Helsinki.

Basic and clinical variables of all the subjects were collected. These included age, gender, height and weight. Blood pressure was measured with an appropriate-sized cuff on the right arm of the patient after the subject had been seated quietly for at least five minutes. Hypertension was diagnosed in subjects having a systolic blood pressure (SBP) of more than 140 mmHg and diastolic blood pressure (DBP) of more than 90 mmHg on at least two separate occasions, or on anti-hypertensive therapy. Files were reviewed to obtain recent laboratory results (less than three months).

The procedure for urine collection was explained to each participant and 5 ml of midstream urine of the first morning void was used for each patient. Patients were asked to avoid exercise or exertion at least 24 hours prior to urine collection. The urine samples were analysed for microalbuminuria using a microalbumin strip (microalbuPHAN®).

Two-dimensional Doppler and M-mode echocardiography was performed using a commercially available machine (Vivid3® Sonoscape, as seen in Fig. 1) with a 3.5-MHz probe. Cardiac echography was done by two experienced cardiologists with

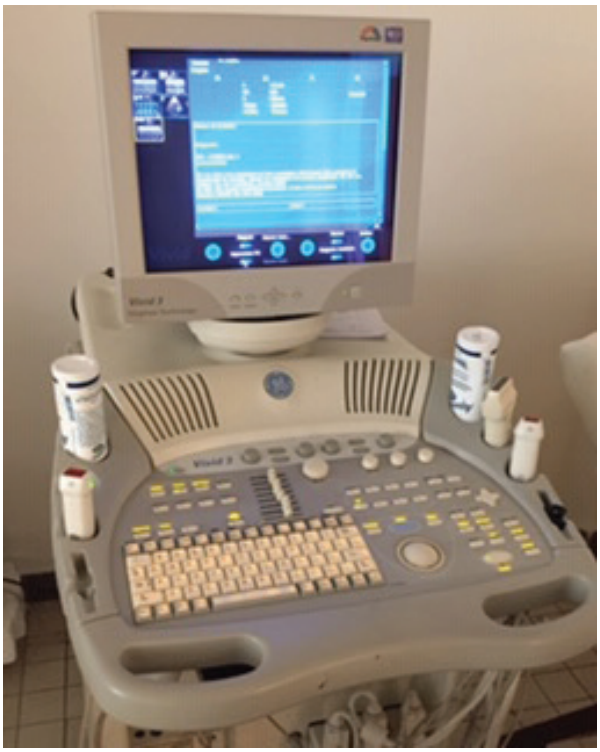

Fig. 1. A Vivid3® Sonoscape was used for two-dimensional Doppler and M-mode echocardiography.

subjects lying in the left lateral decubitus position. A one-lead electrode was placed continuously during the course of the examination. All cardiologists were given a protocol with standard operating procedures for each measurement, which was done according to previously published guidelines.[14] Measurements from at least three different cardiac cycles were averaged and used in the analyses.

The LA anteroposterior linear dimension was obtained from the parasternal long-axis view, from the trailing edge of the posterior aortic wall to the leading edge of the posterior LA wall at the end-ventricular systole (just before the opening of the mitral valve) when the LA chamber is at its greatest dimension. Measurements were indexed to body surface area (BSA).

LA surface and volume were obtained on an apical four-chamber view at end-systole. The inner border of the LA, excluding the area under the mitral valve annulus and the inlet of the pulmonary veins was traced, giving the LA a shape roughly like a square. The LA volume was calculated using the biplane area–length method and the formula is given by

$$0.85(A1 \times A2)/L.$$[15]

where A1 and A2 are the areas of the LA in four- and two-chamber views and L is the shortest of the lengths obtained from the orthogonal views and indexed to BSA (Fig. 2).

The LA length (major axis) and width (minor axis) were also measured in the apical four-chamber view. The length was measured from the plane of the mitral annulus to the roof of the atrium and the width was defined as the distance between the lateral LA wall and inter-atrial septum, at the mid-atrial level, defined by half of the LA long axis.

In the parasternal long-axis view, left ventricular (LV) parameters were measured using the leading edge-to-leading edge convention of the recommendations by the American Society of Echocardiography. End-diastolic and end-systolic LV internal diameters, interventricular septum thickness and posterior wall thickness were measured from two-dimensionally guided M-mode tracings recorded at 50 to 100 cm/s speed during three or more consecutive cycles, according the American Society of Echocardiography guidelines.[14]

Relative wall thickness was defined by the ratio of posterior wall plus interventricular septum thickness to LV internal diastolic diameter. Left ventricular mass (LVM) was calculated using the Devereux-modified Penn formula[16] and was indexed to BSA (calculated using the formula of Dubois).

$$0.8\ \{1.04[(LVEDD + PWTd + IVSTd)3 - (LVEDD)3]\} + 0.6$$

where LVEDD is left ventricular end-diastolic diameter, PWTd is posterior wall thickness in diastole, IVSTd is interventricular septal thickness in diastole.

Left ventricular ejection fraction (LVEF) was calculated using the Teichholz formula. Fractional shortening was calculated from LV internal dimensions in diastole and systole:

$$\frac{LVIDd - LVIDs}{LVID} \times 100$$

where LVIDd is left ventricular internal diameter in diastole and LVIDs is left ventricular internal diameter in systole.

Diastolic function parameters

From the apical four-chamber view, trans-mitral echo-Doppler velocity flow profile was recorded in all patients, positioning the sample volume at the level of the leaflet tips; the highest discernible signal was determined as velocity. The diastolic filling indices were measured: peak flow velocity of early (peak E) and late (peak A) diastole, E/A ratio and deceleration time (DT), defined as the time interval required for the E velocity to decline from its peak to the baseline. The isovolumetric relaxation time (IVRT) was also considered, measured from the aortic valve closure to the beginning of trans-mitral flow.

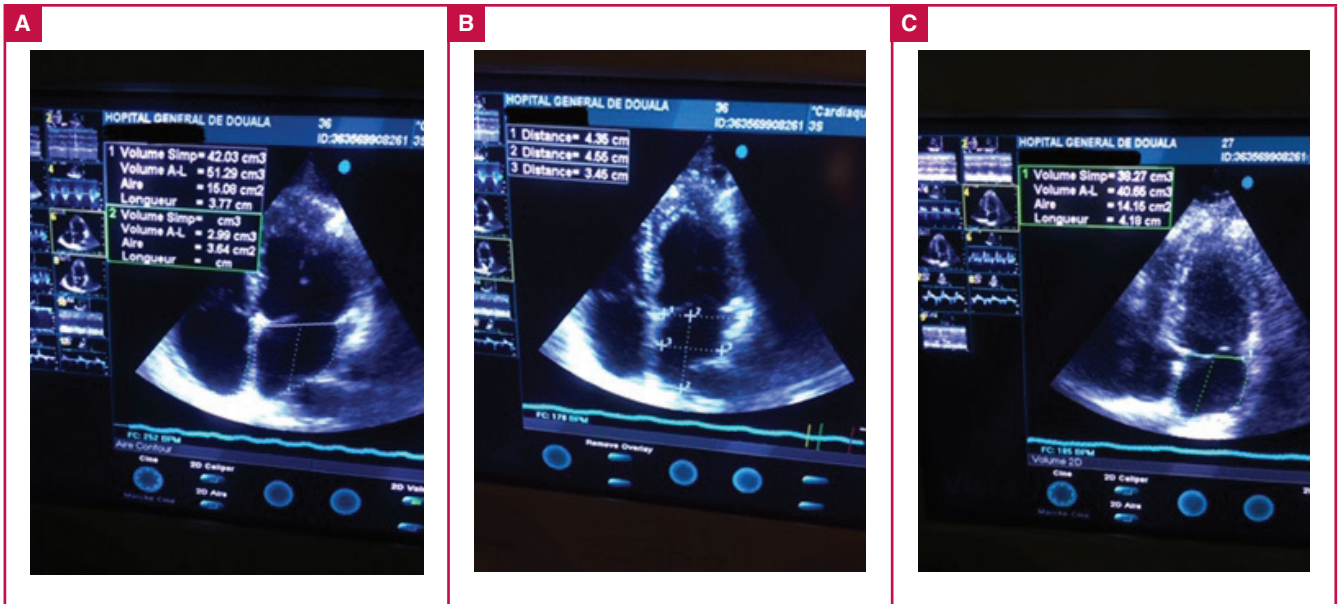

Fig. 2. Measurement of LA volume from the biplane area–length method, using apical four- and two-chamber views to obtain A1, A2 and the longitudinal diameter (L) (distance 2 in B) (courtesy of Doula General Hospital).

The pulsed-wave Doppler tissue imaging (DTI) sample volume was placed on the mitral annuli at the apical four-chamber view. The spectral longitudinal velocity of the myocardium, normally consisting of a positive systolic wave and two diastolic peaks, notably the S′, E′ and A′, respectively, were measured in the lateral and septal mitral annuli.

LAR was defined as changes in LA structure (as evidenced by increased anterior–posterior diameter, surface or volume) or function (increased atrial contraction measured from the late diastolic wave velocity, A) induced by hypertension. Left structural changes were defined as increase in LA volume index (LAVI > 34 ml/m^2). Mild LA enlargement was 35–41 ml/m^2, moderate LA enlargement was 42–48 ml/m^2, and severe LA enlargement was > 48 ml/m^2.[14]

LVH was defined as left ventricular mass index > 114 g/m^2 in men and > 99 g/m^2 in women.[14] Ventricular remodelling was defined based on the relative wall thickness (RWT) and LVM; concentric remodelling was increased RWT and LVM, eccentric remodelling was decreased RWT and normal LVM. Diastolic dysfunction (impaired relaxation) was defined as an E/A ratio < 1 and deceleration time > 220 ms.[14]

ECG criteria for determining LVH was defined by the Sokolow–Lyon index: the sum of the largest R wave of the V5 or V6 derivation with wave S of the V1 ≥ 3.5 mV (35 mm) and/or R wave in aVL ≥ 1.1 mV (11 mm). ECG criteria for LA hypertrophy included: P-wave duration in lead I, II or III > 110 ms; P-wave notching in lead I, II or III with inter-peak duration > 40 ms (P mitrale); any current or former smokers; impaired fasting glucose level of 100–125 mg/dl (5.55–6.94 mmol/l); an abnormal high-density lipoprotein cholesterol < 40 mg/dl (1.04 mmol/l), low-density lipoprotein cholesterol > 110 mg/dl (2.85 mmol/l) and total cholesterol ≥ 200 mg/dl (5.18 mmol/l).

Statistical analysis

Data were analysed using the Statistical Package for Social Sciences version 23 (IBM SPSS, Atlanta). Data are expressed as mean ± standard deviation (SD) or as median and interquartile range (IQR) where appropriate. Medians were compared using the Mann–Whitney *U*-test.

Pearson's correlation was used to assess the individual relationship between LA size with age, body mass index (BMI), SBP, DBP, pulse pressure, LVM, LVH and other echocardiographic parameters. Variables that had significant associations on bivariate analysis were tested in a step-wise linear regression model and adjusted for age and gender.

Results

A total of 52 patients were enrolled along with 40 control subjects. The median age was 49 years. The age ranged between 33 and 75 years with a similar male-to-female ratio between the two groups. There was a significant difference in blood pressure variables (SBP, DBP, mean atrial pressure and pulse pressure) between the two groups. Table 1 shows the clinical characteristics of patients.

The median duration of hypertension was one month and 15% of the patients were not yet treated. Monotherapy with calcium channel blocker (34.6%), followed by combination therapy of thiazide diuretic and angiotensin converting enzyme inhibitors (13.4%) were the most frequently used medication. Table 2 shows characteristics specific to the hypertensive patients.

The LV mass was significantly higher in hypertensive patients compared to the control group. Similarly, the diastolic function assessed by the E/A ratio was significantly impaired in hypertensive patients. These findings are shown in Table 3.

The LA longitudinal diameter ($p = 0.045$), surface area ($p = 0.003$) and biplane volume ($p = 0.002$) were significantly higher in the patients with hypertension. Table 4 shows the difference in LA sizes between hypertensive patients and controls.

LA structural changes, defined by LA enlargement, was found in 14 (26.9%) hypertensive patients versus one (2.5%) control individual ($p < 0.0001$). Among these patients, 64.3% had mild LA enlargement, 21.4% moderate and 14.3% severe LA enlargement, as shown in Figs 3 and 4.

On univariate analysis the following factors were tested for relationship with LA volume: age, gender, systolic and diastolic blood pressures, BMI, LV wall thickness [left ventricular end-systolic diameter (LVESD), interventricular septal diameter at diastole (IVSD), posterior wall diameter at diastole (PWDD)], LVM, and diastolic function (E/A, E/E′). Significant correlations were found with BMI ($r = 0.30$; $p = 0.004$), DBP ($r = –0.30$; $p =$

Table 1. Clinical characteristics of the study population

Variable	*Hypertensives* (n = *52*)	*Controls* (n = *40*)	p-*value*
Age (years)	49.0 (43.2–59.7)	49.0 (43.0–57.7)	0.93
Male, *n* (%)	22 (42.3)	18 (45)	0.834⁺
BMI (kg/m^2)	29.2 (26.9–32.4)	27.7 (24.6–31.0)	0.04
SBP (mmHg)	150.0 (142.0–159.0)	125 (115.0–130.0)	< 0.0001*
DBP (mmHg)	95.0 (89.0–100.0)	79.0 (68.5–89.0)	< 0.0001*
Heart rate (beats/min)	75.5 (69.0–88.7)	75.5 (68.0–82.7)	0.34
Pulse pressure (mmHg)	56.0 (48.2–65.0)	42.0 (35.5–54.0)	< 0.0001*
MAP (mmHg)	113.8 (105.7–118.5)	93.8 (87.5–101.0)	< 0.0001*

Values are presented as median (interquartile range) or number (%). BMI, body mass index; SBP, systolic blood pressure; DBP, diastolic blood pressure; MAP, mean arterial pressure.
⁺*p*-value from Fisher's exact test; **p*-value from Mann–Whitney *U*-test.

Table 2. Characteristics of the hypertensive patients

Variable	*Number (%)*	*Overall,* n
Duration of hypertension (months)	1 (0–6)	52
Alcohol intake	18 (34.6)	52
Former smoker	1 (2)	52
Current smoker	2 (4)	52
Sedentary	32 (61.5)	52
Family history of hypertension	25 (48)	52
ECG LV hypertrophy	8 (15.3)	52
ECG LA hypertrophy	5 (9.6)	52
Elevated LDL-C	5 (19.6)	26
Low HDL-C	7 (26.9)	26
Elevated cholesterol	8 (30.7)	26
Abnormal creatinine	0 (0)	38
Elevated uric acid	2 (12.5)	16
Impaired fasting glucose	2 (5.2)	38
CCB	18 (34.6)	52
ACEI/ARB + thiazides	7 (13.4)	52

Values are presented as median (interquartile range) or number (%). LV, left ventricular; LA, left atrial; LDL-C, low-density lipoprotein cholesterol; HDL-C, high-density lipoprotein cholesterol; CCB, calcium channel blocker; ACEI, angiotensin converting enzyme inhibitor, ARB, aldosterone receptor blocker.

Table 3. Echocardiography parameters

Variable	*Hypertensives (n = 52)*	*Controls (n = 40)*	p-*value*
AOD (mm)	28.8 (26.6–31.0)	28.8 (26.5–31.4)	0.79
IVSD (mm)	9.2 (7.5–10.4)	8.4 (7.1–9.8)	0.28
IVSS (mm)	13.6 (12.7–15.3)	13.8 (12.1–15.0)	0.61
LVEDD (mm)	49.1 (45.0–54.0)	46.8 (43.1–51.0)	0.11
LVEDS (mm)	30.0 (25.9–34.7)	28.5 (25.5–32.6)	0.20
PWDD (mm)	9.4 (8.3–11.1)	8.6 (7.5–9.8)	0.89
PWDS (mm)	15.7 (13.8–17.3)	14.4 (12.7–15.9)	0.19
FS (%)	37.0 (34.2–42.0)	0.35 (0.31–0.40)	0.91
EF (%)	68.0 (61.2–74.0)	83.3 (66.7–76.0)	0.17
LVMI (g/m^2)	86.0 (72.7–101.7)	73.3 (58.4–88.7)	0.01*
RWT	0.35 (0.32–0.44)	0.35 (0.31–0.35)	0.11
Peak E (cm/s)	75.3 (58.8–92.5)	80.0 (67.0–90.0)	0.43
Peak A (cm/s)	83.0 (62.2–96.0)	63.5 (51.0–83.7)	0.001*
E dec (ms)	199.0 (179.0–219.0)	189.0 (165.0–209.0)	0.23
IVRT (ms)	96.0 (83.5–105.0)	90.0 (78.0–101.0)	0.31
E/A ratio	0.89 (0.70–1.2)	1.24 (0.94–1.49)	< 0.0001*
S′ lateral (m/s)	10.0 (7.0–12.0)	9.0 (8.0–12.0)	0.88
Lateral E′ (m/s)	9.0 (7.0–11.0)	11.0 (9.0-15.0)	0.009*
Lateral A′ (m/s)	11.0 (9.0–2.8)	9.0 (7.01–0.0)	0.002*
E/E′ ratio	9.0 (6.9–10.7)	7.25 (5.7–8.8)	0.001*

Values are presented as median (interquartile range). *Statistically significant. AOD, aortic root diameter; IVSD, interventricular septal diameter at diastole; IVSS, interventricular septal diameter at systole; LVEDD, left ventricular end-diastolic diameter; LVEDS, left ventricular end-systolic diameter; PWDD, posterior wall diameter at diastole; PWDS, posterior wall diameter at systole; EF, ejection fraction; FS, fractional shortening; LVMI, left ventricular mass index; RWT, relative wall thickness; E, early mitral flow velocity; A, atrial contraction velocity; dec, E wave deceleration time; IVRT, isovolumetric relaxation time; S′, systolic myocardial velocity at lateral annulus; A′, myocardial velocity associated with atrial contraction; E′, early diastolic myocardial velocity.

Table 4. Comparison of left atrial size between hypertensives and controls

Variable	*Hypertensives (n = 52)*	*Controls (n = 40)*	p-*value*
LA anteroposterior diameter (mm)	38.1 (34.6–38.0)	36.7 (34.1–39.6)	0.064*
LA anteroposterior diameter indexed BSA	19.8 (17.8–19.8)	19.1 (18.0–21.0)	0.148
LA transverse diameter (mm)	37.0 (32.7–49.8)	39.3 (34.6–42.8)	0.097*
LA longitudinal diameter (mm)	50.0 (45.0–55.0)	47.4 (44.0–51.8)	0.045
LA surface area (cm^2)	17.9 (13.3–21.2)	15.5 (13.6–17.4)	0.003
LA volume, biplane (ml)	52.4 (38.9–65.7)	43.8 (35.2–48.5)	0.002
LA volume, biplane indexed BSA (ml/m^2)	28.1 (19.9–34.5)	22.9 (18.8–26.6)	0.003

*Statistically significant. LA, left atrial; BSA, body surface area.

Table 5. Pearson correlation for covariates of left atrial size (volume) in hypertensive patients

Variable	*Correlation coefficient,* r	p-*value (n = 52)*
Age	0.008	0.544
BMI	0.402	0.004*
SBP	–0.040	0.782
DBP	–0.300	0.019*
IVSD	–0.022	0.880
LEVDD	0.360	0.009
PWDD	1.310	0.366
LVM/BSA	0.055	0.704
E/E	0.351	0.013*
E/A	0.368	0.009
RWT	0.073	0.621
Microalbuminuria (mg/g)	0.130	0.350

*Statistically significant. BMI, body mass index; SBD, systolic blood pressure; DBP, diastolic blood pressure; IVSD, interventricular septal diameter at diastole; LVMI, left ventricular mass index; LVEDD, left ventricular end-diastolic diameter; PWDD, posterior wall diameter at diastole; RWT, relative wall thickness.

0.02), LVEDD (r = 0.367; p = 0.009) and E/A (r = 0.368; p = 0.009) among the hypertensive patients (See Table 5).

Variables with significant correlation and a p-value < 0.05 were entered in a step-wise multiple linear regression model and adjusted for age and gender. Diastolic function (E/A < 1) was the only independent predictor of LA volume in hypertensive patients (p = 0.006). This is shown in Table 6.

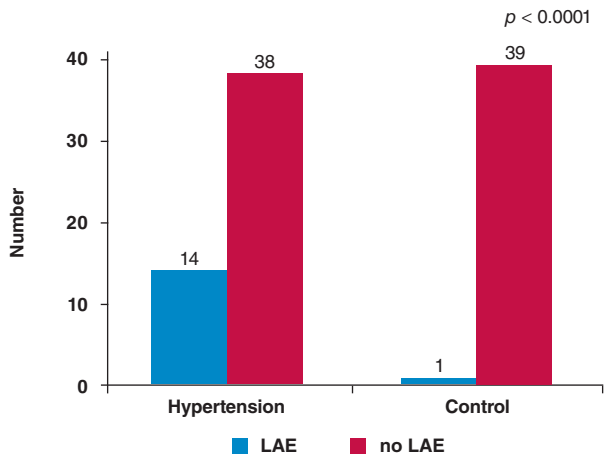

Fig. 3. Proportion of patients with LA enlargement in hypertensive subjects and controls. LAE, left atrial enlargement.

Discussion

Our study showed that there was a significant increase in the LA longitudinal diameter, surface area and volume among hypertensive participants compared to the reference group (non-hypertensive). About a quarter (26.9%) of hypertensive patients had an increase in LA volume. Determinants of LA

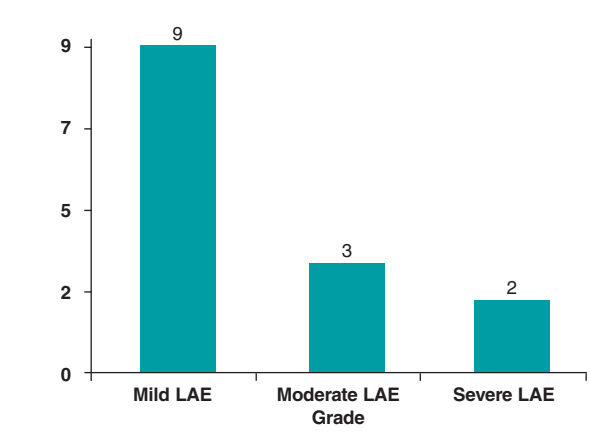

Fig. 4. Classification of severity of LA enlargement according to the American Society of Echocardiography. LAE, left atrial enlargement.

Table 6. Multivariate linear regression analysis for independent predictors of left atrial size

Variable	*B*	*95% CI of the difference*	p-*value*
BMI	0.300	–0.026 to 0.041	0.300
DBP	–0.280	–0.001 to 0.007	0.330
LVEDD	–0.110	–0.013 to 0.020	0.630
E/A	0.370	0.328 to 1.832	0.003*
E/E′	0.150	–0.016 to 0.080	0.290

R^2= 38.3%. *Statistically significant. B, coefficient of regression; CI, confidence interval, BMI, body mass index, BSA, body surface area; SBP, systolic blood pressure, DBP, diastolic blood pressure, LVEDD, left ventricular end-diastolic diameter.

volume were BMI, BSA, DBP, and LV septal thickness at diastole in hypertension. Diastolic dysfunction was the only independent predictor of LAR in hypertensive patients. Also, we found no correlation between microalbuminuria and LA size (volume) among hypertensive patients.

The LA length, surface area and volume were significantly increased in patients with hypertension compared to the controls. This finding was consistent with several reports that showed that there is an increase in LA length and volume in hypertension.[13,17,18,4,25] Contrary to the findings by Sun *et al.* in China, changes in anterior–posterior and transverse diameters were not significant.[12] There are possible explanations to these differences, which include LA anatomical variations and severity of hypertension. Results from the study by Dewland *et al.* suggest that LA diameter is significantly greater in whites than blacks.[19] Severe hypertension in hospitalised patients recruited by Sun *et al.* would have had a greater effect on LA size compared to patients with mild hypertension in this study.

It should be noted that the LA is not shaped symmetrically and LA enlargement does not occur uniformly. Expansion of the LA is constrained by the thoracic cavity, aortic root, right ventricular outflow tract and the rigid trachea bifurcation. With the above in mind, changes in LA size therefore preferentially occur in the superior–inferior axis (longitudinal diameter).[20]

Consequently, all the morphological changes in LA size only become prominent with age and duration of hypertension. Therefore, the aforementioned anatomical factors, coupled with severity of hypertension accounted for the differences observed between our findings and those of Sun *et al.*[12] Our analysis supports the fact that estimation of LA changes by surface and volume will be more relevant and accurate in the clinical setting than anterior–posterior and transverse dimensions.

Up to a quarter of the hypertensive patients in our study had LA enlargement. This is considerable and is a call for concern, given the fact that LA enlargement increases the risk of stroke and is associated with poor cardiovascular outcomes. Our findings are in agreement with of those of Cuspidi *et al.* in Italy.[21] However, we had a lower proportion of participants with LA enlargement relative to those found by Chen *et al.*[22] in Japan and Milan *et al.* in Italy.[23]

Possible explanations for the variations lie in differences in study designs, presence of concomitant pathologies in their subjects, and different diagnostic cut-off values used to define LA enlargement. In these studies, co-morbidities included atrial fibrillation, diabetes mellitus and obesity, among others. In the study by Chen *et al.,* mean age was 69 ± 10 years and diagnostic cut-off for LA enlargement was LAVI > 32 ml/m^2. In the study by Milan *et al.,*[23] the mean age was 50.7 ± 12.2 years with duration of hypertension ranging from 11–120 months and diagnostic cut-off for LA enlargement was LAVI > 22 ml/m^2. Finally, in the study by Cuspidi *et al.*,[21] mean age was 58.3 ± 16 years, with the elderly patients above 65 years making up 41% of patients.

The observation that a large proportion of hypertensive patients had LA changes in the early phase of high blood pressure has important prognostic and diagnostic implications. This highlights the fact that structural changes may occur early in these patients therefore early screening for diagnosis may prevent future cardiovascular events.

Factors that correlated with LA volume were BMI, DBP and diastolic dysfunction. An association between increasing body mass and LA volume has been shown in previous studies by Adebayo *et al.*[18] Although the mechanism is not well understood, obesity is linked with increased stoke volume, which causes cardiac alterations.

Contrary to previous studies, ours did not show any relationship between LAR and LVM and age. Our patients were mostly newly diagnosed and relatively young hypertensive patients, which could explain the differences. In our final analysis, LV diastolic dysfunction was the only predictor of LA size. A clear relationship has been reported by Matsuda *et al.*[24] This strengthens the fact that, in the absence of other pathological disease, hypertension leads to impaired LV relaxation and reduced expandability of the left ventricle. The end result is increased atrial filling pressures and subsequent LA enlargement.

Our study was limited in that we had a small sample size and therefore the resultant loss of power could lead to decreased chances of finding associations (type II error). Second, we worked on both treated and untreated hypertensive patients, which could have modulated changes in LA size. However, there was a significant number of hypertensive patients with increase in LA size compared to the controls, indicating that the blood pressure medication had very little or no effect on LA size. We also believe that the short duration of treatment might have had little or no effect on LA size. Lastly, the case–control design limited this study with regard to establishing a temporal relationship.

The strength of this study is based on the fact that we used newly diagnosed hypertensive patients and/or those with a short duration of hypertension from diagnosis. This makes our finding more relevant in enhancing management.

Conclusion

This study shows that that there was a significant proportion of patients with hypertension who had LA remodelling, even early at diagnosis, and hence there could be early cardiac morphological modifications in these patients. Also, LA size increased disproportionately with a significant increase in the length, surface area and volume.

LA volume measurements should be assessed routinely in order to identify early morphological changes in hypertensive heart disease, and not lay emphasis only on traditional parameters of the left ventricle. Future studies are warranted to better elucidate the biological mechanisms underlying linking of the early phase of hypertension with LAR as well as its prognostic implications in our population.

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