International Journal of Current Advanced Research
ISSN: O: 2319-6475, ISSN: P: 2319-6505, Impact Factor: SJIF: 5.995
Available Online at www.journalijcar.org
Volume 6; Issue 12; December 2017; Page No. 8352-8358
DOI: http://dx.doi.org/10.24327/ijcar.2017.8358.1344

Research Article

RELATIONSHIP BETWEEN LEFT ATRIAL VOLUME CHANGES AND ENDOTHELIAL DYSFUNCTION IN PATIENTS WITH SYSTEMIC HYPERTENSION

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A R T I C L E I N F O

Article History:
Received 15th September, 2017
Received in revised form 25th October, 2017
Accepted 23rd November, 2017
Published online 28th December, 2017

Key words:

Choroidal thickness, endothelial dysfunction, left atrial volumes, systemic hypertension disease, three dimensional echocardiography.

A B S T R A C T

Purpose: The aim of this study was to evaluate the association between left atrial (LA) volume changes measured by three-dimensional echocardiographic (RT3DE) and endothelial dysfunction (ED) in patients with systemic hypertension (HT).
Methods: This study included 66 consecutive systemic hypertensive patients (62.0±10.2 years, 24 males) and 31 healthy control participants (61.4±9.1 years, 14 males). All participants underwent two and three-dimensional echocardiographic measurements. Brachial artery endothelial measurements and spectral-domain optical coherence tomography (SD-OCT) measurements were also performed to assess respectively ED and hypertensive retinochoroidal changes. The systemic hypertensive patients were divided into two groups according to ED which is determined by brachial artery endothelial measurements.
Results: The three groups did not differ with regards to age, sex or metabolic profile. In RT3DE measurements, systemic hypertensive patients had elevated left atrial phasic volumes [Left atrium (LA) maximal volume index, LA minimal volume index, LA preatrial contraction volume index, $p < 0.001$] and worse left atrial mechanical functions (reservoir, conduit, and atrial contraction $p<0.001$). In the logistic regression analysis, the LA total stroke volume index (86% sensitivity and 93% specificity, area under the curve: 0.96, $p<0.001$) and mean choroidal thickness (86% sensitivity and 82% specificity, area under the curve: 0.89, $p<0.001$) were independent predictors of ED in patients with systemic HT.
Conclusion: Patients with systemic HT had increased LA volumes, decrease retinochoroidal thickness, impaired left atrial phasic functions and also endothelial functions. Moreover, RT3DE identified early volume and functional LA changes in these patients better than conventional echocardiography. Assessment of hypertensive patients with RT3DE atrial volume analysis may facilitate an early recognition of target organ damage (TOD).

INTRODUCTION

Affecting 30–45% of all adults worldwide, HT remains the most common, easily diagnosable and reversible risk factor for cardiovascular disease (CVD) [1, 2]. In systemic HT patients, large and small arteries sustain the most damage from persistent blood pressure (BP) elevations which cause TOD[3]. Hence, the first step in treating HT is to do a damage assessment by evaluating the target organs of HT.ED is an early sign of TOD and can be detected before micro- and macrovascular complications of systemic HT occur[4]. The brachial artery flow mediated dilation (FMD) is a well-studied measure of ED [5].

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The LA is a reservoir for the left ventricle (LV) during systole, a conduit (for blood flow from the pulmonary veins to the LV) during early diastole and a muscular pump to complete the process of LV filling in late diastole[6, 7]. There is significant interaction between LA and LV function and events during each phase of LA phasic function are affected by factors from both the LA and LV. Atrial function is an important, and at times, critically important predictor of major adverse cardiovascular eventsboth in the general population and in selected clinical conditions [8].

As a TOD of systemic HT, longstanding HT may significantly affect the retinal andchoroidalcirculations. Hypertensive choroidopathy is characterized by choroidalfibrinoid necrosis and subretinal fluid accumulation induced by ED[9]. Optical coherence tomography (OCT) is a novel and noninvasive

method for cross-sectionally imaging the retina and choroid[10]. Enhanced depth imaging OCT (EDI-OCT), as defined by Spaide *et al*., enables in vivo cross-sectional imaging of the choroid.[11] Eventually, we usedEDI-OCT in order to measure choroidal thickness and determine TOD in hypertensive subjects.

The aim of this study was to evaluate the association between LA volume changes measured by RT3DE and ED in patients with systemic HT.

METHODS

Study population

The study population consisted of 66 systemic hypertensive patients and 31 normotensive controls, who were recruited from a large cohort followed. All patients gave detailed medical history and underwent comprehensive clinical examination and laboratory tests. Exclusion criteria were; presence of LV systolic dysfunction (LVEF< 50 %), acute coronary syndrome, cerebrovascular events, systemic inflammatory disease, renal failure, more than mild valvular regurgitation or stenosis, prosthetic valve, atrial septal defect or aneurysm, AF or conduction disturbances and inappropriate echocardiographic images. We also excluded patients with diabetes, a condition that may interfere with retinal changes and choroidal thickness. The study protocol complies with the Declaration of Helsinki. It was approved by Research Ethics Committee and all subjects gave informed consent.

Diabetes mellitus was defined as a fasting (8 hours) blood glucose level of ≥126 or ≥200 mg/dl 2 h after an oral glucose tolerance test or use of insulin or oral hypoglycemic medication. Coronary artery disease was defined as a history of myocardial infarction, coronary artery disease bypass grafting, percutaneous coronary intervention or an angiographic evidence of a significant coronary artery stenosis (≤50 %). Renal failure was defined as estimated creatinine clearance <30 ml/min/1.73 m^2 (calculated by Modification of Diet in Renal Disease formula).

Diagnosis of arterial hypertension

Sitting blood pressure (BP) was measured 3 times in the right arm of the individual with a mercury sphygmomanometer after a 5-min rest and with at least 1-min interval between readings. The mean value of the last two measurements was accepted discarding the first one. Hypertension was defined as systolic BP ≥ 140 mm Hg, diastolic BP ≥ 90 mm Hg or use of antihypertensive medication.

Opthalmologic Evaluation

All patients received comprehensive ophthalmic examinations. Patients with systemic or ocular disease (glaucoma, uveitis, high myopia, age-related macular degeneration, diabetes mellitus, etc.) and/or a history of ophthalmic surgery that may have affected the choroidal vascular network were excluded. All SD-OCT measurements were performed during the same daily interval (10–12 am) by same technician. The choroidal thickness was measured with SD-OCT (RS-3000, Nidek) manually, on the horizontal EDI line scan, in 3 separate locations: subfoveal, and 2 mm nasal and 2 mm temporal to the fovea. Mean value of both eyes were used for statistical analyzes (Fig.1).

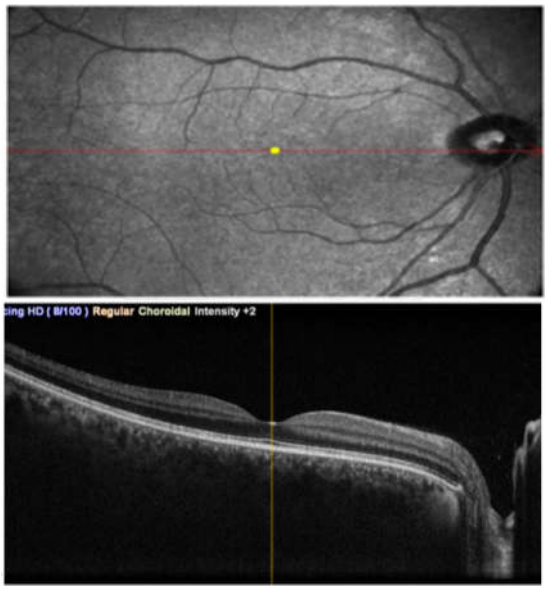

Fig 1 Fundusphotoand SD-OCT image for evaluatingthechoroidalthickness.

SD-OCT: spectral domain opticalcoherencetomography

Echocardiographic Examination

All echocardiographic examinations were performed by two researchers who were blinded to clinical data of the study population by using cardiac ultrasound machine capable of performing RT3DE (IE33, Philips Medical Systems, Andover, MA, USA) with digital storage software for offline analysis. All patients were in sinus rhythm at the time of examination and all measurements were calculated from three consecutive cycles. Average of the three measurements was recorded. All two-dimensional echocardiography (2D-Echo) measurements and DD parameterswere determined according to the American Society of Echocardiography (ASE) guidelines [12, 13].

RT3DE was performed with an X5-1 matrix-array transducer (1–3 MHz) for acquisition of "full-volume" real-time pyramidal volumetric data sets along four consecutive cardiac cycles. Individuals were instructed to hold their breath, and images were coupled with electrocardiographic recordings. The RT3DE data sets were digitally stored and analyzed using analysis software (QLab-Philips version 9.1; Philips Medical systems). Anatomical landmarks used to calculate LA volumes were manually identified as follows: lateral, septal, anterior, inferior points of the mitral annulus and the fifth point at the apex of the LA. Points determined to represent the pulmonary vein ostia or LA appendages were excluded from the measurement. The LA internal endocardial border of each frame was defined by automated processing and manually adjusted for pulmonary vein ostia and LA appendage exclusion. From these data, a three dimensional model of LA volume was generated (see Fig. 2). The narrowest possible image sector angle including the LA was used to achieve the maximum frame rate which was 28 ± 6/sec in this study. The RT3DE data sets were digitally stored and analyzed using analysis software (QLab-Philips version 9.1; Philips Medical Systems). All the stored digital data were analyzed by two observer who were blinded to the both HT and controls (i) LA maximum volume (Vmax): at end systole, the time at which the atrial volume was the largest just before the mitral valve opening, (ii) LA minimum volume (Vmin): at end diastole, the

time at which the atrial volume at its nadir before mitral valve closure, and (iii) before atrial contraction volume (Vpre A): the last frame before mitral valve reopening or at time of P wave on electrocardiogram. From the three volumes, the following measurements were selected as indices of LA function and calculated according to previous studies (i) LA total stroke volume (TSV): Vmax–Vmin; (ii) LA total emptying fraction (TEF): TSV/Vmax × 100; (iii) LA active stroke volume (ASV): Vpre A–Vmin; (iv) LA active emptying fraction (AEF): ASV/Vpre A × 100; (v) LA expansion index (EI): TSV/Vmin × 100; and (vi) LA passive emptying fraction (PEF): (Vmax–Vpre A)/ Vmax × 100. LA RT3DE volumes were indexed to the BSA to obtain the LA RT3DE volume indexes. Accordingly, TEF and EI have been assumed to reflect atrial reservoir function, AEF has been assumed to reflect atrial pump function and PEF has been assumed to reflect atrial conduit function[7].

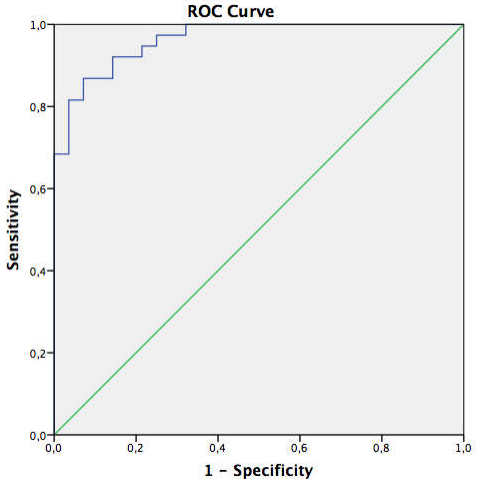

Fig. 2a ROC curve analysis of LA TSV index to predict endothelial dysfunction

AUC:0.96, p<0.001, CI: 0.92-0.99
TSV (ml/m^2): Leftatrium total strokevolumeindex

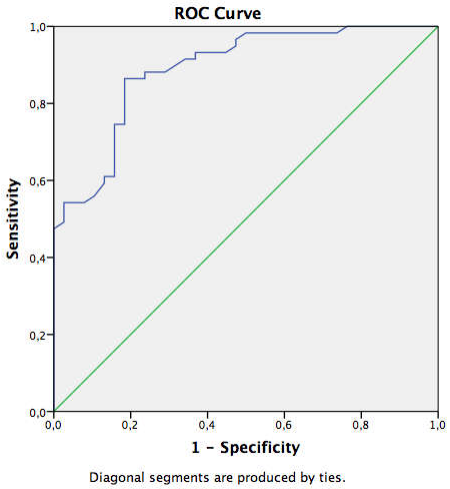

Fig. 2b ROC curve analysis of mean choroidal thickness to predict endothelial dysfunction

AUC:0.89, p<0.001, CI: 0.82-0.95

Assessment of Endothelial Function

Flow mediated dilation method was used to assess endothelial functions of the patients. Imaging was performed using a linear transducer with Vivid 7 (GE) ultrasound system. Imaging procedure for all patients were carried out by two blinded cardiologist. Patients were allowed to rest approximately for 12 min at the room temperature before the imaging procedure. The brachial artery images were obtained above the antecubital fossa using B-mode imaging in the longitudinal plane of the artery. First the baseline diameter of the brachial artery was measured by magnifying this part of the artery. Then, the BP cuff was placed on the proximal forearm, and it was inflated to 50 mmHg above the systolic BP to occlude arterial flow for 5 min. The brachial artery diameter was measured at 30 s after releasing the cuff. The highest value obtained during ischemia-induced hyperemia was used for calculating the FMD ratio [(maximum diameter − baseline diameter) / baseline diameter × 100]. As far as ED studies are concerned, patients who have lower then brachial artery-FMD 8% have higher major adverse cardiovascular disease events [14]. Mutlu *et al*. showed that impaired brachial-artery endothelial function independently predicted coronary arterial disease and suggested brachial-artery FMD <8% might serve as a surrogate endpoint for cardiovascular risk [15]. Accordingly, patients with a brachial-artery FMD <8% were accepted to have endothelial dysfunction.

Statistical analysis

The variables were investigated using visual (histograms, probability plots) and analytic methods (Kolmogorov–Smirnov/Shapiro-Wilk's test) to determine whether or not they are normally distributed. Descriptive analyses were presented (*using tables of frequencies for the ordinal variables), and using medians and interquartile range (IQR) for the non-normally distributed and ordinal variables. Continuous variables are expressed as mean value ± standard deviation (SD). The Mann-Whitney U test was performed to test the significance of pairwise differences using Bonferroni correction to adjust for multiple comparisons. Chi-Square test was employed in order to detect significant differences between categorical variables. Student's t-test was used in order to determine statistically significant differences between groups of continuous variables. For the multivariate analysis, the possible factors identified with univariate analyses were further entered into the logistic regression analysis to determine independent predictors of endothelial dysfunction. Hosmer-Lemeshow goodness of fit statistics were used to assess model fit. Kappa coefficients were calculated to estimate interobserver as well as intraobserver correlations in both RT3DE and FMD examinations [16]. The capacity of TSV index value in predicting presence of endothelial dysfunction was analyzed using Receiver Operating Characteristics (ROC) curve analysis. When a significant cut-off value was observed, the sensitivity and specificity values were presented. Because of both TSV index and mean choroidal thickness parameters were not normally distributed, the correlation coefficient and their tested significance were calculated using the Spearman test. All tests were considered to be significant at 0.05 level. Statistical analysis was performed by using the SPSS software version 15 (SPSS Inc., Chicago, IL).

RESULTS

Subject Characteristics

This study consisted of 31 healthy controls (males = 47%, age = 61.4±9.1 years) and 66 patients with systemic HT (males = 37%, age = 62.0±10.2 years). Clinical and laboratory

characteristics of both groups are shown in Table 1. The systemic hypertensive patients were divided into two groups according to ED. The three groups did not differ with regard to clinical or laboratory characteristics. However, systolic, diastolic, and mean blood pressures differed among three groups.There were significant differences in choroidal thickness and brachial artery FMD percentage among three groups (Table 2,$p< 0.001$).

Vmin index, LA VpreA index, LA TSV index, LA ASV index, and LA PSV index ($p < 0.001$). Furthermore, the three groups differed in regard to TEF, PEF, and expansion index ($p = 0.006$, $p= 0.001$, $p = 0.006$, respectively).

Predictors of Endothelial Dysfunction

Univariate and multivariate logistic regression analyses were performed to demonstrate the predictors of ED in patients with

Table 1 Characteristics of the study population

	Healthycontrols (n:31)	Hypertensive patientswithout ED (n:28)	Hypertensivepatientswith ED (n:38)	p value
Age (years)	61.4±9.1	61.9±9.6	62.1±10.9	0.29
Gender (male)	14(%47)	9(30%)	15(%39)	0.59
Body mass index (kg/m^2)	26.3±4.0	27.9±4.5	28.6±4.8	0.34
Hypercholesterolemia (> 200mg)	11(35%)	8(26%)	13(34%)	0.51
COPD	3(10%)	3(10%)	4(%11)	0.99
Smokers	9(29%)	7(23%)	12(32%)	0.84
Systolic Blood Pressure (mmhg)	125±19	137±17	144±26	**<0.001**
Diastolic Blood Pressure (mmhg)	83±8	87±10	90±11	**0.008**
Mean Blood Pressure (mmhg)	96±12	104±11	108±15	**<0.001**
Triglycerides (mg/dl)	150±34	144±30	149±33	0.46
Total cholestrol (mg/dl)	211±28	208±22	216±30	0.47
Low density lipoprotein (mg/dl)	119±58	128±63	130±64	0.29
High density lipoprotein (mg/dl)	48±11	51±14	47±10	0.26
HS C- reactive protein (mg/dl)	2.0±1.1	1.8±1.1	2.2±1.2	0.55
Fasting blood glucose (mg/dl)	99±15	101±18	97±14	0.56

Data are presented as mean ± standard deviation or percentile. Boldvaluesindicatestatisticalsignificance p<0.05.
Abbreviations: ED: endothelial dysfunction; COPD: Chronic obtructive pulmonary disease; HS; High sensitive.

Table 2 Comparison of two dimensional echocardiographic parameters, retinal, and brachial artery endothelial measures

	Healthycontrols (n:31)		Hypertensivepatientswithout ED (n:28)		Hypertensivepatientswith ED (n:38)		
	median	25-75 percentile	median	25-75 percentile	median	25-75 percentile	p value
Meanchoroidalthickness (mm)	276	267-287	264	244-274	233	217-241	**<0.001**
FMD percentage (%)	12.5	11.5-13.6	9.8	9.1-10.9	6.5	5.4-7.2	**<0.001**
LV Ejection Fraction (%)	59	55-64	59	54-65	58	52-63	0.92
IVS thickness (mm)	8	8-9	9	8-10	12	9-13	**<0.001**
PW thickness (mm)	8	7-8	8	8-10	10	8-11	**<0.001**
LV mass index (g/m^2)	109	93-128	132	104-153	165	137-188	**<0.001**
Left atrial volume index (ml/m^2)	22.0	18.9-26.5	25.6	22.5-28.4	31.3	26.3-40.9	**<0.001**
E (cm/s)	0.69	0.60-0.77	0.71	0.67-0.84	0.61	0.56-0.81	0.27
A (cm/s)	0.68	0.54-0.78	0.73	0.63-0.87	0.78	0.70-0.90	**0.01**
Mean e′	8.9	6.9-12.0	8.9	7.9-10.5	6.6	5.5-8.9	**<0.001**
Mean a′	10.2	8.4-12.2	10.0	8.7-11.2	10.3	8.4-12.9	0.90
Mean s′	7.9	6.6-9.1	8.0	6.9-9.4	7.3	6.5-8.3	0.26
E/é ratio	7.6	5.9-9.4	8.9	7.2-9.9	10.0	9.0-11.2	**<0.001**

Data are presented as median (interquartile range) and 25-75 percentile. Boldvaluesindicatestatisticalsignificance p<0.05. Abbreviations: ED: endothelial dysfunction; FMD: flow mediated dilation LV: left ventricul; IVS: interventricular septum; E: transmitral peak E velocity; A: transmitral peak A velocity PW: posterior wall.

Echocardiography

LA and LV conventional echocardiographic (B-mode, M-mode, pulse wave, continuous wave and tissue Doppler imaging) and RT3DE measures of the study population are shown in Table 2 and Table 3, respectively. With regard to the 2D-Echo measurements, the major determinants of DD and LV hypertrophy (E/é ratio, LA volume index, LV mass index, interventricularseptal and posterior wall thicknesses) are different.

In the RT3DE analysis of the LA, there were significant differences among three groups in the LA Vmax index, LA

systemic HT (Table 4). The variables of RT3DE-LA TSV index>16ml/m^2, mean choroidal thickness<244m, interventricularseptal wall thickness, LA volume index (2D-Echo), and the E/é ratio were included in the multivariate logistic regression model. Of these, LA TSV index>16ml/m^2, and mean choroidal thickness<244mm were independent predictors of ED (p<0.001, OD: 10.91; $p = 0.006$, OD: 5.11, respectively). ROC curve analysis revealed that LA TSV index>16 ml/m^{2}predicted ED with 86% sensitivity and 93% specificity (area under the curve = 0.96, $p< 0.001$, confidence interval: 0.92–0.99) (Fig. 2a) and also mean choroidal thickness< 244mm predicted ED with 86% sensitivity and 82% specificity (area under the curve =

0.89, $p< 0.001$, confidence interval: 0.82–0.95) (Fig. 2b).

Table 3 Comparison of three dimensional left atrial volumes and mechanical function parameters

	Healthycontrols (n:31)		**Hypertensivepatientswithout ED (n:28)**		**Hypertensivepatientswith ED (n:38)**		
	median	**25-75 percentile**	**median**	**25-75 percentile**	**median**	**25-75 percentile**	**p value**
Vmax index (ml/m^2)	16.9	15.2-19.3	22.8	20.1-24.7	35.4	31.7-38.7	<0.001
Vmin index(ml/m^2)	6.6	5.6-8.1	10.5	8.4-11.8	15.4	13.3-17.4	<0.001
VpreA index(ml/m^2)	11.0	9.0-12.5	16.3	13.7-18.4	25.2	21.8-29.9	<0.001
TSV index(ml/m^2)	9.8	8.9-11.4	11.9	10.8-14.1	20.2	17.4-22.4	<0.001
TEF	0.61	0.54-0.64	0.55	0.50-0.60	0.55	0.53-0.59	0.006
ASV index(ml/m^2)	3.8	3.3-5.0	5.8	4.4-7.2	10.5	8.6-12.6	<0.001
AEF	0.38	0.33-0.40	0.37	0.27-0.44	0.40	0.35-0.44	0.08
PSV index(ml/m^2)	5.8	4.5-7.4	6.3	4.1-8.1	9.3	7.7-11.6	<0.001
PEF	0.36	0.29-0.42	0.29	0.19-0.35	0.26	0.23-0.34	0.001
Left atrium expansion index	1.5	1.1-1.7	1.2	0.9-1.5	1.2	1.1-1.4	0.006

Data are presented as median (interquartile range) and 25-75 percentile. Bold values indicate statistical significance p<0.05. Abbreviations: Vmax: Left atrial maximum volume ; Vmin: Left atrial minimum volume; VpreA: Left atrium preatrial contraction volume; TSV: Left atrium total stroke volume; TEF: Left atrium total emptying fraction; ASV: Left atrium active stroke volume; AEF: Left atrium active emptying fraction; PSV: Left atrium passive stroke volume; PEF: Left atrium passive emptying fraction.

Table 4 Univariate and multivariate logistic regression analysis to determinate the endothelial dysfunction

	univariate logistic regression			**multivariate logistic regression**		
	p	**OD**	**95% CI**	**p**	**OD**	**95% CI**
RT3DE- LA TSV index>16ml/m^2	<0.001	12.6	5.81-27.50	<0.001	10.91	3.17-37.6
Mean choroidal thickness< 244mm	<0.001	5.31	3.05-9.24	0.006	5.11	1.60-16.3
Inter ventricular septalWT (mm)	<0.001	1.67	1.23-2.26	0.77	1.08	0.62-1.86
LA volume index (2D-Echo)	0.001	1.18	1.07-1.31	0.98	1.01	0.86-1.15
E/é ratio	0.005	1.60	1.15-2.22	0.35	1.25	0.77-2.01
Gender (male)	0.54	1.37	0.49-3.84			
Age (years)	0.10	1.04	0.99-1.09			
Low density lipoprotein (mg/dl)	0.98	1.01	0.99-1.01			
Left ventricular mass index (g/m^2)	0.002	1.04	1.02-1.06			
Mean blood pressure (mmhg)	0.23	1.02	0.98-1.06			
Smokers	0.56	0.72	0.24-2.15			
Reported duration of HT (years)	0.001	1.24	1.10-1.41			

Bold values indicate statistical significance p<0.05. Abbreviations: OD: oddsratio; CI: confidenceinterval; LA: left atrium; RT3DE; real time three dimensional echocardiography; TSV: total stroke volume 2D-Echo: two dimensional echocardiography; WT:wall thickness; HT:

DISCUSSION

In our RT3DE based study, we explored the relation between LA volume changes and ED in patients with systemic HT. Thirty-eight hypertensive patients had ED according to brachial artery FMD measurements. LA phasic volumes were increased and LA mechanical functions (reservoir, conduit, and contractile functions) were impaired in hypertensive patients, getting worse with the extent of ED.

In systemic hypertensive patients, increased LV afterload (LV end systolic wall stress) leads to LV and LA remodeling, which cause less compliant LV and LA. By means of this pathophysiologic process LVH occurs and LA phasic volumes increase and LA mechanical functions decrease as an TOD of systemic HT[17, 18]. In our present study the determinant of LV remodeling by 2D-Echo measurements were associated with ED in univariate analysis, but multivariate analysis revealedonly RT3DE measurements of LA phasic volumes (86% sensitivity and 93% specificity) and mean choroidal thickness (86% sensitivity and 82% specificity) as independent predictors of ED. Compared with 2D-Echo, RT3DE is currently the more suited method for assessment and follow up of LA size and function. This is owing to geometric assumptions of biplane volume calculations and inappropriate timing of various atrial events.

Furthermore, LA volumes derived from RT3DE demonstrate good agreement with CMR-derived volumes and have a lower intraobserver variability than 2D-Echo [19, 20].

As far as recent studies are concerned, the prognostic importance of LA size has been validated in large cohorts of normal individualsand in patients with various cardiovascular conditions including ischemic heart disease, LV dysfunction or systemic HT [21-23]. In a 2D-Echo based study, Xu *et al* hasrevealed that FMD was lower in hypertensive patients with LA diameter enlargement. In addition, they asserted enlargement of LA diameter is an important predictor of ED [24]. The enlargement of LA phasic volumes (LA maximum volume, LA minimum volume and LA volume before contraction) and its relation with ventricular diastolic impairment by means of cardiac catheterization and bi-plane cineangiogram in systemic hypertensive patients has also reported [25]. Nowadays LA phasic volumes and mechanical functions have been investigated in several systemic HT studies, but only few of them included the measurement of LA by RT3DE. In a RT3DE based study, the relation between LA volumes and extent of hypertensive retinopathy has been shown [26]. To the best of our knowledge, this is the first study to demonstrate that the extent of the ED, as assessed by brachial artery FMD, is associated with RT3DE-derived LA phasic volumes and mean choroidal thickness in systemic HT patients.

As an important clinical implication of our study was the early determination of TOD by means of RT3DE, OCT, and brachial artery FMD in patients with systemic HT .According to the European Society of Cardiology and the American Heart Association guidelines for the management of arterial HT, an early diagnosis of TOD with an appropriate antihypertensive treatment may decrease both primary and secondary endpoints of systemic HT[27].

Study Limitations

Several limitations of our study merit consideration. The main limitation of our study was the small size of the study population. Due to a lack of data on ambulatory or home BP measurements for the whole study population, only office BP measurements were used in our analyses; this could have confounded the results of the present study.

Antihypertensive medication therapy has a crucial affect on ED [28]. In our statistical analysis, we did not use antihypertensive therapy medication due to lack of registration data.

The LA appendage has a considerable role in the function of the LA, therefore we did not include appendage volume for the calculation of LA function. On account of the shape of the LA appendage, the oblique position of the interatrial septum and asymmetric LA enlargement, calculations may have resulted in some errors.[29] According to several studies, echocardiography systematically tends to underestimate LA volumes when compared to MRI, and the LA appendix volume was not included in our study.[30] Finally, our study could only detect cross-sectional relationships between the studied variables; thus, long-term outcome studies are needed.

CONCLUSION

RT3DE is superior to conventional 2D-Echo in the early determination of LA volume changes and mechanical dysfunctions. Moreover, RT3DE and OCT measurements are independent predictors of ED in patients with systemic HT. This finding provides further evidence for links between the micro- and macrovascular complications of HT. Further studies are needed to clarify the involved pathophysiological mechanisms and explore possible causal relationships.

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How to cite this article:

BaturGonenc Kanar *et al* (2017) 'Relationship Between Left Atrial Volume Changes And Endothelial Dysfunction In Patients With Systemic Hypertension', *International Journal of Current Advanced Research,* 06(12), pp. 8352-8358.
DOI: http://dx.doi.org/10.24327/ijcar.2017.8358.1344

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