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Right Ventricular Function in Patients with Systemic Arterial Hypertension: A Comparative Evaluation with Age-matched Normotensives

Cardiology

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ABSTRACT

Background and Aim: Dysfunction of left ventricular function and accompanying compensatory mechanism in systemic hypertension is well-evidenced. However, much less investigation is done on clinical significance of right ventricular function in systemic hypertension. The two ventricles are anatomically-bound and interdependent on each other, so there is absolute possibility of right ventricular disruption along with left ventricular dysfunction. Thus, aim of the study is to compare right and left ventricular filling dynamics between hypertensive patients and age matched normotensive patients through echocardiography.

Methods: It was a prospective, observational, analytical, single-centre study which enrolled 70 patients with essential systemic hypertension and 40 normal control patients. The study was conducted at Medical and Cardiology Department of Medical College, Pariyaram, Kerala India between August 2012 and August 2013. Blood pressure was determined according to the recommendation of American Heart Association. Complete M-mode, two-dimensional and Doppler echocardiographic studies were performed. Parameters such as left ventricle inner diameter in diastole (LVIDd), left ventricular inner diameter in systole (LVIDs), interventricular septum in diastole (IVSd), left ventricular posterior wall thickness in diastole (LVPWd), right ventricle inner diameter in diastole (RVIDd) and right ventricle anterior wall diameter in diastole (RVAWDd) were measured. Mitral and tricuspid inflow filling parameters were also recorded. Right ventricular systolic function was assessed by measuring tricuspid annular motion (TAM) and mean pulmonary artery pressure (MPAP) was also calculated.

Results: Among patients with systemic hypertension, 63% were males and among 40 normal control patients, 62% were males. Mean age and body mass index were not statistically different between both the groups. Hypertensive patients demonstrated significantly higher dimensions of interventicular septum in diastole (1.4 ± 0.4 cm vs. 0.9 ± 0.3 cm) and left ventricular posterior wall in diastole (1.1 ± 0.3 cm vs. 0.8 ± 0.3 cm) when compared to normal subjects. Right ventricular internal diameter in diastole was higher in hypertensive (3.5 ± 0.4 cm vs. 1.9 ± 0.4 cm) and is statistically significant compared to normotensive. Right ventricular anterior wall diameter in diastole was significantly higher in hypertensives (0.5 ± 0.3 vs. 0.3 ± 0.3 cm). Among right ventricular diastolic filling parameters, peak atrial velocity (A wave) was significantly higher in hypertensive as compared to normotensives (0.4 ± 0.1 m/s vs. 0.3 ± 0.1 m/s). E/A ratio was significantly lower in patients with hypertension (1.2 ± 0.29 vs 1.5 ± .26) than normotensives. E deceleration time (EDT) was also higher in hypertensive than normotensive subjects (190 ± 15 msec vs. 160 ± 14 msec). Tricuspid annular motion (TAM) was almost similar among both hypertensive and normotensive subjects (2.43 ± 2.6 vs. 2.53 ± 3.0), while mean values of non-invasively estimated mean pulmonary artery pressures (MPAP) showed higher values in patients with hypertension (17.72 ± 5.2 mm Hg vs. 15.08 ± 4.8 mm Hg).

Conclusion: Hypertensive patients have significantly abnormal right ventricular filling dynamics and mitral inflow parameters when compared to normotensives. Thus, we can say that right ventricular diastolic dysfunction can be impaired in systemic arterial hypertension similar to left ventricular diastolic function.

Introduction

The clinical significance of left ventricular (LV) function in systemic hypertension is well-known and established (Inouye et al., 1984; Palatini et al., 1995). Systemic hypertension leads to altered left ventricular diastolic filling with diminished early filling and increased late or end-diastolic filling (Myśliński et al., 1998). Moreover, the chronic pressure overload consequently causes left ventricular hypertrophy, which is a protective compensatory response to maintain normal systolic function. These are common echocardiographic findings in hypertensive patients (Myśliński et al., 1998).

The data on right ventricular morphology and function is however, less evidenced. Few studies have conjectured that right sided cardiac abnormalities may occur in patients with systemic hypertension. Of them, some studies have performed echocardiographic assessment of right ventricle and its diastolic function in systemic hypertension (Chakko et al., 1990; Cittadini et al., 1995; Habib et al., 1992). Moreover, the complex anatomy of the right ventricle makes it difficult to scrutinize its morphology and function. The flow measurement across tricuspid valve by Doppler echocardiography acts as marker of right ventricular function. Knowing that two ventricles are anatomically-bound and interdependent on each other, the absolute possibility of right ventricular dysfunction along with left ventricular dysfunction due to chronic pressure overload cannot be ignored (Kelly et al., 1971).

Few studies have reported elevated right chamber pressures, impaired right ventricular systolic function and right ventricular hypertrophy in patients with systemic hypertension (Ferlinz, 1980; Nunez et al., 1987). However the data is scarce, inconsistent and needs further investigation. Thus, the study was designed to compare right and left ventricular filling dynamics between hypertensive patients and age matched normotensive patients through echocardiography.

Methodology

It was a prospective, observational, analytical, single-centre study which enrolled 70 patients with essential systemic hypertension. All the patients who presented to the Medical and Cardiology department of Medical College, Pariyaram, Kerala, India between August 2012 and August 2013 were included. The study was conducted according to the principles of Good Clinical Practice and Declaration of Helsinki. The study was approved by the Institutional Review Board and written informed consent was obtained from all the patients enrolled in the study.

Study population

All the patients with essential hypertension were included except the patients with following conditions: 1) Evidence of secondary hypertension 2) Renal insufficiency 3) Chronic obstructive pulmonary disease 4) Diabetes mellitus 5) Clinical, electrocardiographic or Doppler evidence of valvular heart disease, coronary artery disease or congestive heart failure

Age- and sex-matched normal subjects served as the control group. These subjects were normal volunteers with no evidence of underlying cardiovascular disorder by physical examination.

Blood pressure measurement

Blood pressure was determined at the beginning of each study as the mean of three sphygmomanometer readings, taken 5 minutes apart with the patients in the sitting position according to the recommendation of American Heart Association (Pickering et al., 2005). Amongst the patients, hypertension lasted from 2 – 22 years.

Echocardiographic examination

Complete M-mode, two-dimensional and Doppler echocardiographic studies were performed using Philips EnVisor B 0.2 color Doppler echocardiography machine equipped with 4.2 MHZ transducer.

M-mode and two-dimensional recordings were made with the subjects in the lateral recumbent position according to standardization of American Society of Echocardiography (Henry et al., 1980). Left ventricular dimensions and wall thickness were measured according to the recommendations of American Society of Echocardiography. Right ventricular free-wall thickness was measured in parasternal long axis view using M-mode. RV internal dimensions were measured in apical 4-chamber view at a level just beyond tip of tricuspid valve leaflets. Maximum end-diastolic dimension (RVIDd) of the RV body is defined as width (mm) at the middle third of the right ventricle just beyond the tip of tricuspid valve in apical four chamber view.

Two-dimensionally guided pulsed Doppler interrogation of LV and RV inflow was carried out from the apical four-chamber view. Tricuspid inflow velocities were recorded during end-tidal apnea. The E/A ratios were derived from mitral and tricuspid flow-velocity curves. Deceleration time of E wave (EDT) of both mitral and tricuspid in flow was measured. Isovolumetric relaxation time (IVRT) of mitral inflow was measured. IVRT of tricuspid inflow could not be measured, as it is not possible to align both right ventricular inflow and outflow together. Right ventricular systolic function was assessed by measuring tricuspid annular motion (TAM) in apical 4-chamber view by using M-mode.

Mean pulmonary artery pressure (MPAP) was calculated by measuring pulmonary acceleration time (PAT) using the formula, MPAP = 80 – (PAT/2) (Chan et al., 1987; Kitabatake et al., 1983).

Statistical analysis

Data were evaluated using Statistical Package for Social Sciences (SPSS; Chicago, IL, USA) program, version 15. Continuous variables are presented as mean ± standard deviation while categorical variables are presented as counts and percentages. Comparisons between the variables are done using t-test for independent samples. A *p* value ≤ 0.05 was considered as statistical significant.

Result

A total of 70 patients (53 ± 7 years) with essential systemic hypertension were enrolled in the study. Out of which, 63% were males and among 40 normal control patients, 62% were males. Mean age and body mass index were not statistically different between both the groups. Mean systolic and diastolic blood pressures were significantly higher in hypertensive group. Smokers constituted 33% hypertensive and 27% normotensive group. General baseline characteristics of hypertensive and normotensive groups are outlined in **table 1.**

Table: Baseline characteristics

Characteristics	Normal	Hypertensives	p-value
Patients	40	70	
Age, years	48 ± 8	53 ± 7	NS
BMI, kg/m^2	25.6 ± 3.7	26.5 ± 2.8	NS
SBP, mm Hg	122 ± 10	150 ± 18	<0.001
DBP, mm Hg	71 ± 9	103 ± 9	<0.001

SBP - systolic blood pressure, DBP - diastolic blood pressure

Left atrial and aortic root dimensions were on higher side when compared to normotensives. Left ventricular dimensions, both systolic and diastolic, were almost similar between normotensives and hypertensives. Also, left ventricular ejection fraction (69.1 ± 6.6% vs. 72.0 ± 5.4%) was almost similar between both the groups. Hypertensive patients demonstrated significantly higher dimensions of interventicular septum in diastole (1.4 ± 0.4 cm vs. 0.9 ± 0.3 cm) and left ventricular posterior wall in diastole (1.1 ± 0.3 cm vs. 0.8 ± 0.3 cm) when compared to normal subjects. LV mass index was also significantly higher in hypertensives when compared to normotensives. The detailed results of left atrial and ventricular dimensions in hypertensive and normal subjects are reported in **table 2.**

Table : Left atrial and ventricular dimension by M-mode echocardiography

Characteristics	Normal	Hypertensives	*p*-value
LA size, cm	3 ± 0.3	3.5 ± 0.4	<0.001
Aortic root, cm	2.8 ± 0.3	3.7 ± 0.3	<0.001
LVIdD, cm	4.5 ± 0.4	4.7 ± 0.3	0.07
LVIdS, cm	3.1 ± 0.3	3.3 ± 0.3	0.06
EF, %	69.1 ± 6.6	72.0 ± 5.4	0.05
IVSd, cm	0.9 ± 0.3	1.4 ± 0.4	<0.001
LVPWd, cm	0.8 ± 0.3	1.1 ± 0.3	<0.001
LV mass index, gm/m^2 (males)	86 ± 6.6	136 ± 7.2	<0.001
LV mass index, gm/m^2 (females)	77 ± 5.5	123 ± 4.3	<0.001

LA - Left atrial, LVIDd – left ventricle inner diameter in diastole, LVIDs – left ventricle inner diameter in systole, EF – ejection fraction, IVSd – interventricular septum in diastole, LVPWd – left ventricle posterior wall thickness in diastole, LV- left ventricle

Right ventricular internal diameter (RVIDd) in diastole was higher in hypertensive (3.5 ± 0.4 cm vs. 1.9 ± 0.4 cm) and is statistically significant compared to normotensive. Right ventricular anterior wall diameter in diastole (RVAWDd) was significantly higher in hypertensives (0.5 ± 0.3 cm vs. 0.3 ± 0.3 cm). Right ventricular dimensions are also outlined in **table 3.**

Table : Right ventricular dimensions by M-mode echocardiography

Characteristics	Normal	Hypertensives	*p*-value
RVIDd, cm	1.9 ± 0.4	3.5 ± 0.4	<0.001
RVAWDd, cm	0.5 ± 0.3	0.3 ± 0.3	<0.001
RV free wall thickness, cm	2.8 ± 0.3	3.7 ± 0.3	<0.001

RVIDd – right ventricle internal diameter in diastole, RVAWDd – right ventricle anterior wall diameter in diastole, RV – right ventricle

Pulsed Doppler echocardiographic examination of mitral inflow showed mean E/A ratio 0.9 in hypertensives as compared to 1.4 in normal patients. Mean E deceleration time (EDT) (230 ± 19 msec vs. 170 ± 17 msec) and mean isovolumetric relaxation time (IVRT) (116 ± 9 msec vs. 74 ± 11 msec) was significantly higher in hypertensives when compared to normotensives. The mitral inflow filling parameters are described in **table 4**

Table 4 : Mitral inflow filling parameters in Doppler echocardiography

Characteristics	Normal	Hypertensives	*p*-value
Mitral E/A ratio	1.4	0.9	<0.001
EDT, (msec)	170 ± 17	230 ± 19	<0.001
IVRT, (msec)	74 ± 11	116 ± 9	<0.001

E – peak early velocity, A – peak atrial velocity, EDT – E deceleration time, IVRT – isovolumetric relaxation time

Among right ventricular diastolic filling parameters described in **table 5**, peak early velocity (E wave) was not significantly different between hypertensive and normotensive subjects. Peak atrial velocity (A wave) was significantly higher in hypertensive as compared to normotensives (0.4 ± 0.1 m/s vs. 0.3 ± 0.1 m/s). E/A ratio was significantly lower in patients with hypertension (1.2 ± 0.29 vs 1.5 ± .26) than normotensives. E deceleration time (EDT) was also higher in hypertensive than normotensive subjects (190 ± 15 msec vs. 160 ± 14 msec).

Table 5: Tricuspid inflow filling parameters by Doppler echocardiography

Characteristics	Normal	Hypertensives	*p*-value
E wave, m/s	0.5 ± 0.1	0.46 ± 0.1	0.08
A wave, m/s	0.3 ± 0.1	0.41 ± 0.1	0.01
E/A ratio	1.5 ± 0.3	1.2 ± 0.3	0.01
EDT, msec	160 ± 14	190 ± 15	<0.001

E – peak early velocity, A – peak atrial velocity, EDT – E deceleration time

Tricuspid annular motion (TAM) was almost similar among both hypertensive and normotensive subjects (2.43 ± 2.6 cm vs. 2.53 ± 3.0 cm). Mean values of non-invasively estimated mean pulmonary artery pressures (MPAP) showed higher values in patients with hypertension (17.72 ± 5.2 mm Hg vs. 15.08 ± 4.8 mm Hg). These results are organized in **table 6**.

Table 6 : Tricuspid annular motion and mean pulmonary artery pressure

Characteristics	Normal	Hypertensives	*p*-value
TAM, cm	2.53 ± 3.0	2.43 ± 2.6	NS
MPAP, mm Hg	15.08 ± 4.8	17.72 ± 5.2	0.06

TAM – Tricuspid annular motion, MPAP – mean pulmonary artery pressure

Discussion

The study aimed to evaluate and compare left and right ventricular filling dynamics and patterns in hypertensive and normotensive patients. Our study demonstrated that hypertensive patients have an increased right ventricular anterior wall diastolic diameter (RVAWd). Of them 43% had RVAWd more than 5 mm, the upper limit of RVAW diastolic thickness. Gottdiener et al. found that in healthy patients average RVAWd thickness was 4 ± 1 mm (range 3 – 5 mm) measured from parasternal window (Gottdiener et al., 1985). In this study also only the parasternal view and high quality recordings were taken for measurements.

LV mass index significantly differed in both the groups indicating left ventricular hypertrophy. LV hypertrophy and propensity of right ventricular wall thickening suggest the influence of systemic hypertension on both the ventricles. A study by Nunez et al. demonstrated right ventricular hypertrophy in hypertensive patients. In addition, it also showed that in patients with left ventricular hypertrophy, the right ventricular wall was significantly thicker compared to patients without left ventricular hypertrophy (Nunez et al., 1987).

Doppler examination is one of the useful modality for estimating left and right ventricular filling dynamics. Predominant early diastolic filling wave and atrial filling wave, separated by minimal flow during diastasis are usually observed in healthy subjects with sinus rhythm (Thomas et al., 1991). In our Doppler echocardiographic study, we demonstrated significant difference between normotensive and hypertensive regarding parameters of right ventricular diastolic filling similar to left ventricular filling especially for 'A' wave velocity and E/A ratio. E deceleration time was also significantly higher in hypertensives. Increased A wave velocity, diminished E: A ratio and increased E deceleration time reflects impaired RV relaxation (Tumuklu et al., 2007).

RV diastolic filling parameters correlate with corresponding LV filling parameters. This may suggest that interventricular septum, common for both ventricles, may play an important part in RV diastolic dysfunction. Goldstein et al. demonstrated interactions between ventricular function and interventricular septum performance during acute heart ischemia (Goldstein et al., 1992). Although, this study did not assess, a study by Habib et al. reported that a weak significant correlation exists between RV wall thickness and RV peak late inflow velocity in hypertensive patients (Habib & Zoghbi, 1992). This suggests that RV wall thickening may be of importance to RV diastolic function, but it is not a single factor affecting ventricular filling abnormalities.

We also found increased values of MPAP in hypertensive patients but not beyond the cut-off value for pulmonary arterial hypertension. The elevation of MPAP may be the conseqeunce of increased pulmonary artery wedge pressure. A study in hypertensive subjects by Olivari et al. reported increased values of pulmonary artery pressures, pulmonary arteriolar resistance and pulmonary artery wedge pressure (Olivari et al., 1978).

Tricuspid annular motion, which is considered as an important marker of global systolic RV function, was not found to be significantly different between both the groups. A similar insignificance was obtained in studies by Cicala et al. and Tumuklu et al. (Cicala et al., 2002; Tumuklu et al., 2007). This can be due to comparatively younger individuals enrolled in the study as one of the factor affecting reduction in TAPSE include elder age.

The results of our study demonstrate the involvement of the right ventricle in systemic hypertension and the relationship between right and left ventricular function. Thus, the assessment of RV performances may be an additional, sensitive indicator of the course of hypertensive disease.

Study limitation

We assessed RV flow through tricuspid valve using the apical four chambers or alternatively, the parasternal short axis view. This may have resulted in different position of volume sample. Recorded value of flow depends on the position of the volume sample. The inspiration enhances RV and decreases LV filling velocities. All Doppler measurements were obtained at the end of expiration. Moreover, the sample population is smaller to draw any conclusion completely and the study should be carried out in much larger patient population

Conclusion

Hypertensive patients have significantly abnormal right ventricular filling dynamics and mitral inflow parameters when compared to normotensives. Right ventricular systolic function as determined by tricuspid annular motion is not different between hypertensives and normotensives. Thus, we can say that right ventricular diastolic dysfunction can be impaired in systemic arterial hypertension similar to left ventricular diastolic function.

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