Original Article

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Physiology Section

Left Ventricular Systolic Dysfunction among Hypertensive Subjects

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ABSTRACT

Introduction: Hypertension has been established as one of the most significant causes of heart failure. Left ventricular function is a useful measure in the assessment and prognostication of heart disease.

Aim: To determine the prevalence of Left Ventricular Systolic Dysfunction (LVSD) in hypertensive patients and assess the echocardiographic characteristics associated with LVSD.

Materials and Methods: After obtaining informed consent, 650 eligible adults of age ≥18 years attending cardiology OPD diagnosed to have essential hypertension with or without medication were included in the study. Using a predesigned structured questionnaire, details of demographic characteristics and echocardiographic data were obtained from the study participants.

Results: The prevalence of LVSD was 136 (20.9%) in the study population {mild LVSD 78 (12%), moderate LVSD 40 (6.2%), severe LVSD 18 (2.8%)}. In Analysis of Variance (ANOVA), variables such as blood pressure, body surface area, size of left atrium and ventricle, relative wall thickness, stroke volume, left ventricular mass index, diastolic function, ejection fraction, fractional shortening were significantly associated with moderate-severe LVSD.

Conclusion: Higher prevalence of LVSD among hypertensive subjects in this study advocates for use of echocardiography as part of routine evaluation in hypertensive patients.

Keywords: Echocardiography, Ejection fraction, Left ventricular mass, Stroke volume

INTRODUCTION

Globally cardiovascular diseases contribute to major amount of health problems, and hypertension is the most significant risk factor for cardiovascular diseases [1]. In southern Asia, hypertension is considered as the third most important risk factor for attributable burden of disease [2]. It is predicted that by 2025, more than 1.5 billion people will have arterial hypertension worldwide [3,4]. In the year 2001, hypertension was estimated to be responsible for 7.6 million deaths and 92 million disability adjusted life years worldwide [5,6]. In India, hypertension contributes 57% of all stroke deaths and 24% of all Coronary Heart Disease (CHD) deaths [7]. Systemic hypertension as a hypertensive heart disease is a common cause of Left Ventricular Hypertrophy (LVH), systolic and diastolic dysfunction, arrhythmias, and decompensated heart failure [8]. Early identification of symptomless ventricular dysfunction in individuals helps in the treatment by Angiotensin Converting Enzyme (ACE) inhibitors and prevention of heart failure. The ability to measure the abnormalities of left ventricular function is important for both the initial detection of heart failure and for monitoring changes in severity. Echocardiography is helpful in evaluating multiple systolic and diastolic properties of the left ventricle [9,10].

In India, information regarding prevalence of LVSD and associated echocardiographic characteristics among hypertensive patients is scarce [11,12]. The present study was therefore undertaken to determine the prevalence of LVSD in hypertensive patients and assess the echocardiographic characteristics associated with LVSD.

MATERIALS AND METHODS

This cross sectional study was conducted in Institute of Medical Sciences and SUM hospital, Bhubaneswar, at the Department of Cardiology/Physiology during the period from May 2015 to June 2017. Assuming prevalence of LVSD as 18% [5] with absolute precision 3% and 95% confidence interval, the sample size was calculated as 630. However, 650 adults of age ≥18 years, attending cardiology OPD diagnosed to have essential hypertension with or without medication; who were willing to participate were included in our study. All the study participants were explained about the nature and purpose of the study; informed consent was obtained prior to their participation in the study. The study was approved by the Institutional Ethics Committee of the authors' institution and all procedures were followed in accordance with appropriate ethical guidelines. Using a predesigned structured questionnaire, details of demographic characteristics and echocardiographic data were obtained from all the eligible study individuals. Patients with secondary hypertension, diabetes mellitus, coronary insufficiency, pulmonary heart disease (cor pulmonale), congestive heart failure, and renal failure were excluded from the study.

Height of the study respondents was measured with a stadiometer and the reading was taken to the nearest 0.5 cm and body weight was measured with bare feet and in light clothes on a calibrated scale. Body Mass Index (BMI) was calculated as the weight in kilograms divided by square of the height in meters. BMI cut-off values for Asians as per the NICE guideline were followed to define obesity as having a BMI more than 27.5 kg/m^2, overweight 23-27.5 kg/m^2, normal 18.5-23 kg/m^2 and underweight ≤18.5 kg/m^2 [13]. Body Surface Area (BSA) calculation was done using Dubois formula {BSA=0.007184×0.725 (height)×0.425 (weight)} [14]. Hypertension was defined as per JNC7 guidelines [15]. Blood pressure was measured using a standardised calibrated mercury column type sphygmomanometer with subject in sitting position. Two separate measurements were done at five minutes apart and the average of the two reading was recorded.

Echocardiography was performed using a commercially available GE vivid E9 with XD clear (Echocardiography machine-GE VINGMED ULTRASOUND AS Norway, equipped with a broad band transducer) in patients in supine left lateral decubitus position. All echocardiographic measurements were performed by a cardiologist. Echocardiography was performed as per American Society of Echocardiography guidelines [16]. Left Atrial (LA) and Left Ventricular (LV) volume, LV end-diastolic and end-systolic diameter, septal and LV posterior wall thicknesses in diastole and systole were obtained using standard M-mode recordings and 2-Dimensional (2D) imaging. LV mass was determined using the method described by Devereux RB [9] and LV Mass Index (LVMI) was calculated dividing LV mass by body surface area. Left ventricular systolic performance was assessed using the fractional shortening of the left ventricle and the ejection fraction. Left Ventricular Ejection Fraction (LVEF) was calculated using the Teichholz formula [17]. As per the protocol followed in the Department of Cardiology of the authors' institution, LVSD is diagnosed by the echocardiography instrument using Teichholz formula. Fractional shortening was calculated from LV internal dimensions in diastole and systole (Fractional shortening=LVIDd-LVIDs/LVIDd×100, where LVIDd=Left ventricular internal diameter at end diastole, LVIDs=Left ventricular internal diameter at end systole). Relative Wall Thickness (RWT) was derived from 2×LVPWd/LVIDd (where LVPWd=Left ventricular posterior wall thickness in diastole). RWT was considered as increased when it is >0.42 [9]. Conventional doppler tracings of the mitral inflow were obtained from an apical 4-chamber view. For each parameter, the average of 3 cycles was used.

Subjects were categorised into four groups according to their LVEF [18] as normal LV systolic function (LVEF=52-72% in men and 54-74% women), mild LV systolic dysfunction (LVEF=41-51% in men and 41-53% in women), moderate LV systolic function (LVEF=30-40% both in men and women), and severe LV systolic dysfunction (LVEF <30% both in men and women). Stroke Volume (SV) was calculated by the formula EDV-ESV, where EDV=End Diastolic Volume and ESV=End Systolic Volume.

STATISTICAL ANALYSIS

All the data were compiled and analysed using SPSS version 21.0 software. Continuous variables were expressed as mean±SD while categorical variables were expressed as percentages. Student's t-test was used for comparison between two groups and ANOVA with Games Howell post-hoc test was used for comparisons between multiple groups. A two-tailed p-value <0.05 was considered statistically significant.

RESULTS

Data for 650 study subjects 398 (61.2%) males and 252 (38.8%) females were analysed. [Table/Fig-1] shows the demographic characteristics of the three groups of subjects categorised according to their left ventricular systolic function. About 136 (20.9%) of the study participants had LVSD {(mild LVSD=78 (12%), moderate LVSD=40 (6.2%), severe LVSD=18 (2.8%)}. It was observed that LVSD was more prevalent (87, 21.9%) in males than females (49, 19.4%). The overall mean values for age, BMI, BSA, Systolic Blood Pressure (SBP), Diastolic Blood Pressure (DBP), Mean Arterial Pressure (MAP) and Pulse Pressure (PP) of the study subjects were 50.4±12.9, 26.6±4.2, 1.6±0.1, 148.0±9.7, 94.3±5.0, 112.2±6.1, and 53.6±7.0 respectively. Subjects with normal left ventricular systolic function or mild dysfunction had significantly lower BMI, SBP, DBP and MAP compared to those with moderate-severe LVSD whereas subjects with normal LVSF had significantly higher DBP and BSA than those with mild LVSD.

As observed in [Table/Fig-2], aortic root diameter, left atrial diameter, left ventricular internal diameter both in systole and diastole, end systolic and end diastolic volume, LV mass and LV mass index were significantly higher in subjects with moderate-severe LVSD than the other two groups. The LVPWT in systole (p=0.003), RWT (p<0.001), EF (p<0.001) and FS (p<0.001) were highest in subjects with normal LV systolic function compared to those with mild/moderate-severe LVSD (p<0.01). Further, subjects with moderate-severe LVSD had significantly worse diastolic function (highest mitral E/A ratio (p 0.038) compared to those with normal LVSF.

[Table/Fig-3] describes that male subjects had significantly higher aortic root diameter, left atrial diameter, inter ventricular septal thickness and LV posterior wall thickness both in systole and diastole, end systolic and end diastolic volume, stroke volume, LV mass and LV mass index and lower fractional shortening compared to females.

Variable	Normal LV systolic function (n=514) (Mean±SD)	Mild LV systolic dysfunction (n=78) (Mean±SD)	Moderate/ Severe dysfunction (n=58) (Mean±SD)	p-value*
Age (years)	49.6±12.9	53.1±12.3	53.6±12.6	0.012§
BMI (kg/m²)	26.6±4.2	25.9±3.9	28.0±4.0†,‡	0.017
SBP (mmHg)	147.5±9.1	147.4±9.7	152.7±13.7†,‡	0.022
DBP (mmHg)	94.2±4.9	92.7±3.6†	97.0±6.8†,‡	0.000
PP (mmHg)	53.3±6.5	54.6±7.8	55.7±9.5	0.080
MAP (mmHg)	112.0±5.8	110.9±5.1	115.6±8.6†,‡	0.002
BSA (m²)	1.63±0.15	1.59±0.13†	1.66±0.13‡	0.012

[Table/Fig-1]: Demographic characteristics of study participants categorised according to Left ventricular function (n=650).
BMI: Body mass index; SBP: Systolic blood pressure; DBP: Diastolic blood pressure; PP: Pulse pressure; MAP: Mean arterial pressure; BSA: Body surface area
*p<0.05 statistically significant with ANOVA
†p<0.05 vs. normal left ventricular systolic function
‡p<0.05 vs. mild left ventricular systolic function
§Statistically significant with ANOVA, but not significant with Games-Howell post-hoc test

Variable	Normal LV systolic function (n=514) Mean±SD)	Mild LV systolic dysfunction (n=78) (Mean±SD)	Moderate/ Severe dysfunction (n=58) (Mean±SD)	p-value*
AoRD (cm)	2.94±0.51	2.86±0.48	3.14±0.49†,‡	0.005
LAD (cm)	3.29±0.56	3.53±0.85‡	3.98±0.82†,‡	<0.001
AV cusp (cm)	1.56±0.26	1.54±0.24	1.63±0.20†,‡	0.063
IVSTd (cm)	1.20±0.23	1.13±0.19†	1.14±0.28	0.010
LVIDd (cm)	4.27±0.60	4.21±0.91	5.32±0.98†,‡	<0.001
LVPWTd (cm)	1.27±0.29	1.21±0.22	1.19±0.25	0.043§*
IVSTs (cm)	1.40±0.26	1.31±0.26†	1.28±0.28†	<0.001
LVIDs (cm)	2.74±0.46	3.10±0.86†	4.49±0.97†,‡	<0.001
LVPWTs (cm)	1.47±0.30	1.41±0.27	1.35±0.26†	0.003
RWT	0.60±0.20	0.59±0.15	0.47±0.14†,‡	<0.001
EDV (mL)	84.94±28.41	87.35±40.79	139.86±56.81	<0.001
ESV (mL)	30.73±12.30	46.97±23.31†	95.86±45.28†,‡	<0.001
SV (mL)	54.22±18.79	40.37±17.81†	44.0±16.93†	<0.001
LVM (g)	235.66±87.73	226.87±95.50	298.55±122.20†,‡	0.001
LVMI (g/m²)	143.20±47.39	140.97±54.46	179.09±67.74†,‡	0.001
EF (%)	63.71±6.48	46.84±3.28†	32.82±7.12†,‡	<0.001
FS (%)	35.64±5.96	26.89±9.58†	15.41±9.19†,‡	<0.001
MV E/A ratio	1.09±0.48	1.17±0.68	1.43±1.04†	0.038

[Table/Fig-2]: Echocardiographic characteristics of study participants categorised according to left ventricular systolic function (n=650).
AoRD: Aortic root diameter; LAD: Left atrium diameter; AV: Aortic valve; IVSTd: Interventricular septal thickness in diastole; LVIDd: Left ventricular internal diameter in diastole; LVPWTd: Left ventricular posterior wall thickness in diastole; IVSTs: Interventricular septal thickness in systole; LVIDs: Left ventricular diameter in systole; LVPWTs: Left ventricular posterior wall thickness in systole; RWT: Relative wall thickness; EDV: End diastolic volume; ESV: End systolic volume; SV: Stroke volume; LVM: Left ventricular mass; LVMI: Left ventricular mass index; EF: Ejection fraction; FS: Fractional shortening; MV E/A: Mitral valve early diastolic filling wave/late diastolic filling wave
*p<0.05 statistically significant with ANOVA, †p<0.05 vs. normal left ventricular systolic function, ‡p<0.05 vs. mild left ventricular systolic function, §Statistically significant with ANOVA, not significant with Games-Howell post-hoc test

Variable	Male (n=398) Mean±SD)	Female (n=252) (Mean±SD)	p-value*
AoRD (cm)	3.04±0.50	2.81±0.49	<0.001
LAD (cm)	3.49±0.67	3.22±0.61	<0.001
AV cusp (cm)	1.59±0.26	1.53±0.25	0.007
IVSTd (cm)	1.23±0.25	1.12±0.19	<0.001
LVIDd (cm)	4.48±0.76	4.16±0.66	<0.001
LVPWTd (cm)	1.30±0.31	1.18±0.21	<0.001
IVSTs (cm)	1.43±0.27	1.31±0.24	<0.001
LVIDs (cm)	3.06±0.79	2.77±0.71	<0.001
LVPWTs(cm)	1.49±0.29	1.40±0.28	<0.001
RWT	0.59±0.23	0.58±0.13	0.270
EDV (mL)	96.13±38.95	80.66±31.25	<0.001
ESV (mL)	41.48±28.43	33.77±23.08	<0.001
SV (mL)	54.65±20.12	46.89±16.55	<0.001
LVM (g)	262.95±98.28	204.31±73.59	<0.001
LVMI (g/m²)	156.77±53.71	129.35±42.34	<0.001
EF (%)	58.57±12.03	59.50±10.99	0.317
FS (%)	32.11±9.78	33.86±8.00	0.018
MV E/A ratio	1.09±0.57	1.18±0.60	0.089

[Table/Fig-3]: Gender wise distribution of echocardiographic characteristics among study participants (n=650).
AoRD: Aortic root diameter; LAD: Left atrial diameter; AV: Aortic valve; IVSTd: Interventricular septal thickness in diastole; LVIDd: Left ventricular internal diameter in diastole; LVPWTd: Left ventricular posterior wall thickness in diastole; IVSTs: Interventricular septal thickness in systole; LVIDs: Left ventricular internal diameter in systole; LVPWTs: Left ventricular posterior wall thickness in systole; RWT: Relative wall thickness; EDV: End diastolic volume; ESV: End systolic volume; SV: Stroke volume; LVM: Left ventricular mass; LVMI: Left ventricular mass index; EF: Ejection fraction; FS: Fractional shortening; MV E/A: Mitral valve early diastolic filling wave/late diastolic filling wave
*p<0.05 statistically significant with ANOVA

DISCUSSION

The burden of LVSD in hypertensive subjects is largely unknown in India. Our study revealed that about 21% of hypertensive patients had LVSD and the prevalence was higher in men than in women. The prevalence of LVSD observed in our study (21%) is higher compared to 6.7%, 14%, 18.1% as reported in other studies [5,19,20]. However, higher prevalence of LVSD varying from 24.3% to 34.0% has been observed in other studies [21,22]. BMI was found to be more among subjects with moderate-severe LVSD compared to those having normal or mild dysfunction. The relationship between LVSF and BMI was also reported in other studies [19,20]. However, Ogah OS et al., showed that BMI decreased from subjects with normal LVSF to those with severe LVSD [5]. We observed significant association of blood pressure with LVSF which is contrasted by other investigators [5,19,20].

In this study, aortic root diameter was significantly higher in subjects with moderate-severe LVSD than the other two groups. This finding is not in consistency with other studies [5,19]. The left atrial size and left ventricular size were found to be related to LVSF; the larger the left atrium or left ventricle, the poorer the LVSF. Similar findings have been reported in other literatures [5,19,20]. We also observed that relative wall thickness, stroke volume, ejection fraction and fractional shortening were lower among subjects with LVSD whereas LVM, LVMI and MV E/A ratio increased with LVSD. These findings are supported by the results of other studies [5,19].

The present study revealed that almost all the echocardiographic parameters were higher in male participants as compared to females except ejection fraction and fractional shortening. Adebiyi AA et al., also reported similar result [23]. Previous studies reported worse LVSF among males than females [5,19,24] which is similar to result of our study although it is statistically not significant. However, ejection fraction and MV E/A ratio did not differ significantly in both genders. This finding is supported in other study [25].

LIMITATION

There were certain limitations in this study. It was a hospital based study and thus the findings of the study cannot be generalised to the general population. We could not conduct the metabolic function tests such as blood glucose, lipid, uric acid etc., due to lack of funds. As certain diseases were excluded based on clinical history, this might introduce bias. In spite of these limitations, our study has important implications. The higher prevalence of LVSD among study participants advocates for use of echocardiography in asymptomatic hypertensive patients. This might help in early detection and management of LVSD and thereby delaying the progression to symptomatic heart failure.

CONCLUSION

The present study revealed that one in every five hypertensive patients had LVSD. Hence, echocardiography should be part of the routine evaluation of hypertensive patients to help in early detection and management of LV systolic dysfunction, so that further complications can be prevented.

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