Original Research Article

Echocardiography in assessment of left ventricular diastolic dysfunction in patients with pulmonary arterial hypertension

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Abstract

Background: Chronic obstructive pulmonary disease is a leading cause of morbidity and mortality in adults all over the world. While other major causes of non-cancer mortality such as coronary artery disease and stroke have shown a consistent downward trend, COPD is the only one that continues to increase. **Amis and objectives:** To study Echocardiographic assessment of left ventricular diastolic dysfunction in patients with pulmonary arterial hypertension **Materials and method:** The present study was conducted in the department of Cardiology at Sher-I-Kashmir Institute of Medical Sciences, Soura, Srinagar for the two year duration. Thirty five consecutive patients of any age with different severity of pulmonary arterial hypertension due to chronic obstructive airway disease (emphysema and chronic bronchitis) constituted the study group (Group-I) and were labeled as "cases". Pulmonary arterial hypertension was diagnosed in them as presence of right ventricular systolic pressure of more than or equal to 40mmHg. **Results:** Patients with pulmonary arterial hypertension had similar aortic and left atrial dimensions as the control group. Left ventricular internal diameters, particularly the systolic diameter, were decreased in patients with pulmonary hypertension than corresponding dimensions in healthy volunteers. Similarly, left ventricular end-diastolic and end-systolic volumes were significantly reduced in cases as compared to the control group. Left ventricular ejection fraction and fractional shortening were both significantly higher in patients with pulmonary hypertension as compared to the controls. Left ventricular posterior wall and interventricular septum were similar in thickness in both the groups. However, the interventricular septal motion was paradoxical in 15 (42%) of cases and was normal in controls. Right ventricular dimensions were significantly higher in the pulmonary hypertension group as compared to the controls (p=0.000). **Conclusion:** Thus we conclude that patients with pulmonary hypertension secondary to chronic obstructive pulmonary disease have reduced left ventricular internal dimension and that this reduction bears a relation with the level of respiratory compromise and with the severity of pulmonary hypertension. However, left ventricular systolic function is well preserved in these patients irrespective of the severity of lung disease. On the other hand, left ventricular diastolic function is abnormal in patients with pulmonary hypertension as compared to normal age- and sex-matched control population.

Key Word: Echocardiography, left ventricular diastolic dysfunction, pulmonary arterial hypertension

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INTRODUCTION

Chronic obstructive pulmonary disease is a leading cause of morbidity and mortality in adults all over the world. While other major causes of non-cancer mortality such as coronary artery disease and stroke have shown a consistent downward trend, COPD is the only one that continues to increase.[1] In the United States, in the year 2000, COPD was a major cause for health care utilisation with 8 million physician office/ hospital outpatient visits,

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1.5 million emergency department visits, and 673,000 hospitalisations.[2] The epidemiological scenario is expected to worsen and the World Health Organization predicts that COPD will become the third leading cause of death (currently fourth) and the fifth leading cause of disability (currently twelfth) worldwide by the year 2020.[3,4] Pulmonary hypertension in COPD progresses over time and its severity correlates with the degree of airflow obstruction and the impairment of pulmonary gas exchange.[5,6] However, the rate of progression of pulmonary hypertension in COPD is slow and usually Ppa is only moderately elevated, even in patients with advanced disease.[6] Pulmonary hypertension (PH), defined as an elevated mean pulmonary arterial pressure (mPAP) ≥25mmHg, is a common complication of chronic lung disease (CLD). PH often progresses to right heart failure (RHF), with initial compensatory right ventricular (RV) hypertrophy becoming overwhelmed by increased systolic requirements, whilst left ventricular (LV) systolic function remains preserved. The term “cor pulmonale” has been used to describe this form of RHF and hypertrophy. It is a progressive condition, associated with increased mortality in CLD. The World Health Organization (WHO) has classified PH into five groups based on their pathological and haemodynamic characteristics7. This review will focus on group 3 PH secondary to lung diseases and/or hypoxia and its effects on RV. Patients with chronic obstructive pulmonary disease (COPD), interstitial lung disease (ILD), and sleep-disordered breathing (SDB) or obstructive sleep apnoea (OSA) account for majority of the cases in this group8. The pathophysiology of PH in CLD is complex and multifactorial. Increased tone of small pulmonary arteries is the result of hypoxic pulmonary vasoconstriction, capillary endothelial and smooth muscle proliferation, and muscularization of previously nonmuscular arteries9. Hypoxia and chronic inflammation are the main factors driving vasoconstriction, vascular remodelling, and PH.[10,11]

AMIS AND OBJECTIVES

To study Echocardiographic assessment of left ventricular diastolic dysfunction in patients with pulmonary arterial hypertension

MATERIALS AND METHOD

The present study was conducted in the department of Cardiology at Sher-I-Kashmir Institute of Medical Sciences, Soura, Srinagar for the two year duration. Thirty five consecutive patients of any age with different severity of pulmonary arterial hypertension due to chronic obstructive airway disease (emphysema and chronic bronchitis) constituted the study group (Group-I) and were labeled as "cases". Pulmonary arterial hypertension was diagnosed in them as presence of right ventricular systolic pressure of more than or equal to 40 mmHg12. Thirty five normal subjects who were matched for age and sex constituted the other group (Group-II or "controls"). The patients in our study were clinically stable and medications such as inhaled steroids, (3-2 agonists and the ophylline were continued. Complete hemogram including hemoglobin, total leukocyte count, differential leukocyte count, platelet count, and the hematocrit was performed in all the selected patients in both the groups. Liver function tests and Kidney function test was also performed. X-ray chest (PA view) to determine the cardiothoracic ratio, the size of pulmonary arteries and the lung parenchyma was done. Electrocardiograph including all 12leads and Pulmonary function tests to measure Forced Expiratory Volume in first second (FEV1) and Forced Vital Capacity (FVC). The ratio of FEV1 to FVC was noted down. Arterial blood gas analysis to measure the PaO2, PaCO2, pH and the oxygen saturation was done. All patients and controls were made to undergo two-dimensional and M-mode echocardiography and Doppler examinations by a cardiologist who was blinded to the group status of the individual subjects. After properly explaining the procedure to subject, a phased array transducer was placed in standard transthoracic locations and examination performed using a commercially available echocardiograph (TOSHIBA P0WERV1S1ON UZR 1, Model No: SSA 380A, Tokyo. Japan). .All the examinations were performed in partial left lateral decubitus position with careful attention being paid to gain and filter settings to obtain clear images from endocardial and epicardial surfaces. Echocardiography measurements were taken as per the recommendations of American Society of Echocardiography13. Diastolic functions of left ventricle were assessed using pulsed Doppler at the tip of mitral valve. The peak velocities (mseci of the early (E-wave) and late (A wave) left ventricular filling and the deceleration time (dt, m sec) of E velocity from its peak to the baseline were recorded with pulsed Doppler sampling at the mitral in flow and a slight verier tilt to the transducer for simultaneously catching the left ventricular outflow signal, the isovolumic relaxation time (IVRT, msec) was measured from the end of left ventricular outflow signal to the beginning of “E” wave. The SPSS (Statistical Package for Social Sciences) for Windows (version 10.0) was used for data analysis. The tests used included the student's t-test, the chi-square test and bivariate (Pearson) correlation analysis. All the data are presented as mean±SD unless indicated otherwise. A P value of <0.05 was taken as the criterion of statistical significance.

RESULTS

Table 1: Echocardiography findings in the study population

	Cases (n=35)	Controls(n=35)	p value
Aorta (cm)	2.87±0.53	2.97±0.43	0.370
LA (cm)	3.13±0.67	3.08±0.75	0.800
LVIDd (cm)	3.85±1.04	4.14±0.78	0.187
LVIDs (cm)	2.30±0.76	2.73±0.53	0.008
LVEDV (mL)	75.03±43.89	94.99±25.75	0.024
LVESV (mL)	20.61±20.89	33.36±11.75	0.003
LVSV (mL)	53.90±28.40	63.56±15.92	0.085
LVEF (%)	75.09±8.28	68.71±8.63	0.002
LVFS (%)	47.54±9.06	40.03±5.39	0.000
LVPWd (cm)	1.48±0.49	1.50±0.32	0.820
LVPWs (cm)	1.02±0.36	1.05±0.30	0.708
IVSd (cm)	1.49±0.29	1.43±0.30	0.404
IVSs (cm)	1.08±0.30	1.04±0.22	0.534
IVS motion (paradoxical)	15 (42.8%)	0	
RV flat (cm)	3.05±0.81	2.17±0.36	0.000

LA = left atrium; LVIDd= left ventricular internal diameter diastolic; LVIDs = left ventricular internal diameter systolic; LVEDV= left ventricular end-diastolic volume; LVESV= left ventricular end-systolic volume; LVSV= left ventricular stroke volume; LVEF= left ventricular ejection fraction; LVFS= left ventricular fractional shortening; LVPWd= left ventricular posterior wall diastolic; LVPWs= left ventricular posterior wall systolic; IVSd= interventricular septum diastolic, IVSd= interventricular septum systolic; RV= right ventricle.

The results of echocardiographic assessment of left ventricular systolic and diastolic functions and Doppler flow studies are illustrated in tables 1 and 2. The results showed that our cases and controls had similar aortic and left atrial dimensions. Left ventricular internal diameters, particularly the systolic diameter, were decreased in patients with pulmonary hypertension than corresponding dimensions in healthy volunteers. Similarly, left ventricular end-diastolic and end-systolic volumes were significantly reduced in cases as compared to the control group. Left ventricular ejection fraction and fractional shortening were both significantly higher in patients with pulmonary hypertension as compared to the controls. Left ventricular posterior wall and interventricular septum were similar in thickness in both the groups. However, the interventricular septal motion was paradoxical in 15 (42%) of cases and was normal in controls. Right ventricular dimensions were also significantly higher in the pulmonary hypertension group as compared to the controls (p=0.000).

Table 2: Mitral Doppler findings in the study population

Mitral Doppler findings	Cases (n=35)	Controls (n=35)	p value
E velocity (m/s)	0.53±0.23	0.64±0.16	0.031
A velocity (m/s)	0.65±0.20	0.50±0.18	0.003
E/A ratio	0.86±0.35	1.34±0.30	0.000
DT (msec)	248.97±23.69	186.17±31.77	0.001
IVRT (msec)	105.91±48.91	86.02±19.04	0.030

DT = declaration time; IVRT = isovolumic relaxation

Doppler/echocardiographic assessment of left ventricular diastolic functions revealed that E/A ratio was significantly lower in cases than controls (0.86±0.35 vs 1.34± 0.30, respectively, p=0.000). In addition the E/A ratio was <1 in majority of cases as compared to the controls. The isovolumic relaxation time was also significantly longer in the cases group as compared to the control group (105.91±48.91 msec versus 86.02il9.04 msec, p=0.030). The deceleration time (DT) was also higher in cases than in controls (248.97±23.67 msec versus 186.17±31.77 msec; p<0.05).

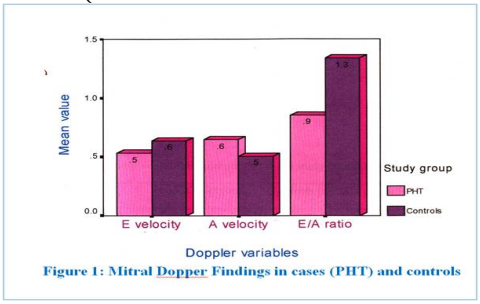

Figure 1: Mitral Dopper Findings in cases (PHT) and controls

Table 3: Pulmonary venous Doppler studies and Pulmonary arterial pressures in the study population

		Cases (n=35)	**Controls**(n=35)	**p value**
Pulmonary venous Doppler	Systolic flow velocity (m/s)	0.44±0.49	0.43±0.35	0.950
	Diastolic flow velocity (m/s)	0.34±0.37	0.33±0.19	0.936
	Atrial reversal velocity (m/s)	0.31±0.22	0.24±0.11	0.093
Pulmonary arterial pressures	Systolic (mmHg)	62.31±21.06	28.80±40.21	0.000
	Diastolic (mmHg)	22.49±17.79	8.72±2.72	0.000
	Mean (mmHg)	45.52±32.84	14.58±3.94	0.000

Pulmonary venous Doppler flow velocities and pulmonary artery pressures in the study group. Theses revealed that atrial reversal velocity was significantly higher in the cases group than controls (0.31 ±0.22 m/s vs 0.24±0.11 m/s, p=0.093). Similarly pulmonary' artery systolic, diastolic, and mean pressures were significantly elevated in the cases than controls of the study group.

Table 4: Correlates of LVEDV, LVEF and RV flat dimension in the study

	LVEDV		**LVEF**		**RV Flat**	
	R	P	R	P	R	P
Age	-.141	.243	.048	.694	.105	.386
Sex	.020	.871	-.032	.729	.039	.748
BMI	.078	.522	.017	.889	-.015	.899
FEV./FVC	.213	.076	-.172	.155	-.362**	.002
$Pa0_2$	-.022	.856	-.071	.561	-.168	.165
$PaC0_2$	-.328**	.006	.286*	.016	.352**	.003
LA	.293*	.014	-.108	.374	.044	.718
LVIDd	.759**	.000	-.286*	.016	-.032	.793
IVSd	.041	.736	-.028	.819	.030	.803
LVPWd	.026	.830	.001	.992	-.021	.862
PAS	-.265*	.027	.316**	.008	.252*	.036
PAD	-.080	.508	.142	.241	.141	.245
PAM	-.023	.851	.192	.112	.459**	.000

**correlation is significant at the 0.01 level (2-tailed). * Correlation is significant at the 0.05 level (2-tailed).

LVEDV= left ventricular end-diastolic volume; LVEF= left ventricular ejection fraction; RV= right ventricle; BMI= body mass index; FEV1= forced expiratory volume in first second; FVC=forced vital capacity; $Pa0_2$= partial pressure of oxygen in arterial blood, $PaC0_2$= partial pressure of carbon dioxide in arterial blood; LA= left atrium; LVIDd = left ventricular internal diameter diastolic; IVSd= interventricular septum diastolic; LVPWd= left ventricular posterior wall diastolic; PAS= pulmonary artery, systolic; PAD= pulmonary artery, diastolic; PAM= pulmonary artery.

Mean On Pearson correlation analysis some interesting findings were observed. Overall, LVEDV showed a significant positive correlation with left atrial size (r=0.293, p=0.014), a significant inverse correlation with pulmonary artery systolic pressure (r=-0.265. p=0.027) and a highly significant inverse correlation with LVIDd (r=0.759, p=0.000) and $PaC0_2$ (r = 0.328, p=0.006).LVEF showed a significant positive correlation with $PaC0_2$ (r=0.286, p=0.016) and pulmonary artery systolic pressure (r=0.316, p=0.008) and an inverse correlation with LVIDd (r = -0.286, p = 0.016). RV flat dimension had a highly significant inverse relation with FEV1/FVC (r =-0.362, p=0.002) and a highly significant positive correlation with the degree of $C0_2$ retention (r = 0.352, p=0.003) and mean pulmonary artery pressure (r =.459, p=0.000).

Table 5: Correlates of E/A ratio, DT and IVRT in the study population.

	E/A ratio		**DT**		**IVRT**	
	R	**P**	**R**	**P**	**R**	**P**
Age	-.127	.295	-.118	.330	.113	.352
Sex	.109	.370	-.230	.055	.131	.280
BMI	.180	.135	-.044	.718	-.005	.650
FEV1/FVC	.544**	.000	-.063	.606	-.357	.002
$Pa0_2$	.039	.749	-.079	.516	-.287*	.016
$PaC0_2$	-.399**	.001	-.047	.700	.322**	.007
LA	-.075	.539	-.153	.206	-.047	.700
LVIDd	.098	.420	.023	.853	-.183	.129
LVEDV	.193	.109	.005	.767	-.303*	.011

LVEF	-.180	.135	-.242*	.043	.150	.215
RV	-.461**	.000	-.172	.155	.150	.216
IVSd	-.091	.453	.025	.840	.147	.224
LVPWd	-.006	.960	-.094	.438	.263*	.028
E/A	-	-	.071	.558	-.324**	.006
DT	.071	.558	-	-	.122	.314
IVRT	-.324**	.006	-.122	.314	-	-
PVs	-.005	.966	.150	.216	-.040	.744
PVd	-.014	.909	.188	.119	-.075	.539
PVar	-.065	.593	.085	.487	.138	.254
PAS	-.239*	.047	-.095	.433	.324**	.006
PAD	-.273*	.022	-.050	.683	.368**	.002
PAM	-.470**	.000	-.014	.908	.269*	.024

** Correlation is significant at the 0.01 level (2-tailed). * Correlation is significant at the 0.05 level (2-tailed).

DT= deceleration time; IVRT= isovolumic relaxation time; PVs•=pulmonary vein, systolic; PVd= pulmonary vein, diastolic; PVar= pulmonary vein, atrial reversal

The important correlates of mitral E/A ratio included a positive correlation with FEV1/FVC (r=0.544, p=0.000) and inverse relationship with $PaC0_2$(r= -0.399, p=0.001), RV flat dimension (r= -0.461, p=0.000), and mean pulmonary artery pressure (r= -0.470, p=0.000).The deceleration time of mitral E velocity did not show a significant relation with any measured variable except for a weakly significant relation with LVEF (r= -0.242, p=0.043). On the other hand, IVRT was significantly related to PaC02 (r=0.322, p=0.007), LVPWd (r=0.263, p=0.028) and pulmonary artery systolic (r=0.324, p=0.006) and diastolic (r=0.368, p=0.002) pressures and inversely related to FEV1/FVC (r= -0.357, p=0.002), Pa02 (r= -0.287, p=0.016), and LVEDV (r= -0.303, p=0.011). Mitral E/A ratio and IVRT showed a highly significant inverse relation with each other (r= -0.324, p=0.006)but no relation with DT.

Table 6: Correlates of pulmonary venous Doppler parameters in the study population

	PVs		PVd		PVar	
	R	P	R	P	R	P
Age	-.125	.304	-.171	.157	.006	.958
Sex	-.009	.942	.051	.678	.031	.801
BMI	.189	.116	-.110	.365	-.105	.385
FEV_1/FVC	.078	.520	.078	.524	-.171	.156
$P0_2$	..137	.259	.160	.187	.041	.734
$PC0_2$	.022	.854	-.145	.230	.153	.205
LA	.050	.681	.042	.727	-.017	.889
LVIDd	.003	.979	-.051	.676	-.130	.285
LVEDV	-.086	.567	-.093	.442	-.303*	.011
LVEF	.087	.475	-.257*	.032	-.099	.417
RV	-.101	.403	-.155	.201	-.043	.725
IVSd	-.011	.930	-.024	.841	-.114	.347
LVPWd	.156	.198	.024	.846	.053	.662
E/A	.005	.966	-.014	.909	-.065	.593
DT	.150	.216	.188	.119	.085	.487
IVRT	-.040	.744	-.075	.539	.138	.254
PVs	-	-	.235	.050	.122	.315
PVd	.235	.050	-	-	.606**	.000
PVar	.122	.315	.606**	.000	-	-
PAS	-.082	.498	-.074	.540	.116	.341
PAD	-.084	.492	-.097	.422	.129	.288
PAM	*-.111*	*.362*	*-.080*	*.512*	*.067*	*.582*

**Correlation is significant at the 0.01 level (2-tailed). * Correlation is significant at the 0.05 level (2-tailed).

The pulmonary venous Doppler velocities did not show any significant relationship except for an inverse relation of PVd velocity with LVEF (r=-0.257, p=0.032) and a similar relationship of PVar velocity with LVEDV (r=-0.303, p=0.011). Also PVd velocity was significantly related to PVar velocity and vice versa (r=0.606, p=0.000).

DISCUSSION

The present Doppler-Echocardiographic study was conducted to examine the left ventricular systolic and diastolic functions in patients with pulmonary arterial hypertension due to chronic obstructive pulmonary disease. A total of 70 subjects (35 patients with chronic obstructive airway disease and 35 apparently healthy persons) were studied by detailed two-dimensional and Doppler examination. Left ventricular dimensions were determined as per the standard protocol and left ventricular systolic functions were recorded. Mitral inflow Doppler was used for the assessment of left ventricular filling patterns and relaxation. The pulmonary venous flow patterns were studied by pulsed Doppler method. In the present study, the aortic and left atrial dimensions in patients with pulmonary arterial hypertension were comparable to the average control values (2.87±0.53 cm versus 2.97±0.43 cm, p=0.370 and 3.13±0.67cm versus 3.08±0.75 cm, p=0.800, respectively). The mean diastolic left ventricular internal diameter (LVIDd) and especially left ventricular end-diastolic volume (LVEDV) were reduced in patients with pulmonary hypertension as compared to the control values (3.85±1.04 cm versus 4.14±0.78 cm, p=0.187 and 75.03±43.89 mL versus 94.99±25.75 mL, p=0.024, respectively). These observations are largely in agreement with the published data. Krayenbuehl HP, *et al* (1978) found that the average transverse LVIDd on transthoracic echocardiography in patients with pulmonary hypertension of different etiologies was significantly lower than that of healthy controls[14]. Lazar JM, *et al* (1993) found that LVEDV in patients with pulmonary arterial hypertension was significantly reduced as compared to that of healthy volunteers[15]. In a recent study by Marcus JT, *et al* (2001), LVEDV in patients with primary pulmonary hypertension, as determined by magnetic resonance imaging, was significantly reduced compared to healthy population[16]. The reduced LVIDd and LVEDV in patients with pulmonary arterial hypertension can be explained by the bulging of interventricular septum towards left in these patients which decreases the left ventricular cavity size. In our study, LVEDV showed a significant positive correlation with left atrial size (r=0.293, p=0.014) and a significant inverse correlation with pulmonary artery systolic pressure (r= -0.265, p=0.027) and $PaC0_2$ (r= -0.328, p=0.006) From these observations, it follows and seems likely that a higher $PaC0_2$ reflecting a more advanced form of pulmonary disease with more severe cor pulmonale causes a greater degree of shift of the interventricular septum towards left causing thereby a severe compromise of left ventricular cavity size. The latter likely causes left atrial distension and a greater degree of left ventricular diastolic dysfunction. The systolic left ventricular internal diameter (LVIDs) and left ventricular end-systolic volume (LVESV) in our patients with pulmonary hypertension were also significantly lower than the corresponding values in the control subjects (2.30±0.76 cm versus 2.73±0.53 cm, p=0.008 and 20.61±20.89 cm versus 33.36±11.75 cm, p-0.003, respectively). The other parameters of left ventricular systolic performance, like left ventricular ejection fraction (LVEF) and left ventricular fractional shortening (LVFS) were significantly higher in the group of subjects with pulmonary arterial hypertension. Previous studies in this regard are scarce and, occasionally, conflicting. In an angiographic study of left ventricular functions, Krayenbuehl HP, *et al* (1978) tailed to demonstrate any difference in the LVESV and LVEF between patients of pulmonary hypertension and healthy controls[14]. Steele P, *et al*[17] measured LVEF in 28 patients with stable chronic obstructive pulmonary disease (COPD) and 92 patients with acutely decompensated COPD by bedside radionuclide ventriculography. They found that LVEF was normal in patients with severe lung disease irrespective of clinical stability in these patients. In the few patients of COPD who had reduced LVEF, the abnormal left ventricular functions were attributable to the associated coronary artery disease. Tutor E, *et al*[18] observed that left ventricular systolic functions were well preserved in patients with chronic cor pulmonale, as evidenced by normal LVFS on echocardiography. On the contrary, in the magnetic resonance imaging study by Marcus JT, *et al*[16], LVESV was found to be normal while LVEF was reduced in patients with chronic right ventricular pressure overload due to primary pulmonary hypertension. The reduced LVEDV in patients with pulmonary hypertension can theoretically reduce left ventricular systolic performance through Frank Starling mechanism. However, the actual importance of such a mechanism in affecting the left ventricular systolic functions of patients with pulmonary hypertension is not clear as of now and seems to be negligible under ordinary circumstances. In fact, in a recent study by Moustapha A, *et al*[19], LVEF was found to be preserved in patients with pulmonary hypertension of different etiologies irrespective of the severity of pulmonary hypertension. In our study, LVEF in patients with pulmonary hypertension was higher than that in the controls. Further, LVEF showed a significant positive correlation with $PaC0_2$ (r=0.286, p=0.016) and pulmonary artery systolic pressure (r=0.316, p=0.008).The reasons for these observations are not clear. An effect of higher heart rate increasing the left ventricular pumping ability in our patients through Bowdich phenomenon seems unlikely since the two groups of subjects in our study had identical

heart rates. It is possible that future studies on larger number of subjects might make the issue more clear since the previous studies including the present one had included only small numbers of patients. Left ventricular stroke volume was normal in our subjects with Pulmonary hypertension. Likewise, the diastolic and systolic thickness of interventricular septum and left ventricular posterior wall were comparable between the two groups. Similar observations have been made by some previous observers as well. On the other hand, interventricular septal motion was found to be paradoxical in 15 (43%) of our patients with pulmonary hypertension as compared to none in the control group. Moustapha A, *et al*[19] found paradoxical interventricular septal motion in 70% of patients with pulmonary hypertension. The paradoxical septal motion in patients with pulmonary hypertension is likely due to the right ventricular pressure overload causing leftward displacement of interventricular septum with flattening or reversal of the septal curvature and subsequent compression of the left ventricular cavity, which is maximal at end-systole and early diastole. Patients with severe pulmonary hypertension are more likely to exhibit paradoxical motion of interventricular septum. The flat right ventricular diameter in patients with pulmonary hypertension was significantly higher than that of controls (3.05±0.81cm versus 2.17±0.36 cm; p=0.000). RV flat dimension had a highly significant inverse relation with FEV1/FVC (r= -0.362, p=0.002) and a highly significant positive correlation with the degree of $C0_2$ retention (r=0.352, p=0.003) and mean pulmonary artery pressure (r=.459, p=0.000). These observations are theoretically plausible and also consistent with some previous observations. The elevated right ventricular dimension in patients with cor pulmonale seems to be due to chronic pressure overload affecting contractile performance of right ventricle, thereby decreasing its pumping ability and increasing the right ventricular end-diastolic volume. Further, the greater the degree of respiratory compromise, the higher the deleterious effects on the performance of right ventricle and the greater the degree of right ventricular enlargement. The mean velocity of early left ventricular filling (E velocity) in patients with pulmonary arterial hypertension was 0.53±0.23 m/s while the mean velocity of late left ventricular filling (E velocity) in such patients was 0.64±0.16m/s, against 0.65±0.20m/s (p=0.031) and 0.50±0.18m/s (p=0.003), respectively, in healthy subjects. The ratio of early to late mitral filling velocity (E/A ratio) was 0.86±0.35 against the value of 1.34±0.30 in normal controls (p=0.000). Johnson GL, *et al* (1991) found that E/A ratio were lower in patients with pulmonary arterial hypertension due to cystic fibrosis than normal controls[20]. Stojnic L, *et al* (1992) found that patients with pulmonary hypertension had a dominant "A" wave on transmitral Doppler, as compared to control who had a dominant "E" wave[14]. Schema M, *et al* (1996) found that patients with pulmonary hypertension had reversed E/A ratio[21]. Tutor, *et al*[18] also reported the E/A ratio in patients with pulmonary arterial hypertension to be on lower side than in healthy population. Moustapha A, *et al*[19] in their study found a reduced E/A ratio in patients with chronic pulmonary hypertension. Importantly, we found the mitral E/A ratio having a positive correlation with FEV1/FVC (r=0.544, p=0.000) and inverse relationship with $PaC0_2$ (r=-0.399, p=0.001), RV flat dimension (r= -0.461, p=0.000), and mean pulmonary artery pressure (r= -0.470, p=0.000). These findings again point towards the strong association between the severity of respiratory impairment in COPD and the degree of left ventricular diastolic dysfunction. With progressively more advanced lung dysfunction and the consequent worsening compromise of left ventricular cavity size, the filling pattern of left ventricle becomes more and more abnormal with late atrial phase of left ventricular filling assuming even greater physiological importance. On pulmonary venous Doppler interrogation, the systolic, diastolic and atrial reversal flow velocities were all found to be normal in patients with pulmonary arterial hypertension, with systolic flow velocity being the most prominent pulmonary venous flow signal. Further, the pulmonary venous Doppler velocities did not show any significant relationship except for an inverse relation of PVd velocity with LVEF (r= -0.257, p=0.032) and a similar relationship of PVar velocity with LVEDV (r= -0.303, p=0.011). Also PVd velocity was significantly related to PVar velocity and vice versa (r=0.606, p=0.000). In the absence of detailed studies about the pulmonary venous Doppler patterns in patients with pulmonary arterial hypertension, especially that due to chronic obstructive pulmonary disease, the significance of our observations in this regard remains elusive. Further studies might be needed for a better understanding of pulmonary venous flow patterns in such patients. In conclusion our study demonstrated that left ventricular diastolic functions are impaired in patients with pulmonary hypertension due to COPD, as compared to normal sex- and age-matched controls. This is confirmed by higher mean velocity of early left ventricular filling (E) than mean velocity of late left ventricular filling (A) and a higher ratio of early left ventricular filling (E) to late left ventricular filling (A) - the E/A ratio. The deceleration time and isovolumic relaxation time are also prolonged in these patients. These results are consistent with literature available on this topic. On the other hand, the pulmonary venous flow velocities are largely normal in patients with pulmonary hypertension.

CONCLUSION

Thus we conclude that patients with pulmonary hypertension secondary to chronic obstructive pulmonary disease have reduced left ventricular internal dimension and that this reduction bears a relation with the level of respiratory compromise and with the severity of pulmonary hypertension. However, left ventricular systolic function is well preserved in these patients irrespective of the severity of lung disease. On the other hand, left ventricular diastolic function is abnormal in patients with pulmonary hypertension as compared to normal age- and sex-matched control population. This is reflected by a higher ratio of late to early left ventricular filling velocities, a prolonged deceleration time of the early left ventricular filling velocity, and increased isovolumic relaxation time of left ventricle in patients with pulmonary arterial hypertension than the control population. Further, the degree of filling abnormalities bears a direct relation with the degree of pulmonary disorder and with severity of pulmonary hypertension.

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