LV DYSFUNCTION IN COPD PATIENTS AND ITS CORRELATION WITH CLINICAL AND ECG FINDINGS

Sreenivasan Sreenath[1], Santhosh Kumar Thulaseedharan Saraswathy[2], Rajeevan Sreekumaran Nair[3]

[1]Additional Professor, Department of Internal Medicine, Government Medical College, Trivandrum, Kerala.
[2]Assistant Professor, Department of Internal Medicine, Government Medical College, Trivandrum, Kerala.
[3]Junior Resident, Department of Internal Medicine, Government Medical College, Trivandrum, Kerala.

ABSTRACT

BACKGROUND

Chronic obstructive pulmonary disease is a chronic debilitating disease that is characterised by poorly reversible airflow limitation. COPD includes emphysema, chronic bronchitis and small airway diseases. It is a leading cause of mortality worldwide. The prevalence of COPD increases with age. The lungs and the heart are so closely interrelated organs that diseases of the one results in impaired functioning of the other. A high prevalence of left ventricular dysfunction has been noticed to exist in patients with COPD and this might result in poor quality of life and exercise intolerance in COPD patients.

MATERIALS AND METHODS

64 patients with COPD confirmed by spirometry were examined clinically after taking relevant history. ECG and chest x-ray findings were noted. Echocardiography was done for these patients to assess the left ventricular functioning and degree of pulmonary artery hypertension.

RESULTS

LV diastolic dysfunction was found in 84% of the patients with COPD in this study. 37.5% had stage I, 46.9% had stage II LV diastolic dysfunction.

CONCLUSION

In our study, it was found that LV diastolic dysfunction was highly prevalent in patients with moderate-to-severe COPD. LV diastolic dysfunction could be a contributing factor to worsening dyspnoea and exercise intolerance in COPD patients.

KEYWORDS

COPD, Electrocardiogram (ECG), Echocardiogram, LV Diastolic Dysfunction, Pulmonary Artery Hypertension.

HOW TO CITE THIS ARTICLE: Sreenath S, Saraswathy SKT, Nair RS. LV dysfunction in COPD patients and its correlation with clinical and ECG findings. J. Evid. Based Med. Healthc. 2017; 4(55), 3336-3342. DOI: 10.18410/jebmh/2017/663

BACKGROUND

The present study is aimed at echocardiographic assessment of the left ventricular function in patients with COPD. The clinical and the echocardiographic findings are correlated with Electrocardiographic (ECG) findings.

Cough, wheeze, sputum production and exertional dyspnoea are the most common symptoms of COPD. Most of the patients have a history of tobacco smoking with a pack year of more than 20 years. Degree of breathlessness can be assessed on the MRC scale. Weight loss and anorexia can occur in severe COPD.[1] Psychiatric morbidity, especially depression is common in patients with COPD. Sleep quality maybe impaired in COPD.[2] The physical signs of COPD are not specific to the disease. Physical signs have low sensitivity in detecting and excluding COPD.[3] Prolonged expiratory phase of breathing and pursed lip breathing maybe noticed. Chest is barrel shaped most often. Accessory muscles are used by the patients during severe exacerbations or advanced diseases. Breath sound intensity is normal most of the times. Wheeze and crackles maybe audible on lung auscultation.[4]

Radiographic features of emphysema can be classified into features of hyperinflation, features due to vascular changes and those due to bullae. Low flattened diaphragms,[5] increase in the retrosternal airspace [6] and obtuse costophrenic angle are due to hyperinflation. Vascular changes often visible on chest x-ray include a reduction in the size and number of pulmonary vessels, vessel distortion and areas of transradiancy.[7]

Echocardiographic Findings of Diastolic Heart Failure[8]

Grade 1- Abnormal relaxation pattern and reversal of the normal E/A ratio.
Grade 2- Elevated left atrial filling pressures (pseudonormal filling pattern).
Grade 3- Reversible restrictive diastolic dysfunction (reversible on Valsalva manoeuvre).
Grade 4- Fixed restrictive diastolic dysfunction.

Characteristic echocardiographic finding of systolic dysfunction is decreased ejection fraction.

Financial or Other, Competing Interest: None.
Submission 31-04-2017, Peer Review 07-05-2017,
Acceptance 09-05-2017, Published 10-07-2017.
Corresponding Author:
Dr. Santhosh Kumar Thulaseedharan Saraswathy,
PMRA B-72, Mangannurkonam Lane,
Pattom Palace P.O., Trivandrum, Kerala-695004.
E-mail: ashasanthosh_ram@yahoo.com
DOI: 10.18410/jebmh/2017/663

Objectives

1. To assess the left ventricular dysfunction in patients with COPD.
2. To correlate the degree of left ventricular diastolic dysfunction with clinical features, electrocardiogram and echocardiography findings.

MATERIALS AND METHODS

64 patients with COPD confirmed by spirometry were examined clinically after taking relevant history. ECG and chest x-ray findings were noted. Echocardiography was done for these patients to assess the left ventricular function and degree of pulmonary artery hypertension.

Study Design

A descriptive design, hospital-based, cross-sectional study conducted in the Department of Internal Medicine, Government Medical College, Trivandrum, for a period of one year 2014-2015 after getting ethical clearance.

Sample Size

$$N = \frac{Z^{\alpha 2}PQ}{d^2}$$

Zα = 1.96.
P = Prevalence.
Q = 100-P.
d = 20% of P.

As per the previous study, prevalence of left ventricular hypertrophy is 60%.

N = 64.

Sample Size = 64.

Inclusion Criteria

1. Patients admitted with acute exacerbation of COPD in the Department of Internal Medicine confirmed by chest x-ray, clinical features and pulmonary function test.
2. Age more than 40 years.
3. Pack year >10 years.

Exclusion Criteria

1. Chronic lung disease other than COPD.
2. Asthma/tuberculosis sequelae.
3. Systemic hypertension.
4. Diabetes mellitus.
5. Patients with poor echo window.
6. Patients who are unable to perform spirometry.
7. Patients with known systemic diseases that can cause pulmonary hypertension.
8. Patients with primary cardiac illnesses.

Statistical Methods

Qualitative variables were described in frequency distribution. Quantitative variables were described in mean and standard deviation. Association between qualitative variables was analysed by Chi-square test. A p value of 0.05 was considered as the level of significance. SPSS 22.0 was used for data analysis.

RESULTS

64 patients with COPD confirmed by spirometry were examined clinically after taking relevant history.

In this study, LV diastolic dysfunction was more commonly found in elderly COPD patients. 100% of the patients above 80 years of age, 61% between 70-79 years, 42% between 60-69 years, 31% between 50-59 years and in none of the patients <50 years had LV diastolic dysfunction. This finding was statistically significant (p = 0.007). Clinical features of pulmonary artery hypertension were more evident in patients with higher stages of diastolic dysfunction (p<0.001). 72% with stage II, 19% with stage I and 9.4% with no LV diastolic dysfunction had clinical features of pulmonary artery hypertension.

ECG findings like PR/ST segment sagging (p = 0.040), absent R-wave in V1-V3 (p = 0.018), poor R-wave progression (p = 0.014) and P pulmonale (p = 0.030) were more common in patients with LV diastolic dysfunction. LV diastolic dysfunction also had correlation with severity of COPD (p = 0.048) and echocardiographic features like RA and RV enlargement (p = 0.004) and the degree of pulmonary artery hypertension (p<0.001).

LV Diastolic Dysfunction	Frequency	Percentage
No	10	15.6
Stage I	24	37.5
Stage II	30	46.9
Total	**64**	**100**

Table 1. Frequency of LV Dysfunction in Our Study

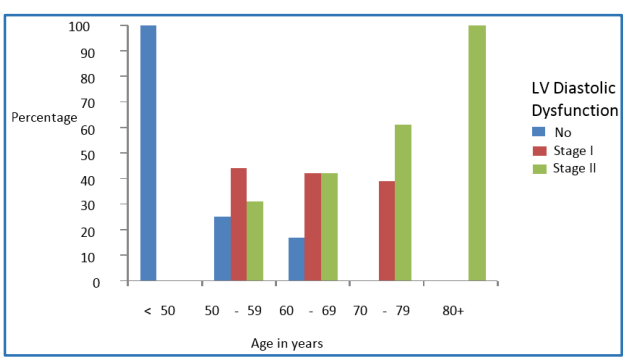

Figure 1. Age (in years) and LV Diastolic Dysfunction

χ^2 = 21.100, df = 8, p = 0.007.

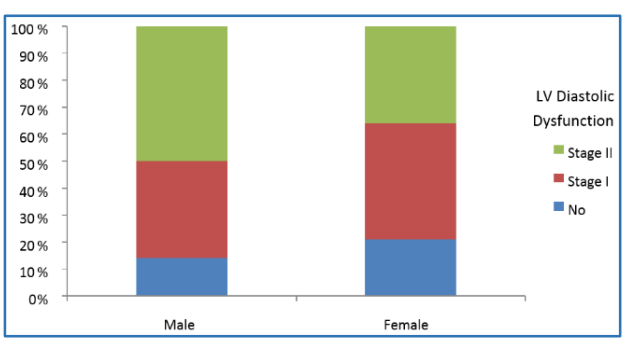

Figure 2. Sex and LV Diastolic Dysfunction

χ^2 = 1.000, df = 2, p = 0.607.

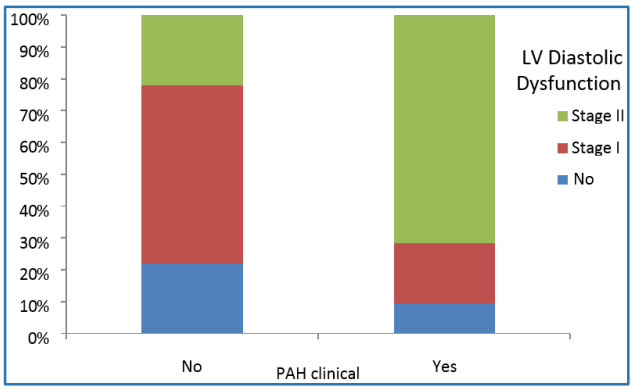

Figure 3. Clinical Features of Pulmonary Artery Hypertension and LV Diastolic Dysfunction

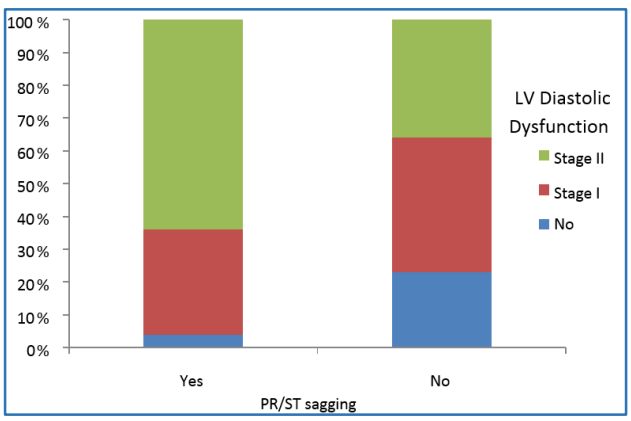

Figure 4. PR/ST Sagging in ECG and LV Diastolic Dysfunction

χ^2 = 6.446, df = 2, p = 0.040.

Chest X-Ray	LV Diastolic Dysfunction							
	No		Stage I		Stage II		Total	
	N	%	N	%	N	%	N	%
Yes	9	14	24	38	30	48	63	100
No	1	100	0	0	0	0	1	100
Total	**10**	**16**	**24**	**38**	**30**	**47**	**64**	**100**

Table 2. Chest X-Ray Findings of COPD and LV Diastolic Dysfunction

χ^2 = 5.486, df = 2, p = 0.064

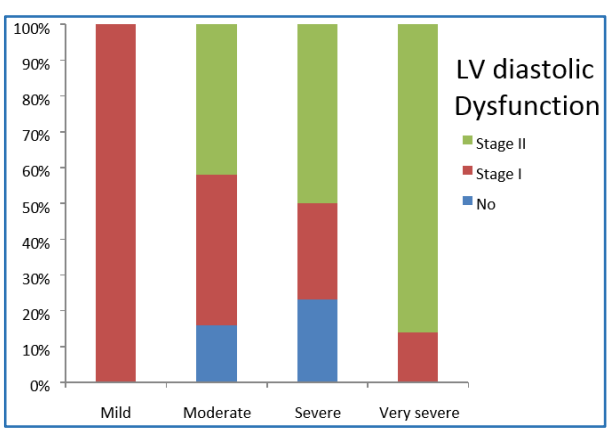

Figure 5. Severity of COPD and LV Diastolic Dysfunction

χ^2 = 12.718, df = 6, p = 0.048.

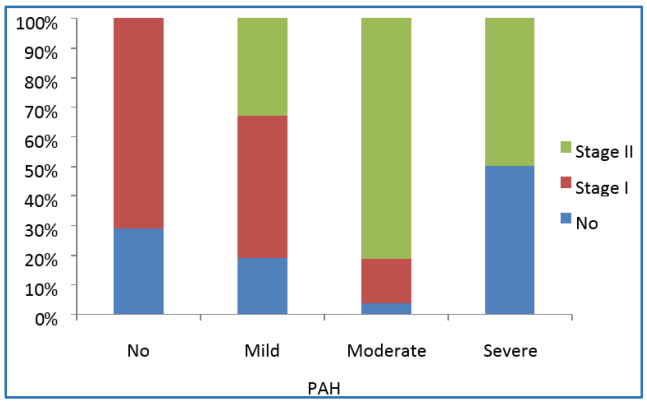

Figure 6. Pulmonary Artery Hypertension and LV Diastolic Dysfunction

χ^2 = 29.240, df = 6, p<0.001.

DISCUSSION

COPD is a progressive disease with high mortality and morbidity. Exacerbations of COPD lead to increasing severity of the illness.[9] Patients who develop respiratory failure have high prevalence of pulmonary hypertension.[10] LV diastolic dysfunction maybe noticed in some of these patients especially in the context of a recent exacerbation. The left and the right ventricles are coupled tightly in a pericardial space. The interventricular septum is relatively compliant. In COPD, right ventricle suffers from systolic overload. This can cause changes in the geometric configurations of the left ventricle. The maximum effect of right ventricular pressure changes on the left ventricle is observed at endsystole.

At this time, the interventricular septum is maximally displaced to the left. The septal curvature is flattened or reversed. Therefore, one ventricle can act upon the other through this interventricular septum.[11]

Progressive airflow limitation observed in COPD along with emphysema results in chronic hypoxia. Hypoxia results in pulmonary vasoconstriction and pulmonary hypertension. Myocyte hypoxia can impair intracellular calcium transport. This is supposed to interfere with the relaxation of both left and right ventricles.[12] Over a period of time, this results in right ventricular enlargement and dysfunction known as cor pulmonale. Right ventricular dysfunction is a known complication of COPD. But, there are some studies that have assessed the left ventricular function in COPD patients.[13,14] These studies noticed a high prevalence of left ventricular diastolic dysfunction (>50%) in COPD patients. A prevalence of 76% was observed by Boussuges et al.[15] A very high prevalence of 88% was observed by Caram et al.[16] In our study, we have observed a prevalence of 84% for LV diastolic dysfunction in COPD.

LV diastolic dysfunction can present in different ways. It can be totally asymptomatic or the patients can present with features of heart failure.

The increase in the prevalence of diastolic heart failure with age is in accordance with previous studies. Padeletti et al[17] observed similar results in their study. The prevalence of heart failure increases with age as observed by Maisel et al.[18] COPD is very common in elderly and highly prevalent in

individuals above 75 years of age.[19] COPD may be contributing to the worsening diastolic heart failure in the elderly.

Degree of diastolic heart failure was not found to have any sex predilection in the present study. Heart failure is more common in men. The overall prevalence of heart failure is however similar in both sexes as observed by Stromberg and Martensson et al.[20] This is supposed to be due to the longer survival of women than men. COPD is more common in males than females.

Clinical Features of COPD

The clinical features of COPD were present in most of the patients and hence did not contribute much to the prediction of the degree of diastolic dysfunction. 90% of patients had clinical features of COPD in our study.

Clinical/Echocardiographic Features of Pulmonary Artery Hypertension

Clinical features of pulmonary artery hypertension were found to correlate with the degree of diastolic dysfunction. 74% of patients on our study had pulmonary hypertension by echocardiography. 50% of total number of patients had clinical features of pulmonary hypertension. 88% of patients with pulmonary hypertension had some degree of diastolic dysfunction. The exact prevalence of pulmonary hypertension in COPD is not known. According to the previous studies, it may range from 20 to 91%.[21]

With regard to pulmonary artery hypertension, two clinical patterns of disease exist. One is the 'pink puffers' and the other is the 'blue bloaters.' The pink puffers have normal blood gas values till the very late stages of the disease. So, they usually do not develop pulmonary hypertension. The 'blue bloaters' develop pulmonary hypertension, cor pulmonale and thus oedema very early. COPD patients with pulmonary artery hypertension have double the mortality rate than those who do not.[22]

The physical findings of pulmonary artery hypertension include loud pulmonic component of the second heart sound, prominent 'a' wave in jugular venous pressure. Right ventricular failure results in elevated JVP, hepatomegaly, peripheral oedema, ascites and pleural effusion. Systolic and diastolic murmurs maybe audible at pulmonary area suggests pulmonary hypertension. Tricuspid regurgitation may cause systolic murmur at tricuspid area.

In our study, the presence of pulmonary artery hypertension clinically or by echocardiography was associated with higher degrees of diastolic cardiac dysfunction. This was statistically significant. 72% of patients with clinical features of pulmonary artery hypertension had stage II diastolic dysfunction, whereas 19% had stage I diastolic dysfunction and 9.4% had no LV diastolic dysfunction.

The echocardiographic evidence of pulmonary artery hypertension was also associated with higher degree of diastolic heart failure. The presence of heart failure may worsen pulmonary hypertension and vice versa. Increased pulmonary artery pressure is most commonly due to left heart disease.[23] When there is diastolic dysfunction, passive transmission of elevated end-diastolic pressure occurs to the pulmonary circuit. This causes reactive vasoconstriction and remodeling of the pulmonary vessels.[24-26]

Pulmonary artery hypertension is a known complication of COPD. Usually, mild-to-moderate pulmonary hypertension is seen. There is increased risk of recurrent exacerbations and decreased survival due to pulmonary hypertension. Sleep and exercise worsens pulmonary hypertension.[27,28] The prevalence of severe pulmonary hypertension in COPD is less than 5%.[29] Oswald-Mammosser et al noticed in their study that two-third of the patients had exercise-induced pulmonary hypertension while they were normal at rest.[30,31]

ECG

Various changes can occur in the ECG of COPD patients. The lungs are hyperinflated in COPD. Hyperexpansion of the lungs compresses the heart and pushes diaphragm downwards. As a result, the heart elongates and gets vertically oriented. The heart has fixed attachments to the great vessels. This causes clockwise rotation of the heart in the transverse plane. The right ventricle moves anteriorly and the left ventricle is displaced posteriorly. The volume of air between the heart and the precordial electrodes is increased in COPD.

This produces a dampening effect. The amplitude of the QRS complexes is thus reduced. The pulmonary artery pressure is chronically elevated. This causes compensatory enlargement of the right atrium and the right ventricle.[32,33]

ECG changes, which are commonly noticed in COPD patients include prominent P waves in inferior leads and flattened or inverted P waves in leads I and aVL; right axis deviation; PR and ST segment sagging below the baseline (TP); low voltage QRS complexes especially in the precordial leads; poor progression of R wave; complete absence of R wave in leads V1 to V3; P pulmonale; right bundle branch block and multifocal atrial tachycardia.[34]

'Lead I sign' may also be seen in some ECGs. This is characterised by very low or absent P, QRS and T-wave complexes in the lead I.[35,36]

The low voltage in ECG occurs due to the insulating effect of the lungs, which are hyperinflated. The lowering of the heart, which becomes tubular in appearance also contributes to this. The heart rotates in horizontal and frontal planes. This leads to right axis deviation.

PR and ST segment occurs because of the exaggerated atrial depolarisation.

The right ventricular and the right atrial enlargement lead to the development of P pulmonale in the ECG. Poor progression of R waves occurs as the heart is often located at a lower position with respect to the recording electrodes. The rotation of the heart also contributes to this finding. Marked shifting of the QRS axis to the northwest axis produces a SI, SII and SIII pattern. Right ventricular hypertrophy can cause inverted T waves in leads V1 and V2. Global hypoxaemia causes global ischaemia of the myocardium. This may result in generalised ST depression in the ECG.

Cardiac arrhythmias can occur in COPD patients. In these patients, supraventricular arrhythmias are more common than ventricular arrhythmias. Multifocal atrial tachycardia is common in severe COPD. It is characterised by rapid and irregular atrial tachycardia.

Most of the patients (63 out of 64 patients) in the study had sinus rhythm in the ECG.

The ECG Changes Considered in the Present Study were-

1) PR/ST Segment Sagging

The presence of PR/ST segment sagging was statistically significant (p = 0.040).

64% of patients with PR/ST sagging in ECG had stage II LV diastolic dysfunction, 32% had stage I LV diastolic dysfunction and 4% had no LV diastolic dysfunction. This finding was statistically significant (p = 0.040).

This shows that patients with PR/ST sagging in ECG are more likely to have associated LV diastolic dysfunction.

The prevalence ST change in our study is 39%, which is slightly higher than the previous studies.[34,37] Study by Banker and Verma et al showed a prevalence of 21% in their study.

2) Absent R Wave in V1 to V3

Absent R wave in V1 to V3 was present in only 15% of the patients. However, 89% of patients with absent R wave had diastolic dysfunction. This was statistically significant. The absence of R wave in leads V1 to V3 may suggest a coexisting diastolic heart failure. In a previous study, 38% of COPD patients had absence of R wave in the ECG.[34]

3) Poor R-Wave Progression

59% of the cases with poor R-wave progression had stage II LV diastolic dysfunction, whereas only 11% had no LV dysfunction. This observed difference was statistically significant (p <0.05).

This was statistically significant (p = 0.014). Poor R-wave progression was noticed in 68% of the patients with COPD in our study. This was 62 to 74% in the previous studies.[34,38]

4) RBBB

The presence of RBBB in ECG was not statistically significant to predict a coexisting diastolic heart failure (p=0.342). The prevalence of RBBB in ECG in our study was 35%. Banker and Verma et al noticed a prevalence of 12% in their study.[34] However, a very high prevalence of 60% RBBB in severe COPD patients was noticed in another study by Jain et al.[39]

5) Multifocal Atrial Tachycardia (MAT)

Only 5 (7.8%) patients in this study had multifocal atrial tachycardia. 4 of them had stage II LV diastolic dysfunction. The presence of multifocal atrial tachycardia was not statistically significant in our study. Its presence indicates severe COPD and carries a very high mortality rate.[40]

6) P Pulmonale

The presence of P pulmonale was noticed more in patients with severe diastolic dysfunction. This finding was statistically significant. 79% of the patients had P pulmonale in their ECG. Previous studies had 35% prevalence of the same.[34] 55% of COPD patients with P pulmonale in ECG had stage II LV diastolic dysfunction, whereas only 12% had no LV diastolic dysfunction. This observation was statistically significant (p<0.05).

Most of the patients in our study had stage II diastolic heart failure (46.9%). The high prevalence of P pulmonale in the ECG may be due to high prevalence of diastolic dysfunction in the study group.

Chest X-Ray

In the chest x-ray of patients in this study, we looked only for features of hyperinflation. Most of the patients (63 out of 64) had features of hyperinflation in the chest x-ray. The finding was not statistically significant to predict the coexistence of left ventricular diastolic dysfunction (p>0.05). Chest x-ray has limited value in the diagnosis of COPD. Chest x-ray becomes an important investigation to find out factors that exacerbate COPD.[41]

Duration of COPD, BMI of the patient and pack years were not statistically significant to be able to predict the degree of diastolic dysfunction in patients with COPD in the present study.

Echocardiography

Echocardiography is a very useful investigation in the diagnosis of coexisting heart failure in COPD patients. LV diastolic dysfunction was assessed using E/A ratio and deceleration time. In our study, 84% of the patients had LV diastolic dysfunction. 86% of patients having very severe COPD and 50% of those with severe COPD cases had stage II LV diastolic dysfunction. Stage II LV diastolic dysfunction was also found in 50% of severe, 42% of moderate COPD cases. However, none of the patients with mild COPD had stage II diastolic dysfunction. This observation was statistically significant (p<0.05).

Patients with diastolic heart failure have a mortality of 28% at one year and 65% after 5 years (70). There is increased risk of hospitalisation in these patients. They also have frequent exacerbations.[42]

Right atrial and right ventricular enlargement was also assessed in these patients. 70% of the patients had RA and RV enlargement in our study. Among the 45 patients who had RA and RV enlargement, 60% had stage II diastolic dysfunction, 27% had stage I and 13% had no diastolic dysfunction at all.

Right ventricular hypertrophy indicates development of cor pulmonale in COPD. This is associated with high mortality. Scott et al in 1976 observed that 71% of patients dying due to COPD had right ventricular hypertrophy.[43] Right ventricular hypertrophy is one of the earliest signs of right ventricular pressure overload.[44]

Hypoxaemia is another factor for RV hypertrophy.[45]

CONCLUSION

1. In our study, it was found that left ventricular diastolic dysfunction was highly prevalent in patients with moderate-to-severe COPD.
2. Presence of clinical features of pulmonary artery hypertension correlated with the degree of left ventricular diastolic dysfunction.
3. The ECG findings that were significantly related to the presence of a left ventricular diastolic dysfunction include PR/ST segment sagging, absent R wave in V1-V3, poor R-wave progression and P pulmonale.
4. The severity of pulmonary artery hypertension was found to have positive correlation with the degree of left ventricular diastolic dysfunction.
5. Presence of right ventricular and right atrial enlargement was found to be significantly associated with left ventricular diastolic dysfunction.
6. Left ventricular diastolic dysfunction could be a contributing factor to worsening dyspnoea and exercise intolerance in COPD patients.

REFERENCES

[1] Wilson DO, Rogers RM, Hoffman RM. Nutrition and chronic lung disease. Am Rev Respir Dis 1985;132(6):1347-1365.

[2] Beauchamp M. Clinician's commentary on Roig et al. Physiother Can 2011;63(4):432-433.

[3] Maitre B, Similowski T, Derenne JP. Physical examination of the adult patient with respiratory diseases: Inspection and palpation. Eur Respir J 1995;8(9):1584-1593.

[4] Marini JJ, Pierson DJ, Hudson LD, et al. The significance of wheezing in chronic airflow obstruction. Am Rev Respir Dis 1979;120(5):1069-1072.

[5] Katsura S, Martin CJ. The roenrgenologic diagnosis of anatomic emphysema. Am Rev Respir Dis 1967;96(4):700-706.

[6] Simon G, Pride NB, Jones NL, et al. Relation between abnormalities in the chest radiograph and changes in pulmonary function in chronic bronchitis and emphysema. Thorax 1973;28(1):15-23.

[7] Morgan MD, Denison DM, Strickland B. Value of computed tomography for selecting patients with bullous lung disease for surgery. Thorax 1986;41(11):855-862.

[8] Lindqvist P, Calcutteea A, Henein M. Echocardiography in the assessment of right heart function. Eur J Echocardiogr 2008;9(2):225-234.

[9] Hillas G, Perlikos F, Tsiligianni I, et al. Managing comorbidities in COPD. Int J Chron Obstruct Pulmon Dis 2015;10:95-109.

[10] Biernacki W, Flenley DC, Muir AL, et al. Pulmonary hypertension and right ventricular function in patients with COPD. Chest 1988;94(6):1169-1175.

[11] Glantz SA, Misbach GA, Moores WY, et al. The pericardium substantially affects the left ventricular diastolic pressure volume relationship in the dog. Circ Res 1978;42(3):433-441.

[12] MacNee W. Pathphysiology of cor pulmonale in chronic obstructive pulmonary disease. Part two. Am J Respir Crit Care Med 1994;150(4):1158-1168.

[13] Funk GC, Lang I, Schenk P, et al. Left ventricular diastolic dysfunction in patients with COPD in the presence and absence of elevated pulmonary arterial pressure. Chest 2008;133(6):1354-1359.

[14] Sabit R, Bolton CE, Fraser AG, et al. Subclinical left and right ventricular dysfunction in patients with COPD. Respir Med 2010;104(8):1171-1178.

[15] Boussuges A, Pinet C, Molenat F, et al. Left atrial and ventricular filling in chronic obstructive pulmonary disease. An echocardiographic and Doppler study. Am J Respir Crit Care Med 2000;162(2 Pt 1):670-675.

[16] Caram LM de O, Ferrari R, Naves CR, et al. Association between left ventricular diastolic dysfunction and severity of chronic obstructive pulmonary disease. Clin Sao Paulo Braz 2013;68(6):772-776.

[17] Padeletti M, Jelic S, LeJemtel TH. Coexistent chronic obstructive pulmonary disease and heart failure in the elderly. Int J Cardiol 2008;125(2):209-215.

[18] Maisel AS, Clopton P, Krishnaswamy P, et al. Impact of age, race, and sex on the ability of B-type natriuretic peptide to aid in the emergency diagnosis of heart failure: results from the Breathing Not Properly (BNP) multinational study. Am Heart J 2004;147(6):1078-1084.

[19] Vijayan VK. Chronic obstructive pulmonary disease. Indian J Med Res 2013;137(2):251-269.

[20] Strömberg A, Martensson J. Gender differences in patients with heart failure. Eur J Cardiovasc Nurs 2003;2(1):7-18.

[21] Shujaat A, Bajwa AA, Cury JD. Pulmonary hypertension secondary to COPD. Pulmonary Medicine Article ID 203952 2012;2012:1-16.

[22] Renzetti AD, McClement JH, Litt BD. The veterans administration cooperative study of pulmonary function. 3. Mortality in relation to respiratory function in chronic obstructive pulmonary disease. Am J Med 1966;41(1):115-129.

[23] Guazzi M, Labate V. Pulmonary hypertension in heart failure patients: pathophysiology and prognostic implications. Curr Heart Fail Rep 2016;13(6):281-294.

[24] Segers VFM, Brutsaert DL, De Keulenaer GW. Pulmonary hypertension and right heart failure in heart failure with preserved left ventricular ejection fraction: pathophysiology and natural history. Curr Opin Cardiol 2012;27(3):273-280.

[25] Neuman Y, Kotliroff A, Bental T, et al. Pulmonary artery pressure and diastolic dysfunction in normal left ventricular systolic function. Int J Cardiol 2008;127(2):174-178.

[26] Lam CSP, Roger VL, Rodeheffer RJ, et al. Pulmonary hypertension in heart failure with preserved ejection fraction: a community-based study. J Am Coll Cardiol 2009;53(13):1119-1126.
[27] Gologanu D, Stanescu C, Bogdan MA. Pulmonary hypertension secondary to chronic obstructive pulmonary disease. Rom J Intern Med 2012;50(4):259-268.
[28] Chaouat A, Naeije R, Weitzenblum E. Pulmonary hypertension in COPD. Eur Respir J 2008;32(5):1371-1385.
[29] Elwing J, Panos RJ. Pulmonary hypertension associated with COPD. Int J Chron Obstruct Pulmon Dis 2008;3(1):55-70.
[30] Oswald-Mammosser M, Apprill M, Bachez P, et al. Pulmonary hemodynamics in chronic obstructive pulmonary disease of the emphysematous type. Respiration 1991;58(5-6):304-310.
[31] Christensen CC, Ryg MS, Edvardsen A, et al. Relationship between exercise desaturation and pulmonary haemodynamics in COPD patients. Eur Respir J 2004;24(4):580-586.
[32] Harrigan RA, Jones K. ABC of clinical electrocardiography. Conditions affecting the right side of the heart. BMJ 2002;324(7347):1201-1204.
[33] Punja M, Mark DG, McCoy JV, et al. Electrocardiographic manifestations of cardiac infectious-inflammatory disorders. The American Journal of Emergency Medicine 2010;28(3):364-377.
[34] Banker H, Verma A. Electrocardiographic changes in COPD. NHL J Med Sci 2013;2(2):55-58.
[35] Schamroth L. Personal experience. South Afr Med J 1976;50(9):297-300.
[36] Padmavati S, Raizada V. Electrocardiogram in chronic cor pulmonale. Br Heart J 1972;34(7):658-667.
[37] Agarwal RL, Kumar D, Gurpreet, et al. Diagnostic values of electrocardiogram in Chronic Obstructive Pulmonary Disease (COPD). Lung India 2008;25(2):78-81.
[38] Chappell AG. The electrocardiogram in chronic bronchitis and emphysema. Br Heart J 1966;28(4):517-522.
[39] Jain J, Apte S, Soni P, et al. A study of correlation between the ECG changes with the duration and severity of chronic obstructive pulmonary disease. Journal of Evolution of Medical and Dental Sciences 2014;3(7):1739-1744.
[40] McCord J, Borzak S. Multifocal atrial tachycardia. Chest 1998;113(1):203-209.
[41] Ghobadi H, Pourfarzi F, Ansari H, et al. The evidence of hyperinflation on chest x-ray and its correlation with air flow obstruction in COPD patients. J Cardiothoracic Med 2013;1(3):89-94.
[42] Abusaid GH, Barbagelata A, Tuero E, et al. Diastolic dysfunction and COPD exacerbation. Postgrad Med 2009;121(4):76-81.
[43] Scott KW. A clinicopathological study of fatal chronic airways obstruction. Thorax 1976;31(6):693-701.
[44] Vonk-Noordegraaf A, Marcus JT, Holverda S, et al. Early changes of cardiac structure and function in COPD patients with mild hypoxemia. Chest 2005;127(6):1898-1903.
[45] Calverley PM, Howatson R, Flenley DC, et al. Clinicopathological correlations in cor pulmonale. Thorax 1992;47(7):494-498.