Original Article

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Role of Concurrent use of Thoracic Ultrasonography with 2D Echocardiography among Patients with Commonly Diagnosed Respiratory Illnesses: A Cross-sectional Study

Internal Medicine Section

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ABSTRACT

Introduction: Respiratory diseases may affect the functioning of the heart, lung and heart work synchronously. Clinical assessment and work-up of patients with pulmonary problems may need an extension to cardiac disease. Thoracic Ultrasonography (TUS) is a diagnostic modality being used to assess respiratory conditions as it carries the inherent advantages of ultrasonography such as being reliable, inexpensive, safe, reproducible, and having no radiation hazard.

Aim: To assess the usefulness of performing Thoracic Ultrasound (TUS) and 2D Echocardiography in the same sitting, so as to confirm the respiratory diagnosis and to early identify various cardiac dysfunctions in patients with respiratory illnesses.

Materials and Methods: This cross-sectional study was conducted in the Outpatient Department (OPD) of Respiratory Medicine at Netaji Subhash Chandra Bose Medical College (tertiary care hospital), Jabalpur, Madhya Pradesh, India, from January 2019 to March 2020. Patients hospitalised with clinico-radiological diagnosis of pleural effusion, pneumonia, pulmonary fibrosis of interstitial lung disease, pulmonary oedema and Chronic Obstructive Pulmonary Disease (COPD) were subjected to TUS and echocardiography. Sonological findings and cardiac abnormalities were recorded. Data was analysed by applying descriptive statistics, t-test, and Chi-square test. A p-value <0.05 was considered as statistically significant.

Results: A total of 133 patients were enrolled with diagnosis of pleural effusion (n=46), COPD (n=33), pneumonia (n=22), pulmonary fibrosis (n=18) and pulmonary oedema (n=14). Out of total 46 patients, 36 patients with pleural effusion had cardiac findings. The presence of pleural effusion showed a significant association with cor-pulmonale (p-value=0.012), dilated Right Ventricle (RV) (p-value=0.012), septal deviation (p-value=0.012), Pulmonary Hypertension (PH) (p-value=0.0002), Left Ventricular (LV) dysfunction (p-value=0.02) and Left Ventricular Ejection Fractions (LVEF) (p-value=0.006). The focal B-lines were seen in patients with pneumonia. Patients with Pulmonary fibrosis had scattered B-Lines, and patients with pulmonary oedema had bilateral diffuse B-lines. Among patients with pulmonary fibrosis, 11 (61.1%) had cor-pulmonale and dilated RV, whereas 10 (55.5%) had septal deviation. Patients with scattered B-lines more commonly had PH. In patients with COPD, cor-pulmonale was detected in 21 (63.6%), LV dysfunction in 5 (15.1%), mild PH in 14 (42.4%), moderate PH in 7 (21.2%), and severe PH in 5 (15.1%) using echocardiography.

Conclusion: This study reveals the importance of performing a combination of TUS with 2D Echocardiography and suggests its usefulness in early diagnosis of cardiac dysfunctions in patients with various respiratory illnesses.

Keywords: Cor-pulmonale, Dilated right ventricle, Pleural effusion, Pulmonary fibrosis, Septal deviation

INTRODUCTION

Any disease that affects the lung may have an effect on the functioning of the heart and vice-versa [1]. Clinical assessment and work-up of patients with pulmonary problems may need an extension to cardiac disease. Thoracic Ultrasonography (TUS) is a diagnostic modality being used to assess respiratory conditions as it carries the inherent advantages of ultrasonography such as being reliable, inexpensive, safe, reproducible, and having no radiation hazard. Also, guided procedures such as aspiration of fluid-filled areas and solid tumors can be done using it. This procedure aids in the better assessment of the surface of the lung through the intercostal spaces rather than the examination of deeper thoracic structures limited by the presence of ribs and air in the expanding lung [2]. The TUS in critical care settings can help in the evaluation of acute dyspnoea, pulmonary embolism, for diagnosis of pleural effusion, pneumothorax, and pneumonia. It can also help in differentiating cardiogenic from non cardiogenic pulmonary oedema [3]. The TUS can also be considered for a quick and reliable assessment of decompensation in patients with heart failure [4].

On the other hand, echocardiography is an equally important diagnostic tool in respiratory care for the immediate evaluation of patients with cardiopulmonary failure. It is a bedside investigation that can establish an initial diagnosis and serial examinations may be performed to guide ongoing management. It helps to evaluate the cardiac function both systolic and diastolic that can be compromised.

The concurrent use of TUS may be important along with echocardiography in especially those respiratory conditions that are known to have cardiac complications or cardiac associations. It will be also useful if patients are subjected to these two non invasive investigations at the time of presentation, as it can help in providing an immediate diagnosis and thereby making quick patient management possible without the need for any sophisticated investigations. The incorporation of Electrocardiography (ECG) and echocardiographic information, addressing to the clues of right ventricular impairment, pulmonary embolism and PH, and other less frequent conditions like congenital, inherited and systemic disease, usually allows more timely diagnosis.

The concomitant use of TUS is important, because, despite the evidence of the clear links between respiratory and cardiac

illnesses, heart and lung ultrasonography imaging approaches are still isolated. Echocardiography is an investigation which also helps to study and monitor several respiratory conditions and helps even in its detection, so that this is now-a-days an established functional complementary tool in pulmonary fibrosis and diffuse interstitial disease diagnosis and monitoring. It is also important that cardiologist extend their approach to lung and pleura which will give information on pleural effusion, even minimal, lung consolidation and pneumothorax [5].

Some studies recommend the complimentary use of echocardiography improve the diagnostic accuracy of TUS in patients with Acute Respiratory Failure (ARF) [6,7]. This approach was found to be particularly important in cases of acute haemodynamic pulmonary oedema and pneumonia, highlighting the unavoidable place of echocardiography in the diagnosis and management of ARF [8]. The addition of TUS to echocardiography provides an additive insight into the eventual pulmonary involvement. The cardiopulmonary system is so inter-connected, that an integrated approach is mandatory. The TUS help in identifying those patients who, although asymptomatic, but would decompensate and require more aggressive treatment. The use of TUS along with echocardiography would require only a few minutes in addition to the time needed for either of these investigations alone [9]. Hence, this study aims to assess the usefulness of performing TUS and 2D Echocardiography in the same sitting, so as to confirm the respiratory diagnosis and to early identify various cardiac dysfunctions in patients with respiratory illnesses.

MATERIALS AND METHODS

This cross-sectional study was conducted in the Outpatient Department (OPD) of Respiratory Medicine at Netaji Subhash Chandra Bose Medical College (tertiary care hospital), Jabalpur, Madhya Pradesh, India, from January 2019 to March 2020. Prior to initiating the study, ethical clearance was taken from the Institutional Ethics Committee in a meeting held on (Letter No. IEC/2021/8447). A duly informed written consent from study subjects was taken before the enrollment. The subjects enrolled into study did not had extra cost burden due to these tests, since the patients were managed free of cost after waiving off test charges.

Inclusion criteria: Patients were diagnosed {pleural effusion, pneumonia, interstitial pulmonary fibrosis, non cardiogenic pulmonary oedema and Chronic Obstructive Pulmonary Disease (COPD)} on the basis of history, clinical examination, chest x-ray, and lung function test such as spirometry and Diffusing capacity of the Lungs for Carbon Monoxide (DLCO). In the present study, patients with interstitial pulmonary fibrosis graded to have moderate to severe restrictive lung disease in spirometry and moderate to severely reduced DLCO. The patients with COPD belonging to Global Initiative for Chronic Obstructive Lung Disease (GOLD) grade 2, 3 or 4 severity of airflow limitation/GOLD group C or D [10] without any known cardiac co-morbidities were included for the study participation, since mild category of such cases most of the time are managed on outpatient basis of the hospital.

Exclusion criteria: Patients who had already diagnosed with cardiac diseases, aged less than 18 years of age, pregnant women and those patients who were critically ill and admitted under intensive care units were excluded from the study. The patients who were unwilling for undergoing TUS or echocardiography test were also excluded for the study.

Procedure

Thoracic ultrasound

All these patients offered TUS test for further evaluation as part of routine workup, using DC-30 Mindray machine with colour Doppler, a linear probe of frequency 7.5-10 MHz, and a curvilinear probe of frequency 2-5 MHz to achieve a maximum area of thorax scanning. The TUS was performed in different positions such as supine, lateral decubitus, or prone. The probe was positioned both longitudinally, perpendicular to the ribs, and obliquely, along with the intercostal spaces, to see various radiological signs in lung sonography. Assessment for presence of pleural effusion, distribution of B-lines, if any, for assessing pulmonary fibrosis and pneumonia, air-bronchogram or fluid-bronchogram for confirming presence of pneumonia was done. In patients with COPD, a 2-2.5 MHz phased array transducer was used to assess the diaphragmatic excursion in M-mode. Subsequently, all the study subjects underwent an echocardiography using HD7XE Philips machine with colour doppler, with monitor size 15" and the 5 MHz transducer (probe), irrespective of any history suggestive of cardiac illness. Two dimensional, M-mode and colour doppler echocardiography was performed, with the patient in supine and left lateral decubitus. An expert radiologist and cardiolgist performed the TUS and echocardiography respectively in all the study participants.

2D Echocardiography

In this study, normal 2D Echocardiography measurements were as follows:

- Left Ventricular End Diastolic Diameter (LVEDD) (37-57 mm)
- Left Ventricular End Systolic Diameter (LVESD) (14-21 mm)
- Aortic Roots (2.3-3.7 cm)
- Left Atrium (1.9-3.4 cm)
- Right Ventricle (0.7-2.3 cm)
- Interventricular septal thickness was measured at the end of diastole as well as systole (7-11 mm)
- Thickness of LV posterior wall was taken at the end of diastole as well as systole (7-11 mm)
- Left Ventricle Ejection Fraction (LVEF) was calculated as follows: LVEF%=(LVEDD3-LVESD3×100)/LVEDD3
- Mild Pulmonary Hypertension (PH): Pulmonary Artery Systolic Pressure (PASP) 30-50 mmHg
- Moderate PH: PASP >50-70 mmHg
- Severe PH: PASP >70 mmHg [11]

The echocardiographic features suggestive of cor-pulmonale and those with isolated findings of dilated Right Atrial (RA), dilated Right Ventricle (RV), septal deviation, LV dysfunction or PH were reported separately. In our study PASP was estimated using Right Ventricular Systolic Pressure (RVSP). Doppler echo was used to calculate RVSP in the presence of tricuspid regurgitation jet. $RVSP=4V^2+RAP$ (Modified Bernoulli equation) [12], where 'v' is the velocity of tricuspid jet in meters per second and Right Atrial Pressure (RAP) was assessed from echocardiographic features of inferior vena cava. The PASP is assumed to be equal to RVSP when the pulmonic valve is normal.

STATISTICAL ANALYSIS

All the information collected during these tests were recorded in a structured proforma, and then statistical analysis was done using the software IBM Statistical Package for the Social Sciences (SPSS) version 23.0 for windows. Range, frequencies, percentage, mean, standard deviation was used wherever applicable. Students t-test was used for comparison of means and Chi-square test was used to analysis difference in categrorical variable. The p-value <0.05 was considered as statistically significant.

RESULTS

A total of 133 patients were enrolled during the study period. The majority were in the age group of 51-60 years, and 60.2% of participants were males. Pleural effusion and COPD were the two most frequent diagnosis [Table/Fig-1].

Diagnosis	Number (n, %)	Gender		Age (years) (mean±SD)
		Male	Female	
Pleural effusion	46 (34.6%)	28	18	54.72±12.04
COPD	33 (24.8%)	18	15	55.98±10.32
Pneumonia	22 (16.5%)	12	10	60.17±12.84
Pulmonary fibrosis	18 (13.5%)	12	6	53.89±4.75
Pulmonary oedema	14 (10.5%)	10	4	51.7±8.3

[Table/Fig-1]: General profile of various respiratory illnesses (N=133).

The patients with a clinico-radiological diagnosis of pleural effusion underwent TUS. TUS could confirm pleural effusion in all the patients (bilateral pleural effusion in 16, right sided pleural effusion in 19, and left sided pleural effusion in 11).

These patients underwent ultrasound-guided pleural fluid aspiration, on the basis of Light's criteria, the pleural effusions were categorised into transudative and exudative pleural effusion. Among these patients, 25 had transudative effusion and 21 had exudative effusion. Among the transudative type of pleural fluid, bilateral effusion was seen in 12, right sided in 7 and left sided effusion in 6 cases respectively, whereas the right sided pleural effusion was most common in exudative type of pleural fluids (12 out of 21 cases). The frequency of the cardiac findings in these two types of pleural effusion is shown in [Table/Fig-2].

Cardiac findings	Transudative pleural effusion (n=25)	Exudative pleural effusion (n=21)
Detected	20 (80%)	16 (76.2%)
Not Detected	5 (20%)	5 (23.8%)

[Table/Fig-2]: Characteristics of pleural effusion and the frequency of cardiac findings in these patients.

Various cardiac findings in the patients of pleural effusion, subdivided into transudate and exudate pleural effusion, are shown in [Table/Fig-3]. Among the cardiac finding detected using echocardiography, both transudative and exudative pleural effusions had significant association with cor-pulmonale, dilated RV, septal deviation, PH, and LV dysfunction (p-value <0.05), but cardiac findings of Right Ventricular Hypertrophy (RVH) and pericardial effusion had no statistically significant association with pleural effusion. Among 25 patients with transudative pleural effusion, only two patients had findings of mild PH, whereas among 21 patients with exudative pleural effusion 10 patients had mild PH. Moderate to severe PH was not seen in any of the two groups of patients with pleural effusion. There was also a statistically significant difference of means of LVEF between transudative and exudative type of pleural effusion [Table/Fig-4].

Cardiac findings	Transudative pleural effusion (n=25)		Exudative pleural effusion (n=21)		p-value (Chi-square test)
	Present	Absent	Present	Absent	
Cor-pulmonale	2	23	8	13	0.012
Dilated right ventricle	2	23	8	13	0.012
Septal deviation	2	23	8	13	0.012
Left ventricle dysfunction	16	9	4	17	0.02
Right ventricular hypertrophy	2	23	4	17	0.266
Pericardial effusion	12	13	16	9	0.499
Pulmonary hypertension	No PH=23		No PH=11		0.0002
	Mild PH=2		Mild PH=10		

[Table/Fig-3]: Association of various cardiac findings with characteristics of pleural fluid in cases of pleural effusion.
p-value <0.05 was considered as statistically significant

Nature of pleural effusion	N	Mean left ventricle ejection fraction (Unit %)	p-value (student t-test)
Transudate	25	36	0.006
Exudate	21	66	

[Table/Fig-4]: Difference of means of Left Ventricle Ejection Fraction in the types of pleural fluids.
p-value <0.05 was considered as statistically significant

The characteristic focal B-lines and air bronchograms seen on TUS confirmed the presence of 22 cases of pneumonia, 18 patients of pulmonary fibrosis had scattered B-lines and 14 patients of pulmonary oedema had diffuse bilateral B-lines. Among 22 patients with pneumonia (focal B-lines) and 14 patients with pulmonary oedema (bilateral diffuse B-lines), none had cor-pulmonale, dilated RV, or septal deviation. Among 18 patients with pulmonary fibrosis (scattered B-lines), 11 patients had cor-pulmonale and dilated RV and 10 had septal deviation. Among 22 patients with pneumonia, one patient had mild PH. Among 18 patients with pulmonary fibrosis, 5 patients had mild PH, three had moderate PH and 4 had severe PH. Among 14 patients with pulmonary oedema, two patients had mild PH and one patient had moderate PH. Apart from patients with pulmonary fibrosis and pulmonary oedema, one patient with pneumonia had echocardiographic features suggestive of cardiac involvement. The presence of B- lines or air-bronchogram was confimed in remaining 21 patients with pneumonia without any other cardiac involvement. The findings shows that patients with chronic parenchymal lung diseases have more cardiac dysfunctions, compared to acute diseases like pneumonia [Table/Fig-5].

2D echocardiography findings		Pneumonia (n=22)	Pulmonary oedema (n=14)	Pulmonary fibrosis (n=18)	COPD (n=33)
Cor-pulmonale		None	None	11	21
Dilated RV		None	None	11	21
Septal deviation		None	None	10	21
Pulmonary hypertension	Mild	1	2	5	14
	Moderate	0	1	3	7
	Severe	0	0	4	5
	Total	1	3	12	26
RV hypertrophy		None	None	11	15
LV dysfunction		None	14 (6-Moderate, 8-Severe)	1 (Moderate)	5 (1-Mild, 3-Moderate, 1-Severe)

[Table/Fig-5]: Table showing 2D echocardiography findings in various lung diseases.
RV: Right ventricle; LV: Left ventricle

There is a statistically significant association between TUS detected B-lines and dilated RV, cor-pulmonale, septal deviation, RV hypertrophy and PASP (p-value <0.005). None of the patients in this study, with TUS detected B-lines had regional wall motion abnormality and pericardial effusion in 2D echocardiography.

Among the 33 patients with COPD, 23 patients belonged to GOLD group-C and remaining 10 patients belonged to GOLD group-D. All patients with COPD had decreased diaphragmatic excursion and 27 patients had reduced diaphragmatic thickness (23 with GOLD group-C and four with GOLD group-D) noted in M-mode ultrasonography. Of these patients cor-pulmonale was detected in 21 patients (63.6%) and five patients (15.1%) had LV dysfunction. Of these five patients with LV dysfunction, three had moderate LV dysfunction, one had mild and one had severe LV dysfunction. Among 33 patients with COPD, seven patients (21.2%) had no PH, 14 (42.4%) had mild PH, 7 (21.2%) had moderate PH and 5 (15.1%) had severe PH. Seven patients with COPD also had regional wall motion abnormality on 2D echocardiography. The frequency of these cardiac findings in echocardiography in patients with COPD is shown in [Table/Fig-5].

DISCUSSION

Congestive Heart Failure (CHF) represents the most common cause of transudative pleural effusions, present in 50% to 90% of patients admitted for CHF [13-15]. LV failure is considered an essential factor for producing effusions [16]. In the present study, 36 out of a total of 46 patients with pleural effusion had some cardiac findings detected on echocardiography. Among the patients having transudative pleural effusion in this study, 72% (18/25) had cardiac abnormalities.

Although Congestive Heart Failure (CHF) is the most common cause of bilateral pleural effusions (60-85%); unilateral effusions are more commonly right sided, right-to-left ratio being 2:1 [17]. In present study, also 75% (12 out of 16) of pleural effusion in the transudative category were bilateral in location. Among the remaining 4 patients with LV failure, 2 had right sided and 2 had left sided transudative pleural effusion. However, it has been discovered that approximately 25% of cases of pleural effusion of uncomplicated heart failure can be exudatve in nature, which can be distributed bilaterally worse on any side [18,19]. In the present study, it was found that 16% of patients with exudative pleural effusion had uncomplicated LV dysfunction. Another co-existing condition of pericardial effusion along with pleural effusion has been commonly observed in patients having uncomplicated heart failure, which was also seen in the patients (n=12) who had transudative pleural effusion along with LV dysfunction in the present study.

The presence of B-lines on TUS with varying distributions is seen in various lung parenchymal disorders. Pulmonary fibrosis being one of the very common condition seen in patients with interstitial lung disease. In them, scattered B-lines are seen on TUS. The cardiovascular manifestations of Idiopathic Pulmonary Fibrosis (IPF) include PH, heart failure, Coronary Artery Disease (CAD), cardiac arrhythmias and cardiac side-effects of drugs used to treat IPF [20]. Among these Right Heart Failure (RHF) are very severe complications of IPF and contribute significantly to patient morbidity and mortality in IPF [21]. Despite this, PH in IPF is not well studied at an early stage of IPF, until the fibrosis becomes quite severe [22].

Right Heart Catheterisation (RHC), is considered to be the gold standard in the diagnosis of PH of any cause, but it is invasive and inconvenient which has made it hard to study PH-IPF in longitudinal studies. Lastly, most of the data that is available about PH-IPF comes from a small cohort of patients who are referred for lung transplantation evaluation, which does not represent all patients with IPF. Echocardiography has been considered to be not a very specific test to detect PH as the accuracy of diagnosis of PH in IPF with transthoracic echocardiogram has been seriously questioned. The PH in IPF has been found in around 10-32% of patients in various clinical studies, but they have used the RHC for diagnosing PH [23,24].

Confirming PH with RHC have technical and logistics issues in developing countries like ours, where echocardiography is a helpful tool, with an added advantage, of that, it can be applied at an early stage of IPF and detect early PH with IPF. In the present study, PH was detected in 12 out of 18 (66%) patients with Pulmonary fibrosis in echocardiography, although th test being non specific, none of the echocardiography screened patients could be subjected for RHC for confirmation, due to logistic constraints and clinical settings in which this study had been done.

There is a high prevalence of cardiovascular co-morbidities which are associated with considerable morbidity and mortality in patients with COPD [25]. They have two-to three-fold increased cardiovascular morbidity and mortality risk compared to non COPD patients [26]. This has been associated with disease severity, and systemic inflammation is seen to be particularly important [27]. As cardiac abnormalities contribute to the overall morbidity associated with COPD, a clear understanding of their role and potential for treatment is vital. Echocardiography plays a key role in the diagnostic and therapeutic work-up of these patients as a valuable tool for tracking right ventricular function in patients with cor-pulmonale, helps in assessing its stability, deterioration, or improvement during follow-up [28]. Echocardiographic evaluation on a timely basis has a pivotal role in early detection of various cardiovascular alterations in COPD like PAH, LV or RV dysfunction, TR, and cor-pulmonale [29].

Although COPD patients are known to have cardiac co-morbidities, none of the enrolled patients had any known cardiac illness history prior to enrollment in the study. As TUS and 2D Echocardiography was used concurrently in this study and the cardiac co-morbidities were detected. These patients could have been missed if the concurrent 2D echocardiography was not done in the patients being assessed only for pulmonary findings on TUS.

Limitation(s)

The main limitation of the present study was the small sample size as it was carried out within a fixed period of time, operator skill dependant, therefore the possibility of variation in subjective interpretation of findings, cannot be ruled out. These tests cannot surely eliminate the need of further advanced investigations, that may be necessary for complete evaluation of such patients.

CONCLUSION(S)

From the present study, it was concluded that TUS along with 2D Echocardiography is useful in early confirmation of diagnosis. A combination of TUS with 2D Echocardiography in the same sitting in cases of pleural effusion yields better diagnostic accuracy. Cardiac involvement in diseases like pulmonary fibrosis, pulmonary oedema, and COPD could be detected early with the use of 2D Echocardiography and TUS. This would assist in diagnostic work-up plan and this may contribute in better patient management.

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