

Correlation between HRCT chest findings, Spirometry, ABG and 2D ECHO in patients with bronchiectasis.

Dr. Yellapu Gayatri devi MD, Dr. Allena Prem kumar MD, Dr. Namballa Usha rani MD, Dr. Sarella Joshua

Assistant Professor. Government Chest Hospital, Andhra Medical College, Visakhapatnam, Andhra Pradesh INDIA.

Professor. Government Chest Hospital, Andhra Medical College, Visakhapatnam, Andhra Pradesh, INDIA.

Associate Professor. Government Chest Hospital, Andhra Medical College, Visakhapatnam, Andhra Pradesh, INDIA.

Post Graduate in Pulmonary Medicine. Government Chest Hospital, Andhra Medical College, Visakhapatnam, Andhra Pradesh, INDIA.

Abstract: BACK GROUND: Since bronchiectasis continues to be a common disease in our country with significant morbidity due to complications like repeated acute exacerbations and chronic respiratory insufficiency.

AIM: This study was done to assess whether the type of Bronchiectasis and the extent of involvement have any correlation with pulmonary arterial hypertension and right heart dysfunction and correlate these findings with impairment of lung function and pulmonary gas exchange.

Materials and methods: This was a prospective observational study conducted over a period of one year. Patients who presented with clinical features and CXR findings consistent with Bronchiectasis at Government chest Hospital / Andhra medical college, were subjected to HRCT Thorax, for confirmation of disease and to assess extent of involvement. 60 patients were included in the study. Demographic and clinical data were collected, routine blood investigations, ABG analysis on room air, spirometry and 2D ECHO were done in all the patients and data were analysed.

Results: Of the 60 patients included in the study, 34 patients (57%) were men and 26 patients (43%) were women. The mean age was 35.9 years (SD \pm 13.4 YRS) Majority of the study group 48/60 (80%) had cystic Bronchiectasis, 16.7% of cases (10/60) had cylindrical Bronchiectasis and 2 patients had varicose Bronchiectasis. Lingula was considered as a separate lobe. The lobar distribution of Bronchiectasis was described as wide spread and extensive if 5/6 lobes involved. 12 had extensive disease and all of them belonged to cystic variety and were associated with severe ventilatory impairment and some of them also associated with gas exchange abnormalities like hypoxemia and hypercapnea leading to PAH and right ventricular dysfunction. Mixed ventilator pattern was the most commonly observed defect. The mean values of FEV1/FVC, FEV1 AND FVC were lower in patients with cystic bronchiectasis than the mean values in patients with cylindrical bronchiectasis. Of the 60 patients 4 showed hypoxemia and 3 showed hypercapnea all of them belonged to cystic type of bronchiectasis with wide spread disease. In cystic bronchiectasis patients there was a significant negative correlation between RVSP and PaO₂ and mildly significant positive correlation with PaCO₂ and no significant correlation with FEV1. In patients with cylindrical type there was no correlation between RVSP and FEV1, PaO₂ and PaCO₂.

Conclusion: Mixed ventilator defects, abnormal gas exchanges, development of pulmonary hypertension and right ventricular dysfunction are more common in cystic than cylindrical type of bronchiectasis. Significant correlation between RVSP and PaO₂ suggests chronic hypoxia has a central role in development of pulmonary hypertension and right ventricular dysfunction. Therefore aggressive management of pneumonias, childhood respiratory infections and early detection of bronchiectasis are important since severe forms are associated with several complications and morbidity.

Key words: Bronchiectasis, high resolution chest tomography, spirometry, ventilator defects, pulmonary arterial hypertension.

I. Introduction

Bronchiectasis is airway disease characterized by abnormal and permanent dilatation of the bronchi, affecting the medium size bronchi (< 2mm). Bronchiectasis was a common disabling and fatal condition in the pre-antibiotic era, but after the advent of antibiotics, introduction of childhood immunization against measles and pertusis, the advent of improved social and living conditions and due to improved sanitation and nutrition, the incidence has decreased in developed countries. However in developing countries the incidence is not decreased due to low socio-economic condition^{1,2,3}.

In bronchiectasis the altered airway anatomy is in the form of abnormal bronchial dilatation with bronchial wall destruction and trans-mural inflammation and also destruction of peri-bronchial alveolar tissue resulting in diffuse peri-bronchial fibrosis. This altered airway anatomy predisposes to colonization and infection with pathogenic organisms, contributing to the purulent expectoration observed in these patients. This vicious cycle of bronchial damage, bronchial dilatation, impaired clearance of secretions, recurrent infection, and more bronchial damage continues. Bronchiectasis can have important hemodynamic consequences because of proliferation of bronchial circulation and development of broncho pulmonary shunting which contributes to the development of pulmonary arterial hypertension and alterations in right ventricular function with subsequent development of cor pulmonale^{5,6,7}.

Since bronchiectasis continues to be a common disease in our country with significant sequelae, this study was done to assess whether the type of bronchiectasis and the extent of involvement have any correlation with pulmonary arterial hypertension and Right heart dysfunction and correlate these findings with impairment of lung function and pulmonary gas exchange.

II. Materials And Methods

This was a prospective observational study conducted over a period of one year. Patients who presented with clinical features and CXR findings consistent with Bronchiectasis at Government chest Hospital / Andhra medical college, were subjected to HRCT Thorax, for confirmation of disease and to assess extent of involvement. Patients who are smokers / ex-smokers, patients with hypertensive heart diseases, patients with H/O valvular heart diseases / rheumatic heart diseases and congenital heart diseases, Ischemic heart diseases, Cardio-myopathies, Patients with other concomitant lung diseases like Asthma, COPD, sleep related disorders, TB were excluded from the study. 60 patients were included in the study. Written informed consent was obtained from all the patients before enrolment in the study. All the patients were in steady state with no history suggestive of infective exacerbations in the past three weeks. Demographic and clinical data were obtained. Patients were screened for sputum AFB, gram staining and culture sensitivity. chest x-ray was taken. Routine blood investigations (Hb%, TC, DC, ESR, RBS, Serum Creatinine, blood urea) were done. All the patients were subjected to arterial blood gas analysis on room air, spirometry and 2D Echocardiography. Hospital ethics committee approval was taken.

HRCT Chest : HRCT Chest has replaced Bronchography as the investigation of choice in diagnosis of bronchiectasis. HRCT scanning has sensitivity of 97% and specificity of 93%⁸. The HRCT imaging technique consists of obtaining 1mm to 2mm collimation scans at 10mm intervals from apex to base of the chest with a window level (WL) of -700 Hounsfield units (HU) and a window width (WW) of -1000 HU. All patients were scanned in supine position in full suspended inspiration. The interpretation of HRCT scan was done by radiologists of the department of radiology who were blinded to the study. The HRCT scan findings suggestive of bronchiectasis are the following (**Naidich-criteria**)⁹ :

- The internal bronchial diameter greater than that of the adjacent artery.
- Lack of bronchial tapering (the same diameter as the parent bronchus for > 2cms).
- The bronchi may be within 1cm of costal pleura or abutting the Mediastinal pleura.
- Bronchial wall thickening may be seen.
- A cystic cluster of thin walled cystic spaces may be present, often with air fluid levels.

Other findings may be associated with bronchiectasis :

- Areas of increased and decreased perfusion and attenuation.
- Tracheo-bronchomegaly.
- Enlarged mediastinal nodes.

Reids classification of Bronchiectasis¹⁰: The appearance of “ectatic bronchi” varies depending on the type of bronchiectasis and the orientation of the airways relative to the plane of the HRCT scan.

A. Cylindrical bronchiectasis : Bronchi coursing horizontally are visualized as parallel lines (tram lines), where as vertically oriented bronchi appears as circular lucencies larger than the diameter of the adjacent pulmonary artery (signet ring appearance).

B. Varicose bronchiectasis : Presence of non uniform bronchial dilatation.

C. Cystic bronchiectasis or saccular bronchiectasis : Clusters of thin walled cystic

spaces often containing air fluid levels.

ABG : Arterial blood gases were measured while patients were breathing room air. Blood sample was collected from the radial artery according to the guide lines and subjected for analysis without any delay. The machine used was Cobal b 120 model. PH, PaO₂, PaCO₂ were recorded. The normal PH being 7.35 – 7.45, PaO₂ 80 –

100 mmHg and PaCO₂ 35 – 45 mmHg. Findings outside the range are considered as abnormal. Hypoxemia is defined as a PaO₂ of < 60 mmHg and hypercapnea is defined as PaCO₂ of >45 mmHg.

Spirometry: Pulmonary function assessment was measured as FEV₁, FVC and percentages of predicted values using the standard protocol from American Throacic society. Patients were divided into three groups on the basis of spirometry data¹¹.

1. Obstructive disease: Defined as FEV₁/FVC ratio of less than 75% predicted. FEV₁ of less than 80% predicted (FEV₁ observed / FEV₁ predicted), FVC of greater than 80% predicted.
2. Restrictive disease : Defined as preserved FEV₁ / FVC ratio > 75% , FEV₁ and FVC < 80% of the predicted.
3. Mixed disease : FEV₁ & FVC < 80% of the predicted and FEV₁ / FVC ratio < 75%.

2D Echo and Doppler : A complete echocardiographic examination was done with GE-LOGIQ 3,GE VOLUSON. Standard measurements were taken with M-mode and Doppler study. Left ventricular dimensions were taken and ejection fraction was calculated using Teicholz fomula. Tricuspid jet velocity interrogated and RV systolic pressure was calculated according to modified Bernouli equation. Right atrial pressure was added based on inferior vena cava collapsibility¹².

$$\text{RVSP} : 4V^2 + \text{RAP}$$

RVSP–Right ventricular systolic pressure.

V is tricuspid jet velocity in meters / sec.

RAP is right atrial pressure.

In those for whom the tricuspid regurgitant jet signal was not adequate, RVSP was calculated by using pulmonary acceleration time (PAT). Mean pulmonary arterial pressure = 80-PAT/2¹³. RVSP > 30mmHg was taken as pulmonary arterial hypertension. 2D Echo was done by a cardiologist who did not know the aim of the study.

The following parameters were measured.

- RV function was measured qualitatively.
- RVSP (right ventricular systolic pressure).
- Left ventricular ejection fraction (LVEF), FS (Fractional shortening).

Patients considered to have pulmonary hypertension when RVSP is more than 30mmHg. 30–40 mmHg is considered as mild, 40–70 mmHg is considered as moderate and more than 70 mmHg as severe pulmonary hypertension¹⁴.

Data were analyzed using statistical soft ware (Micro soft excel 2007). Continuous variables that followed a normal distribution were summarized as mean \pm SD. Comparisons between cystic bronchiectasis and cylindrical bronchiectasis were done using student t test (two tailed), and the proportions were compared using Chi-square (X²) test. Pearson correlation co-efficient was calculated to quantify the relationship of two continuous variables. P< 0.05 was considered statistically significant.

III. Results

Of the 60 patients included in the study, 34 patients (57%) were men and 26 patients (43%) were women. Mean age was 35.9 years (SD \pm 13.4 years). The age range of the study population was 13 to 72 years. 43 out of 60 (71.7%) patients have presented in the most economically productive age group (21-50years). According to the amount of sputum produced daily by patients, patients were categorized into (**ELLIS categorization**) mild, moderate and severe types. 32/60 cases were having sputum production of 10–150ml/day (moderate). 18/60 cases were having > 150ml/ day (severe) and in 10/60 cases sputum production was of 10ml/day (milder form). Patients with cystic bronchiectasis who had > 150ml sputum/day, had the most severe form of the disease.

Majority of the study group, 80% of the patients (48/60) had cystic bronchiectasis and 16.7% of cases (10/60) had cylindrical bronchiectasis, whereas varicose type of bronchiectasis was present in only 2 patients. However varicose variety also had cylindrical type bronchiectatic changes. Therefore for analysis varicose type was included in the cylindrical type of bronchiectasis. Lingula was considered as a separate lobe. The lobar distribution of bronchiectasis was described as widespread and extensive if 5/6 lobes involved. Predominant lower lobe involvement was seen 20 patients. About 12 cases had extensive disease and all of them had cystic type of bronchiectasis, who also have severe ventilatory impairment and some of them also associated with gas exchange abnormalities like hypoxemia and hypercapnea which finally leading to increased pulmonary artery hypertension and right ventricular dysfunction. 10 patients had middle and lower lobes equally affected. 13 patients were classified as unclassified who did not belong to the above categories.

44/48 cases of cystic bronchiectasis had abnormal spirometric results. Mixed pattern was the most commonly observed defect. 8/12 of cylindrical bronchiectasis patients were associated with abnormal spirometry. In this group also the most commonly observed pattern was mixed type. 2 cases among cystic type and 4 cases among cylindrical type showed normal spirometry results, all of them had mild type of bronchiectasis with only part of the lobe or 1 or 2 lobes affected. The lowest observed value of FEV1/FVC in this study was 33.79, FEV1 was 11.37% of the predicted and FVC was 34.46% of the predicted which indicates the severe obstruction and restriction. The mean values FEV1/FVC, FEV1 and FVC were lower in patients with cystic bronchiectasis than the mean values in patients with cylindrical bronchiectasis though they are not statistically significant (**Table - 1**).

Of the 60 patients 4 showed hypoxemia ($\text{PaO}_2 < 60\text{mmHg}$), and 3 showed hypercapnea ($\text{PaCO}_2 > 45\text{ mmHg}$), all of them belongs to cystic type of bronchiectasis with wide spread disease pattern. The mean PaO_2 values of the cystic bronchiectasis group were significantly lower than in cylindrical type ($P < 0.050$). But there was no statistically significant difference in the mean values of PH, and PaCO_2 between the two groups though they were less in the cystic group (**Table- 2**).

The mean RVSP was higher and LVEF and FS were lower in cystic group compared to cylindrical type though they are not statistically significant (**Table -3**). Pulmonary hypertension ($> 30\text{mm Hg}$) was found in 11/60 of patients (18.4%), affecting 10/48 of cystic bronchiectasis patients (20.8%) and 1/10 of cylindrical bronchiectasis patients (10%). ($X^2 = 2.010$). The two patients who had severe PH (RVSP $>70\text{mmHg}$) belonged to cystic bronchiectasis with extensive disease (5/6 lobes involvement) (**Table - 4**).

In cystic bronchiectasis patients there was a significant negative correlation between RVSP and PaO_2 and mildly significant positive correlation with PaCO_2 and no significant correlation with FEV1. In patients with cylindrical type there was no correlation between RVSP and FEV1, PaO_2 , PaCO_2 . (**Tables – 5&6**).

IV. Discussion

Bronchiectasis continues to be a clinically significant disease in the developing countries in spite of the advent of antibiotic therapy. Advances in radiologic imaging with HRCT, improved the recognition of early disease and can be useful in evaluating the type, the extent and the distribution of bronchiectasis. Cylindrical bronchiectasis is the mild form of the disease, varicose bronchiectasis being more severe type and cystic form is the most severe type. The vicious cycle of chronic infection and damage to the airways leads to increasingly severe symptoms, physiological impairment manifesting as ventilatory defects, abnormalities in gas exchange and hemodynamic consequences of development of pulmonary hypertension, RV dysfunction and cor pulmonale. The present study is aimed at examining the possible relationship between the type of bronchiectasis and spirometric abnormalities, 2D Echo parameters and ABG abnormalities.

This study comprised of 60 consecutive patients with radiologically proven bronchiectasis (X-Ray Chest, HRCT Thorax) after carefully applying exclusion criteria, of which 26 were females and 34 were males. Majority of patients belong to active, young middle age group (21-50 years) i.e. 71%. The youngest of affected was 13 years. According to Ellis categorization 18/60 (30%) had severe type of bronchiectasis with more than 150ml of sputum production per day and 32/60 (53.34%) had moderate type with 10 to 150 ml of sputum per day. 10/60 of cases had mild bronchiectasis with 10ml/day of sputum.

In the total 60 cases the HRCT findings classified 48 cases as cystic, 10 cases as cylindrical and 2 cases as varicose bronchiectasis. In a large study of 261 patients with bronchiectasis by David A.Lynch et.al¹⁵, the most common type was cystic bronchiectasis (163/261) followed by varicose type. In another study by Abdulazi Z.H. Alzeer et.al¹⁶ about 2/3 of the study group (62/94) had cystic bronchiectasis and the remainder being cylindrical type. Extensive involvement (5/6 lobes) was seen in 12/60 (20%) in the present study and all were cystic type of bronchiectasis and majority had predominantly lower lobe involvement. In the study by David A. Lynch et.al¹⁵, 176/261 (67.4%) had severe extensive disease with lower lobe disease being the more predominant.

Obstruction is the predominant ventilator defect in bronchiectasis cases because of the presence of infection and inflammation was associated with increased airway obstruction. The spirometric measurements of the patients in the present study showed that 44/48 of cystic bronchiectasis had mixed ventilatory defects. The mean values of FEV1, FVC, FEV1/FVC were lower in the cystic type than in the cylindrical type, though there was no statistical significance ($P=0.33, 0.4, 0.42$ respectively). 6/60 patients (10%) showed normal spirometric pattern of which four belonged to cylindrical type and two belonged to cystic type and all of them had single lobe involvement, which can be due to milder form of disease with less extensive involvement. The mixed ventilatory defect is explained by the combination of the airway damage, bronchiolitis, secretions, scarring and atelectasis and possibly irreversible hyper-inflation which are common as the disease becomes more severe, similarly in the study by David A. Lynch et.al¹⁵ the cystic type had mostly mixed ventilatory defects but the cylindrical group had mostly obstructive defect. In other studies by Shah et.al¹⁷, Abdulaziz H. Alzeer et.al¹⁶ and David A.Lynch et.al¹⁵ a weakly significant correlation was observed between the type of bronchiectasis and the mean values of FEV1, FVC, FEV1/FVC.

Of the ABG analyses of the bronchiectasis only 4 out of 60 cases showed hypoxemia with PaO_2 of ($<60\text{mmHg}$) and 3 patients showed hypercapnia of PaCO_2 ($>45\text{ mmHg}$), all of them belong to cystic type of bronchiectasis with extensive disease. The mean PaO_2 in cystic bronchiectasis was significantly lower than in cylindrical bronchiectasis ($p < 0.05$) and there was no statistically significant difference in the mean values of PH, PaCO_2 between the two groups. These findings are slightly different from Abdulaziz H. Alzeer et.al¹⁶, study where the mean PaCO_2 was higher and mean PaO_2 was lower in cystic bronchiectasis group than cylindrical group and the difference had statistical significance. ($p < 0.001$).

The analyses of the 2D Echo findings in the present study showed that pulmonary hypertension (RVSP $>30\text{mmHg}$) was present in 11/60 (18.4%) of the cases, of these 10 patients had cystic bronchiectasis and only one case had cylindrical

bronchiectasis, the mean RVSP was higher and LVEF and LVFS were lower in cystic group than in cylindrical group though there was no statistical significance. Three cases of cystic bronchiectasis with extensive involvement (5/6 lobes) had severe pulmonary Hypertension (RVSP>70MMHg), but none had left ventricular dysfunction. The etiology of the observed pulmonary hypertension in these patients is multi factorial. Leibow¹⁸ and others described several pathological changes in bronchiectasis, including dilatation and hypertrophy of bronchial circulation with extensive bronchopulmonary anastomosis, which can lead to left to right shunt. Ashour¹⁹ expanded this further with more emphasis on hemodynamic changes. These changes were mainly seen in cystic type and were described as non perfused segments. These hemodynamic alterations increase right sided after load due to the contribution of systemic pressure on pulmonary vascular resistance, which further increases the pulmonary artery pressure. Although Kolling et.al²⁰ demonstrated left ventricular diastolic dysfunction in 9 patients with bronchiectasis and Abdulaziz H. Alzeer et.al¹⁵, study showed LV diastolic dysfunction in 10 patients with cylindrical bronchiectasis with (>70mmh RVSP), and in another case control by Mehmet Gencer et.al²¹ LV diastolic dysfunction was observed in some cases but none had LV systolic dysfunction. It is explained that RV and LV dysfunction are related to each other with the negative inotropic effect of the hypoxia leading to reduced RV and LV systolic performance. The anatomic features of both ventricles and the presence of pericardium and the inter-ventricular septal shift may be other contributing factors.

If we observe the correlation between RVSP and FEVI, PaO₂, Pa CO₂ the RVSP have a significant negative correlation with PaO₂, a weakly significant positive correlation with PaCO₂ and no correlation with FEVI in cystic bronchiectasis patients. Abdulaziz H. Alzeer et.al¹⁶ study showed that RVSP correlated negatively with FEVI and Pa O₂ and positive correlation with PaCO₂ in cystic bronchiectasis patients. In contrast, no statistically significant correlation was found between the above parameters in patients with cylindrical bronchiectasis, similar to Abdulaziz H. Alzeer et.al¹⁶ study, suggesting that the cylindrical type has more favorable course. The high RVSP and lower PaO₂ and a high PaCO₂ suggest a consequence of poor gas exchange on RVSP. The above findings of deteriorating pulmonary physiology, particularly in patients with cystic bronchiectasis, have an important role in the pathogenesis of pulmonary Hypertension and suggest that pulmonary arterial hypertension is a marker of lung damage in these patients.

Limitations Of The Study

This study has certain limitations because the assessment of RA, RV dimensions was not done. Secondly the diagnosis of pulmonary Hypertension was based on RVSP measurements rather than mean pulmonary artery pressure which can be measured by right heart catheterization the gold standard which was not done. The difficulty in measuring pulmonary arterial systolic pressure in the absence of tricuspid regurgitation is a limitation of the study.

V. Conclusions

It is concluded that mixed ventilatory defects, abnormal gas exchanges, development of pulmonary Hypertension and right ventricular dysfunction are more common in cystic than in cylindrical type of bronchiectasis. The significant correlation between RVSP and PaO₂ suggests that chronic hypoxia has a central role in development of pulmonary Hypertension & RV dysfunction. Since pulmonary Hypertension is seen more frequently with cystic bronchiectasis and therefore can be a useful marker of lung damage. It is suggested that future studies with large study group are recommended that there is need for early detection of bronchiectasis, since its advancement to more severe forms is associated with several complications and morbidity. Aggressive management of pneumonias and childhood respiratory infections and physiotherapy have a definite role in preventing the development of bronchiectasis and its progression to more severe forms and associated complications.

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Legends :

Table 1: Spirometric Measurements

Spirometry parameter	All cases (n=60) Mean \pm SD	Cylindrical bronchiectasis cases (n=12) Mean \pm SD	Cystic bronchiectasis cases (n=48) Mean \pm SD	Cystic vs cylindrical P-VALUE
FEV1/FVC	71.22 \pm 17.94	75.44 \pm 9.53	70.36 \pm 19.50	0.42681
FEV% Predicted	51.52 \pm 19.56	56.80 \pm 22.34	50.16 \pm 19.23	0.33733
FVC % predicted	62.42 \pm 17.45	66.46 \pm 21.68	61.25 \pm 16.87	0.40

Table 2: Abg Parameters

ABG parameters	All cases (n=60) Mean \pm SD	Cylindrical bronchiectasis cases (n=12) Mean \pm SD	Cystic bronchiectasis cases (n=48) Mean \pm SD	Cystic vs cylindrical P -VALUE
PH	7.39 \pm 0.02	7.4 \pm 0.01	7.39 \pm 0.02	0.27
PaO2	71.34 \pm 9.20	76.91 \pm 6.19	70.38 \pm 9.42	0.0410
PaCO2	41.06 \pm 3.69	36.86 \pm 3.61	41.30 \pm 3.76	0.2724

Table 3: 2 D Echo Parameters

2D ECHO parameters	All cases (n=60) Mean \pm SD	Cylindrical bronchiectasis cases (n=12) Mean \pm SD	Cystic bronchiectasis cases (n=48) Mean \pm SD	Cystic vs cylindrical P -VALUE
TR jet velocity	1.65 \pm 0.946	1.27 \pm 0.71	1.74 \pm 0.99	0.16393
RVSP	24.76 \pm 16.98	18.10 \pm 4.91	26.42 \pm 18.52	0.49023
LVEF	67.43 \pm 5.84	68.8 \pm 6.56	67.04 \pm 5.81	0.39851
FS	36.05 \pm 4.27	38.6 \pm 3.89	36.14 \pm 4.31	1.10205

Table 4: Prevalence Of Pulmonary Hypertention In All Patients, Cystic And Cylindrical Bronchiectasis Patients

SPAP	All cases (n=60)	Cystic bronchiectasis cases (n=48)	Cylindrical bronchiectasis cases (n=12)
<30 mmhg	49 (81.6%)	38 (79.2%)	11 (91.67%)
30-40 mmhg	4 (6.7%)	3 (6.25%)	1 (8.33%)
40-70 mmhg	5 (8.3%)	5 (10.4%)	-
> 70 mmhg	2 (3.3%)	2 (4.16%)	-
Mean \pm SDTV	24.8 \pm 17	23.4 \pm 19.2	19 \pm 4.12

Table 5: Correlation Coefficients For Cystic Bronchiectasis Patients

Dependent variable	Independent variables	Correlation coefficient (r)
RVSP	FEV1	- 0.06886
	PaO2	- 0.4
	PaCO2	+ 0.35

Table 6: Correlation Coefficients For Cylindrical Bronchiectasis Patients

Dependent variable	Independent variables	Correlation coefficient (r)
RVSP	FEV1	- 0.26
	PaO2	+ 0.030
	PaCO2	- 0.1324