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Original Article

An Assessment of Tracheal Index and Thoracic Cage Ratio in Patients with Chronic Obstructive Pulmonary Disease

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Abstract

Introduction: Chronic obstructive pulmonary disease is a heterogeneous lung condition characterized by chronic respiratory symptoms due to abnormalities of the airways and/or alveoli that cause persistent, often progressive, airflow obstruction.

Objectives: The present study was undertaken to assess the tracheal index and the thoracic cage ratio in patients with COPD.

Methods: Male COPD patients diagnosed in accordance with GOLD guidelines were included; all study subjects had with smoking history of ≥ 20 pack years and age ≥ 40 years. Patients who had any evidence of coexisting lung disease other than COPD were excluded. Patients having comorbid systemic disorders were also excluded. High-resolution CT scans were obtained without using any contrast. Tracheal Index, defined as the ratio of transverse/anteroposterior diameter at a plane 1-cm above the aortic arch, was analyzed. A tracheal index is < 0.67 was considered as Saber-sheath trachea. In the present study, the thoracic cage ratio was evaluated at two planes: carina and 5 cm below the carina.

Results: A total of 40 COPD patients completed the study. Their mean age was 59.86 ± 9.46 years. Mean smoking history of 37.67 ± 12.26 pack years. Total duration of illness due to COPD was a mean of 14.58 ± 4.86 years. Their FEV1/FVC ratio varied from 0.49 to 0.66 and the resting oxygen saturation was 87.6 to 95.6%. Saber Sheath Trachea was assessed in 14 patients, thoracic cage ratio > 0.75 at Carina was seen in 5 patients, and Thoracic Cage Ratio > 0.75 at 5 cm below Carina was found in 11 patients. Tracheal Index had significant correlations with age, duration of illness, pack years and FEV1/FVC Ratio. Thoracic Cage Ratio at carina and that 5 cm below carina had significant correlations with age, duration of illness, pack years and FEV1/FVC Ratio

Conclusion: HRCT was observed to be a useful imaging modality to detect characteristics of pulmonary hyperinflation – Tracheal index and the thoracic cage ratio. These parameters had significant correlations with the severity of the disease.

Keywords: COPD, HRCT, Tracheal index, Thoracic cage ratio, Lung hyperinflation, Saber Sheath Trachea, Airways disorders

Introduction

Chronic obstructive pulmonary disease is presently considered as a heterogeneous lung condition characterized by chronic respiratory symptoms (cough, expectoration, dyspnea, and/or exacerbations) due to abnormalities of the airways and/or alveoli that cause persistent, often progressive, airflow obstruction[1]. Smoking is particularly identified as a most significant risk factor associated with COPD, characterised by increased prevalence of airflow obstruction and a faster annual rate of FEV_1 decline, and an increased COPD mortality[2]. Worldwide, COPD carries a prevalence of around 10% in the general population aged 40 years or more.[3]

COPD is often characterised by the loss of lung elastic recoil pressure, the loss of alveolar walls and attachments, rendering the airways more liable to collapse during expiration. There is expiratory flow limitation. The fine balance between inward recoil associated with the elastic properties of the lungs and outward recoil of the thoracic cage is altered, resulting in in static lung hyperinflation, and, in patients with flow-limited

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COPD, leading to gas trapping[4,5]. End-expiratory lung volume (EELV) can increase momentarily above the resting value in situations where expiratory flow is rapidly worsened or when ventilatory demand is abruptly increased, characteristics of dynamic lung hyperinflation[6]. These patients have limitations in physical activities due to exertional dyspnoea and peripheral muscle weakness[5].

CT imaging has an important upcoming role in the investigation of COPD, where it can help in making a diagnosis and offer relevant information regarding concomitant diseases[7]. CT imaging is often helpful to plan interventional strategies in patients with severe COPD. It is also able to detect extrapulmonary manifestations of the disease. The assessment of lung hyperinflation by measuring the thoracic cross-sectional ratio using CT scans is one of the most reliable characteristics. Similarly, identification of tracheal index and characterisation as sabre-sheath trachea is a pathognomonic finding of COPD. Despite all this, the place of CT in the investigation and management of COPD is yet to be implemented in clinical management to its full potential[7]. Our study was undertaken to assess Tracheal Index and Thoracic Cage Ratio, which are important parameters of lung hyperinflation, in patients with COPD.

Methods

The present study was carried out in our Institute involving the Departments of Radiodiagnosis and Respiratory Medicine. Appropriate Ethical clearance was taken, though the study was descriptive in nature, no invasive procedure was involved and HRCT thorax is a widely used modality for the management of various respiratory disorders.

The study subjects comprised male patients with COPD and having age 40 years or older. COPD was considered on the basis of established criteria defined by the Global Initiative for Chronic Obstructive Lung Disease (GOLD) 2023 update[1]. Informed written consent for the study was obtained from each study subject. All included patients were current smokers; the quantum of smoking in each study subject was at least 20 pack years. All included patients had irreversible or partially reversible airflow limitation characterised by the spirometric value of postbronchodilator FEV1 < 80% of the predicted value in combination with FEV1/FVC < 70%. The procedure of spirometry was required to be repeated 20 minutes after 2 puffs of inhaled salbutamol given through a spacer attached to a salbutamol metered dose inhaler. The reversibility was present if the increase in FEV1 was more than 200 mL or more than 12% of the baseline value; this was an exclusion criterion for patients in the present study. The presence of any concomitant respiratory disorder or any coexisting systemic disease in COPD study subjects was also an exclusion criterion. Spirometric indices were calculated using satisfactory performances as per the recommendations of the American Thoracic society[8].

All study subjects underwent standardized and structured evaluation, including complete blood examination, urine examination, chest radiograph, electrocardiography, and echocardiography.

All patients underwent high resolution computed tomography (HRCT) study that was carried out using the spiral CT scanner, Siemens, Erlangen, Germany. Scanning was performed at a field of view large enough to encompass the patient. Images were obtained at maximum inspiration by using 1-mm collimation at 120 kV (p) and 90 mAs with a 0.75 sec acquisition time. Axial CT Scans were taken at 01 cm intervals, with the patient lying in supine posture. Images were reassembled using a high spatial frequency algorithm and a 512 x 512 matrix. No contrast medium was used. For analysis purposes, following parameters were evaluated using HRCT:

Measurement of the Tracheal Index using HRCT

Axial HRCT images of the trachea were obtained. The standardized level chosen for measuring the Tracheal Index was 1 cm above the aortic arch. Coronal (transverse) diameter was selected out of the widest point of the trachea in the coronal plane and the distance was measured. Sagittal (anteroposterior) diameter was selected out of the widest point of the trachea in the sagittal plane and the distance was measured. Tracheal Index was calculated by dividing the coronal diameter by the sagittal diameter.

Assessment of the saber-sheath trachea using HRCT

A tracheal index of less than 0.67 was considered as saber-sheath trachea, indicating airway narrowing, particularly in the coronal plane. This finding is considered a pathognomonic HRCT feature of COPD patients.

Measurement of the Thoracic cage ratio using HRCT

The thoracic cage ratio (TCR), sometimes described as the thoracic cross-sectional ratio, was measured using Axial HRCT images and was calculated by dividing the anteroposterior (AP) diameter of the thorax by its transverse (lateral) diameter at the specific level mentioned here:

a. Tracheal carina plane

b. 5 cm below carina plane

The thoracic cage ratio in a normal adult is less than 0.75; a ratio greater than 0.75 in COPD patients suggests hyperinflation and is typically seen in advanced emphysema. This increase is due to the chronic overinflation of the lungs, which alters the shape of the chest cavity, making it wider and rounder[9]. A thoracic cage ratio more than 0.9 is characterised as "barrel-chest" appearance, which is due to increased lung volume and hyperinflation

For statistical analyses, group means and standard deviations for each variable were calculated for the entire COPD group. Individual patients having abnormal values in

reference to the normalized laboratory/software range were identified as having significant HRCT features. All statistical analyses were done taking the help of SPSS software.

Results

The study subjects in the present study comprised of 40 male patients with COPD. Their mean age was 59.86 ± 9.46 years (range: 50–72 years). Each of the study subjects was a current smoker. Their mean quantum of smoking was 37.67 ± 12.26 pack years. Total duration of illness due to COPD was a mean of 14.58 ± 4.86 years. Their FEV1/FVC ratio varied from 0.49 to 0.66 and the resting oxygen saturation was 87.6 to 95.6%. They were attending the COPD Clinic at our Institute regularly with compliance with the treatment advised to them.

Chest radiographs were undertaken in all study subjects. The patients showing one or more features of lung hyperinflation were as mentioned below: low flat diaphragm (8), hyperinflated lungs (11), attenuated peripheral blood vessels (6) and tubular cardiac silhouette (9) on postero-anterior view; and large retrosternal space (4) and barrel chest (6) on left lateral view.

Individual COPD patients had characteristic findings in various study parameters were as shown in Table 1. Overall, twenty-eight COPD patients had one or more HRCT findings suggestive of hyperinflation of the thoracic cage and, altered tracheal index.

In the present study, amongst 40 study subjects, the mean value of tracheal index was 0.672 ± 0.107. Each of the study subjects had a transverse diameter less than the anteroposterior diameter. The majority of patients (30/40) had a value of tracheal index less than 0.70. Saber-sheath trachea was observed in 14 subjects (35% of study subjects)

At carina, the mean thoracic cage ratio was 0.71± 0.08; 35 patients had a ratio less than 0.75, and 5 patients had a ratio more than 0.75. At a point 5 cm below the carina, the mean thoracic cage ratio was 0.73 ± 0.09; 28 patients had a ratio between 0.70 and 0.80, and 4 patients had a ratio over 0.9, which was suggestive of barrel chest. Distributive analyses showed that the thoracic cage ratio was greater at 5 cm below the carina.

In our study, tracheal index had significant correlations ($p < 0.05$) with age, duration of illness, pack years and FEV1/FVC ratio. The thoracic cage ratio at carina and that 5 cm below carina had significant correlations ($p < 0.05$) with age, duration of illness, pack years and FEV1/FVC ratio.

Table 1: HRCT features observed in study subjects comprising off COPD patients (n = 40)

HRCT features	Number of Patients	Percentage of study subjects
Saber Sheath Trachea with Tracheal Index less than 0.67	14	35
Thoracic Cage Ratio, at the plane of tracheal carina, more than 0.75	5	12.5
Thoracic Cage Ratio, at the plane 5 cm below tracheal carina, more than 0.75	11	27.5

Legend to Figure 1 A to Figure 1 D

Axial scans from HRCT of the COPD patients found to have saber sheath trachea. Saber sheath trachea, a pathognomonic HRCT feature of COPD, is considered when the tracheal index is less than 0.67; that is calculated by dividing the coronal diameter by the sagittal diameter of the trachea in an axial scan taken at the level 1 cm above the aortic arch.

Legend to Figure 2A to Figure 2F

Axial scans from HRCT of the COPD patients taken at the level of the tracheal carina plane. There is a gross increase in the thoracic cage ratio, more than 0.75, calculated by dividing the anteroposterior diameter of the thorax by its transverse diameter. This feature is pathognomonic for lung hyperinflation due to air-trapping seen in COPD patients.

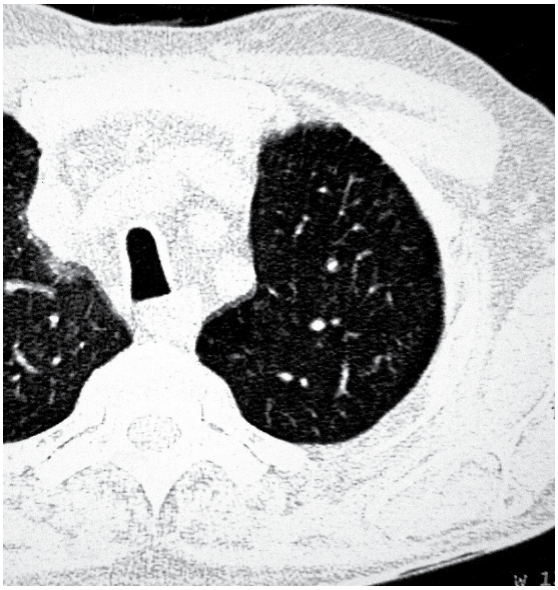

Figure 1: A

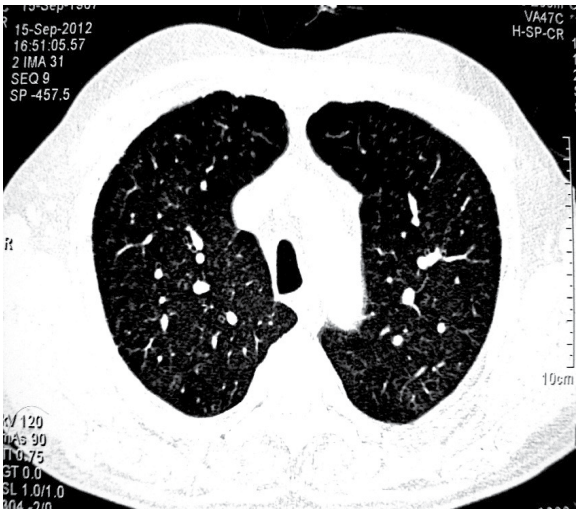

Figure 1: B

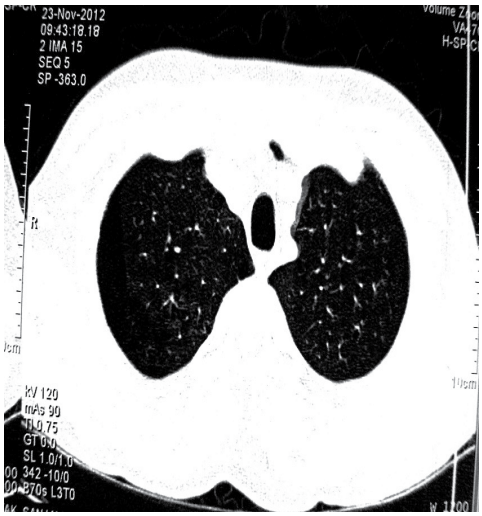

Figure 1: C

Figure 2: B

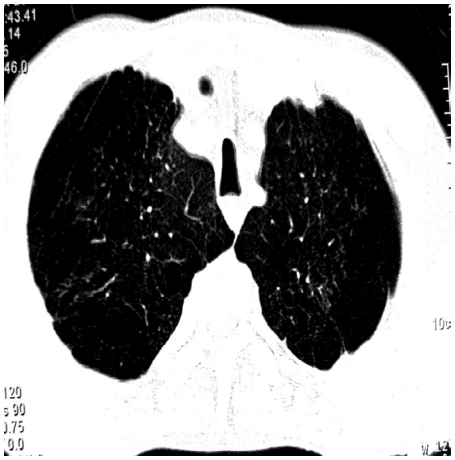

Figure 1: D

Figure 2: C

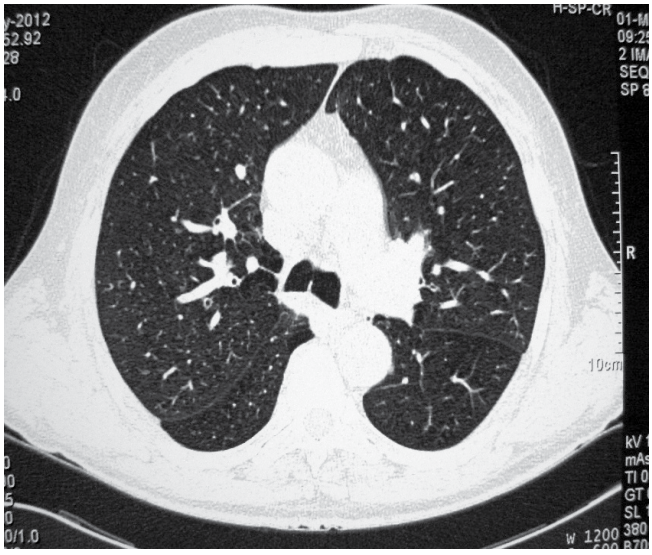

Figure 2: A

Figure 2: D

Figure 2: E

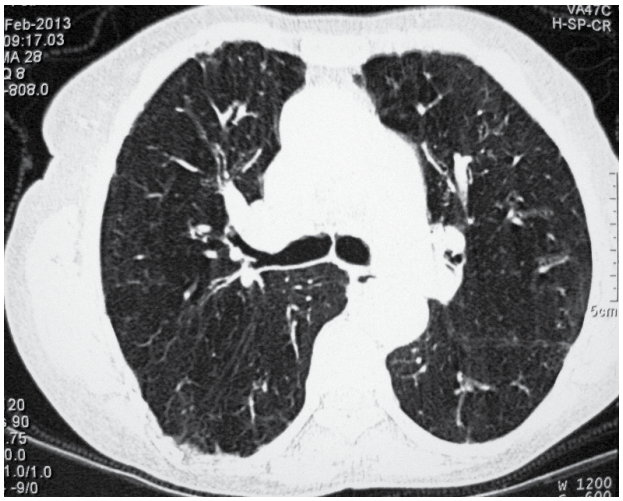

Figure 2: F

Figure 3: A

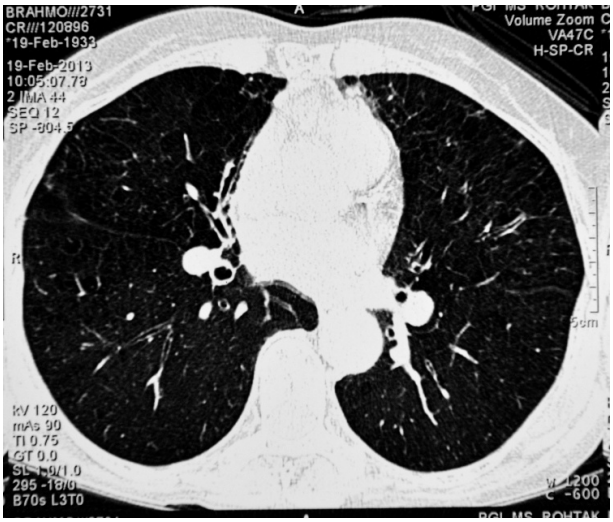

Figure 3: B

Legend to Figure 3 A to Figure 3B

Axial scans from HRCT of the COPD patients taken at the level 5 cm below the tracheal carina plane. A gross increase in thoracic cage ratio, more than 0.75, calculated by dividing the anteroposterior diameter of the thorax by its transverse diameter, is seen here. This feature is pathognomonic for lung hyperinflation seen in COPD patients.

Discussion

Way back, even during the 17th century, hyperinflated lungs were the characteristic observations during autopsies carried over on patients expired due to the diseases later characterised as COPD[10]. With the invent of the spirometer as a diagnostic tool, airflow obstruction was measured objectively in patients with COPD by the mid-20th century. As early as in 1950s, measurements of FEV1 and FEV1/ FVC ratio were established as a significant modality for diagnosis and prognosis of COPD. A further understanding of COPD provided further insights into pathogenesis and altered physiology in these patients and the fact that a vast number of COPD patients may have normal spirometric values, particularly during the early course of the development of COPD.

There has been a clinical scenario when a patient having symptoms and/or signs of COPD, along with well-identified risk factors like tobacco smoking, but with normal spirometry values, was not fulfilling the criteria for a diagnosis of COPD despite having characteristic findings on CT scan imaging. In 2015, the Genetic Epidemiology of COPD (COPDGene) Study observed that in around 54% of subjects with clinical findings suggesting COPD had a CT scan suggested emphysema, gas trapping, or airway disease.[11] Further, 32% of these patients had airway wall thickening and 10% had emphysema found on analysis of CT scans.

COPD encompasses a heterogeneous group of patients, and the increasing use of CT imaging has identified the different phenotypes among the COPD patients. Disease identification, classification, and subtyping are potential applications of CT

scan imaging in a patient management algorithm. Moreover, CT imaging is helpful for the detection of comorbidities in COPD patients and prognostic anticipation[12]. A recent publication by the Lancet Commission on COPD[13] suggested that chest CT scans should be reviewed for COPD, including early abnormalities. The authors suggested that CT scan-detected emphysema, air trapping, and airway remodelling be considered diagnostic of COPD, even in the absence of airway obstruction on spirometry. Further understanding of the role of lung imaging shall drastically change the way the early detection of COPD is made and that may help in the possible prevention of disease progression.

Chest radiographs are the standard first-line imaging modality undertaken in any suspected respiratory disorder. These involve significantly less radiation and are inexpensive. Chest radiographs often suggest characteristics of emphysema by identifying a flattened diaphragm, hyperlucent and hyperinflated lung fields, vascular pruning, tubular cardiac silhouette and increased retrosternal airspace[14]. Though chest radiographs have yielded a sensitivity of 90% and a specificity of 98% for emphysema, they are insensitive for the detection of early emphysema.[15]

COPD is often characterised by a reduction in tracheal index that is calculated by dividing the coronal diameter by the sagittal diameter of the trachea at a plane 1-cm above the aortic arch. Interestingly, though, the intrathoracic trachea's shape is drastically altered; that of the extrathoracic trachea is preserved. Saber-sheath trachea is characterized by fixed deformity of the intrathoracic trachea involving a reduction in tracheal index to less than 0.67. Saber-sheath trachea is a pathognomonic sign of hyperinflation and air trapping, as more than 95% of patients with this deformity show clinical evidence of COPD[16]. Saber-sheath Ber-sheath trachea found to have a prevalence as high as 25% in patients with COPD, with a higher prevalence in severe airflow obstruction (GOLD stages III-IV)[17]. The cause of this deformity remains hypothetical; that hyperinflated lungs and a high intrathoracic pressure flatten the intrathoracic trachea. CT imaging is now considered the procedure of choice for evaluation of tracheal index and saber-sheath trachea. In our study, we found saber sheath trachea with tracheal index < 0.67 in 35% of patients with COPD. We analysed that saber-sheath trachea had significant correlations with age, duration of illness, pack years and the severity of COPD in terms of FEV1/FVC Ratio.

In the present study, a thoracic cage ratio more than 0.75, at the plane of tracheal carina, was observed in 12.5% of COPD patients and a thoracic cage ratio more than 0.75, at the plane 5 cm below tracheal carina, was seen in 27.5% of study subjects. We observed the thoracic cage ratio at the carina and that 5 cm below the carina had significant correlations (p <0.05) with age, duration of illness, pack years, and the severity of COPD in terms of FEV1/FVC Ratio.

Finally, to conclude, HRCT imaging is an authentic modality that can assess the thoracic alterations associated with hyperinflated lungs, which are commonly encountered in patients with moderate to severe COPD and can provide necessary inputs for clinical assessment and management. HRCT imaging is a prerequisite for planning surgical interventions like lung volume reduction surgery and lung transplantation.

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