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Role of quantitative CT in COPD & its correlation with pulmonary function test values

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Abstract
Aim: To assess the role of Quantitative CT in COPD & evaluate relationship between Quantitative CT(QCT) and spirometric measurements of disease severity in subjects with and without chronic obstructive pulmonary disease (COPD).
Background: The chronic airflow limitation characteristic of COPD is caused by a mixture of parenchymal destruction and small airways disease the relative contributions of which vary from person to person. Standard pulmonary function test results fail to determine the relative contribution of the two pathologic processes involved in COPD. QCT of the lung parenchyma uses accurate measures of lung density to generate histogram statistics of the lung to detect lower-density areas of the lung that correspond to emphysema on total lung capacity (TLC) scans and can also look at lower-density areas of the lung that correspond to air trapping on CT scans of the lung obtained at functional residual capacity (FRC) or residual volume (RV). Computed tomography can also quantitatively assess morphologic changes such as emphysema, hyperinflation, bronchial wall thickening & vascular pruning.
Materials and Methods: QCT of subjects were performed in 16 slice CT and evaluated using Lung Volumetry Software. Measures examined include emphysema, defined as the percentage of low-attenuation areas ≤ –950 HU on inspiratory CT, air trapping, defined as the percentage of low-attenuation areas ≤ –856 HU on expiratory CT, and the inner diameter, inner and outer areas, wall area of segmental airways. Correlations determined between spirometry and several QCT measures.
Results: Progressively increasing LAA-950I (Low attenuation area in Inspiration <-950HU) and LAA856E (Low attenuation areas in Expiration <-856HU) were noted for increasing GOLD stage and COPD disease severity. Mean LAA-950I and LAA856E values progressively increased with increasing GOLD stage (p< 0.005). For air trapping, LAA-856E showed correlation for both FEV1 and FEV1/FVC (r = –0.93 and –0.79, respectively). Emphysema showed similar results, with LAA-950I showing correlation for FEV1 and FEV1/FVC (r = –0.81 and –0.69, respectively). Measures of inner diameter, inner area, outer area and airway wall thickness showed good correlation to both FEV1 and FEV1/FVC for all subjects in the cohort. Measures of wall area showed poor correlation to both FEV1 (r -.01) and FEV1/FVC (r -.02)

Keywords: Spirometry, COPD, airway, CT

Introduction
Chronic obstructive pulmonary disease (COPD) is a gradually progressive disorder characterized by irreversible or partially reversible airway obstruction [1]. It is predicted to be the fifth leading cause of disability in the world by the year 2020 [2]. The accompanying histopathological changes that lead to air flow limitations appear to be a combination of varying degree of parenchymal destruction (emphysema), small and large airway changes (bronchiolitis and bronchitis), air trapping on expiration, vascular alterations, and chest wall and diaphragmatic changes [3, 4].
High-resolution computed tomography (HRCT) allows detailed anatomical analysis of pulmonary structure, and hence, is currently widely used for the detection and characterization of COPD. HRCT has been used to define and categorize these patients into two predominant groups – those with emphysema-predominant disease and those with airway-predominant disease. The former group can be further subclassified based on the type of emphysematous disease into centrilobular, panlobular, paraseptal, and bullous emphysema [5]. The management of COPD is based on the relative distribution and severity of small airway remodelling and loss of elastic recoil.

However there maybe variations in the contributions of the individual processes even in patients with similar values of pulmonary function tests. Hence, routine pulmonary function tests are of not much use to assess the specific contribution of each pathological process. These changes are better evaluated by quantitative computed tomography analysis of the lungs.

Various researchers have shown that CT is of considerable value in quantifying the severity of the disease in COPD, either using visual or, more preferably, using quantitative CT techniques (QCT). The aim of this prospective study was to assess the relationship between the commonly used QCT parameters and commonly utilized clinical measures of disease severity in patients with COPD.

Rationale of the study

The chronic airflow limitation characteristic of COPD is caused by a mixture of parenchymal destruction and small airways disease the relative contributions of which vary from person to person. The potential usefulness of CT for identification of regions of pulmonary emphysema and air trapping has been addressed in many investigations [6]. Emphysematous changes in the lungs of patients with COPD are represented as low attenuation areas on CT images [7-9].

QCT of the lung parenchyma uses accurate measures of lung density to generate histogram statistics of the lung to detect lower-density areas of the lung that correspond to emphysema on total lung capacity (TLC) scans and can also look at lower-density areas of the lung that correspond to air trapping on CT scans of the lung obtained at functional residual capacity (FRC) or residual volume (RV). The detection of the emphysema is a direct measure of lung remodelling in COPD, and the detection of air trapping is believed to be an indirect measure of small airway disease [10].

Standard pulmonary function test results fail to determine the relative contribution of the two pathologic processes involved in COPD. However, the degree of contribution of the two pathologic processes is clinically important in the planning and response to therapeutic intervention [11]. For example, pulmonary function may be improved by lung volume reduction surgery in patients with emphysema-predominant COPD. However, medical treatment may be more effective in cases of airway-predominant COPD. Computed tomography can also quantitatively assess. morphologic changes such as emphysema, hyperinflation, bronchial wall thickening, air trapping & vascular pruning. Thus, airway-predominant and emphysema-predominant COPD can be effectively differentiated by computed tomography [11, 12].

The purpose of our study was to determine whether measurements of lung attenuation obtained from 3D lung reconstructions at inspiration and expiration reflect the severity of COPD. We correlated lung function measurements at inspiration and expiration with measurements of lung attenuation on 3D lung reconstructions. We also evaluated the relation between the severity of COPD, reflected by Global Initiative for Chronic Obstructive Lung Disease (GOLD) stage [1], and measurements of lung attenuation on 3D lung reconstructions.

Materials and Methods

Aim of the study

Primary Aim: To assess the role of Quantitative CT in COPD 2. Secondary Aim - To evaluate the relationship between Quantitative CT(QCT) and spirometric measurements of disease severity in subjects with and without chronic obstructive pulmonary disease (COPD).

Study area

Dept. of Radiodiagnosis, S.P Medical College &A.G. of P.B.M. Hospitals, Bikaner, Rajasthan.

Study period

1 year (April 2022 to March 2023)

Sample size: 70

Study design: Prospective Comparative Study

Inclusion criteria

Cases: Eligible subjects between the ages of 40 and 65 years & having COPD.

Controls: Subjects between the ages of 40 and 65 years & not having COPD.

Exclusion criteria

- Subjects with concomitant respiratory disorders other than COPD.
- Non-Cooperative patients
- COPD patients who are unable to hold their breath for sufficient period of time to allow for examination.

Methodology

This prospective study was performed after obtaining clearance from our Institutional Ethics Committee and institutional informed consent guidelines were observed.

Study population

Patients referred from Thoracic Medicine department for CT chest who were proved to have COPD by Pulmonary Function Test were included in this study during the period from April 2022 to March 2023.

Controls were subjects with normal Pulmonary Function Test values & normal CT chest findings who were referred for reasons other than COPD.

The patients were screened using the drawn inclusion/ exclusion criteria. Relevant entries in the proforma for each patient were made after reviewing his/her case sheet & previous medical records.

QCT data were suppressed from the cohort if scans showed extreme motion or had other technical inadequacies (e.g., non-protocol reconstruction kernel, low exposure, or a value of > 1 for the ratio of functional residual capacity [FRC] to total lung capacity [TLC]).

The resultant dataset consists of a total of 70 subjects: 21 subjects without COPD (no spirometric evidence of airway obstruction) who served as control, 6 subjects with GOLD stage 1 disease (12%), 18 subjects with GOLD stage 2 disease (37%), 13 subjects with GOLD stage 3 disease (27%), and 12 subjects with GOLD stage 4 disease (24%). The cohort consists of 57 men (81%) and 13 women (19%).

airway wall thickness, inner area, inner diameter and outer area showed good correlation to both FEV1 and FEV1/FVC for all subjects in the cohort. Measures of wall area showed poor correlation to both FEV1 (r -.01) and FEV1/FVC (r -.02).

All patients were required to provide written informed consent before study participation.

CT Examination

All the Quantitative CT studies were performed in a 128 slice CT scanner (TOSHIBA-ALEXION).

In each case, CT of the thorax was performed from the lung apices through the level of the adrenal glands. These scans were reconstructed with a slice thickness of 1 mm and corresponding slice interval of 1mm, to achieve near-isotropic voxels.

Inspiratory & expiratory scans were acquired at 100 mAs; all scans were acquired at 120 kVp. CT dose modulation and IV contrast agents were not used for this study.

Scanning was performed as follows:

Inspiratory CT:

Subject was asked to take a deep breath & plain CT chest was taken at full inspiration to obtain Total Lung Capacity.

Expiratory CT: Subject was asked to hold breath in normal expiration & CT chest was taken to obtain Functional Residual Capacity.

Image postprocessing & analysis

Three-dimensional models of the lungs were reconstructed with analysis software (TOSHIBA lung Analysis Software). In this software, areas of low attenuation (HU threshold set as -950 for inspiratory CT & -856 for expiratory CT) are highlighted in yellow. Lung volume, low attenuation volume, low attenuation percentage and mean lung attenuation were calculated. Inner & outer diameters measured manually in anterior segmental bronchus of bilateral upper lobes (4th generation bronchi) and their average value was taken. Wall area & wall thickness were calculated manually.

Case 1

51 year old male, smoker for 20 years, stopped for past 4 years. Diagnosed to have COPD GOLD stage 1 by PFT.

FEV1 – 1.33

FVC – 1.84

FEV1/FVC – 0.72

Quantitative CT

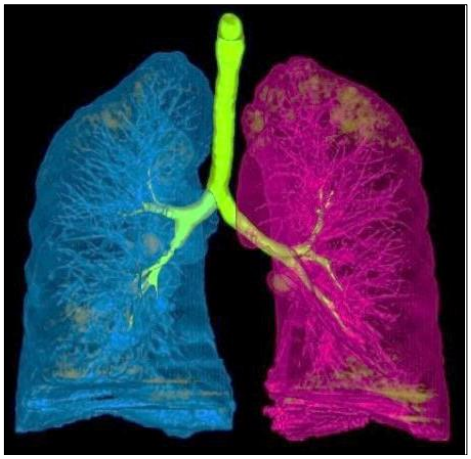


Fig 1: Inspiration

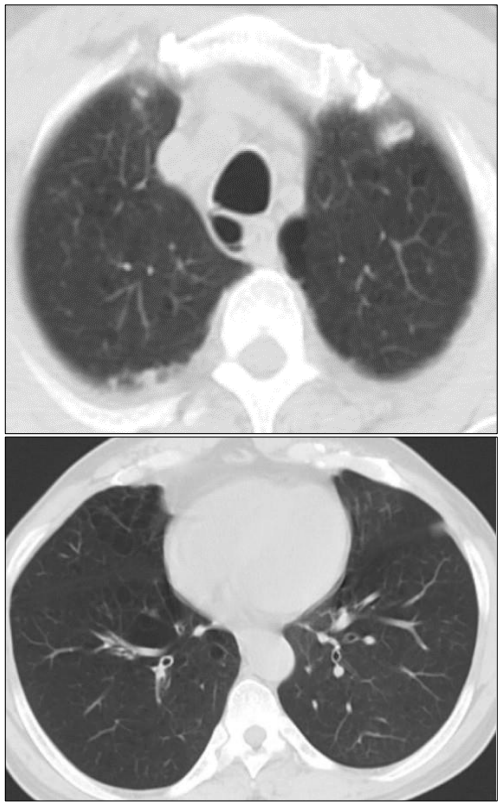
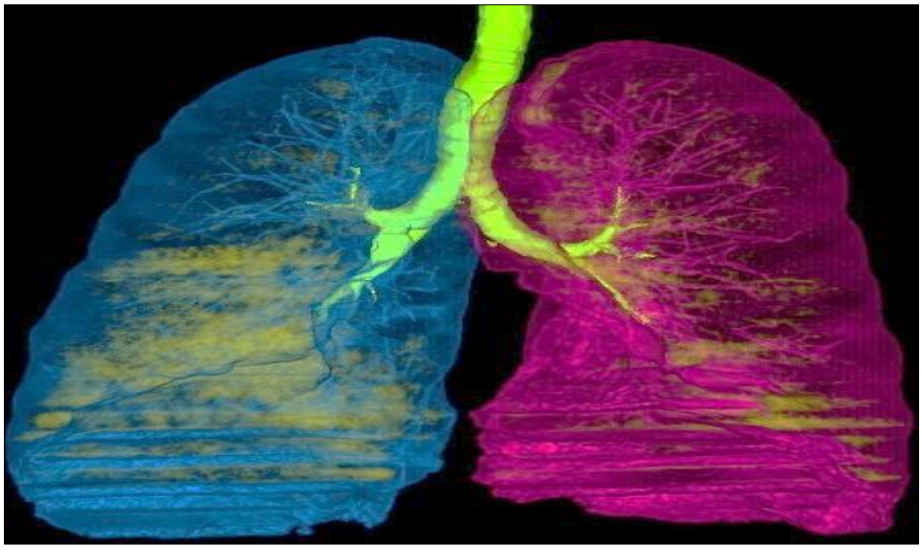
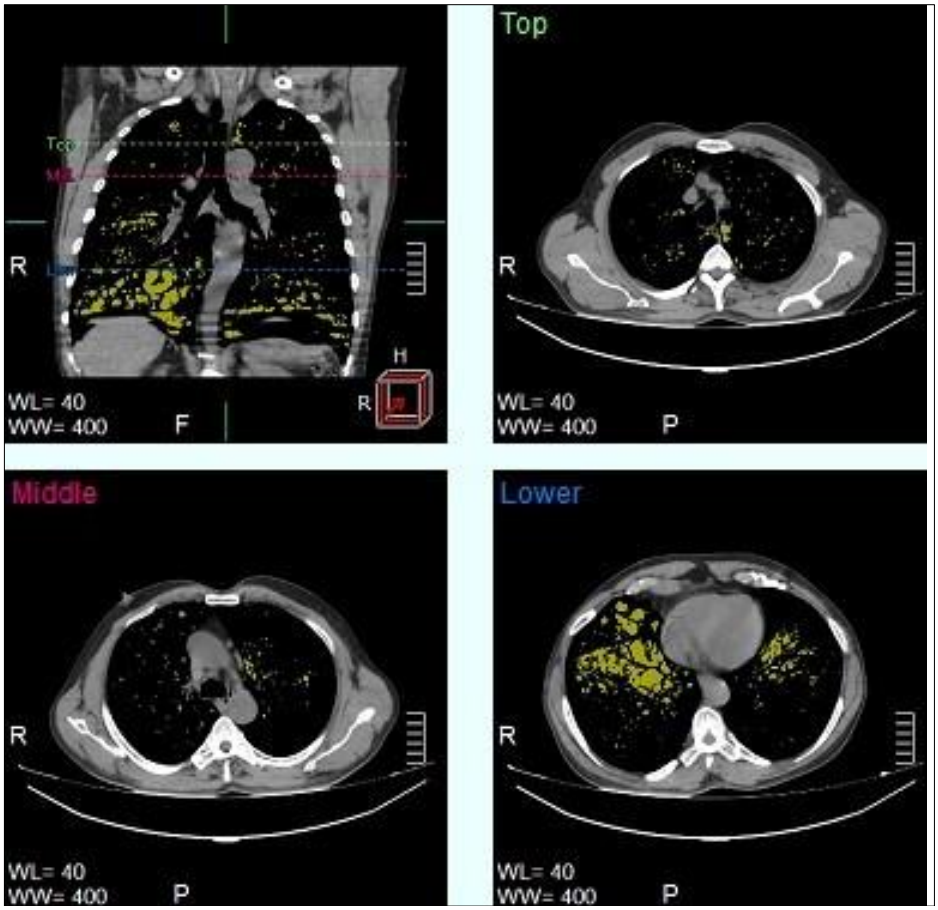


Fig 2: Expiration





PARAMETERS	VALUES
% lung attenuation <-950HU	5.4
Mean lung attenuation in Inspiration	-843 HU
Total Lung Capacity	5.3 L
% lung attenuation <-856HU	25.3
Mean lung attenuation in Expiration	-733 HU
Functional Residual Capacity	3.1 L
Inner Diameter	3.6mm
Airway Wall Thickness	1.4mm
Inner Area	$7.5mm^3$
Outer Area	$32.1mm^3$
Wall Area	$24.6mm^3$

Statistical analysis

- The collected data were analysed with IBM.SPSS statistics software 23.0 Version.
- To describe about the data descriptive statistics frequency analysis, percentage analysis were used for categorical variables and the mean & S.D were used for continuous variables.
- To find the significant difference between the bivariate samples in Independent groups the Unpaired sample t-test was used.
- For the multivariate analysis the one way ANOVA with Tukey's Post-Hoc test was used.
- To assess the relationship between the variables Pearson's Correlation was used with Scatter plot.
- To identify the influence of the variables the multiple regression model with enter method.
- To find the significance in categorical data Chi-Square test was used similarly if the expected cell frequency is less than 5 in 2×2 tables then the Fisher's Exact was used.
- In all the above statistical tools the probability value .05 is considered as significant level (significant, not significant)

Results

1. Among the 70 subjects studied, 21 subjects without COPD (no spirometric evidence of airway obstruction) served as control and 49 cases with COPD served as cases.
2. The study group consisted of 6 subjects with GOLD stage 1 disease (12%), 18 subjects with GOLD stage 2 disease (37%), 13 subjects with GOLD stage 3 disease (27%), and 12 subjects with GOLD stage 4 disease (24%).
3. The cohort consists of 57 men (81%) and 13 women (19%).

In the 49 subjects with COPD

- Progressively increasing LAA-950I (Low attenuation area in Inspiration <-950HU) and LAA856E (Low attenuation areas in Expiration <-856HU) were noted for increasing GOLD stage and COPD disease severity.
- Mean LAA-950I and LAA856E values progressively increased with increasing GOLD stage ($p < 0.005$).
- For air trapping, LAA-856E showed correlation for both FEV1 and FEV1/FVC ($r = –0.93$ and $–0.79$, respectively) (Figure 7.6 & 7.7).
- Emphysema showed similar results, with LAA-950I showing correlation for FEV1 and FEV1/FVC ($r = –0.81$ and $–0.69$, respectively) (Figure 7.4 & 7.5).
- Other measures, such as the difference in mean lung attenuation, showed very high correlation with spirometric measures also.
- Both TLC and FRC increase across GOLD stage.

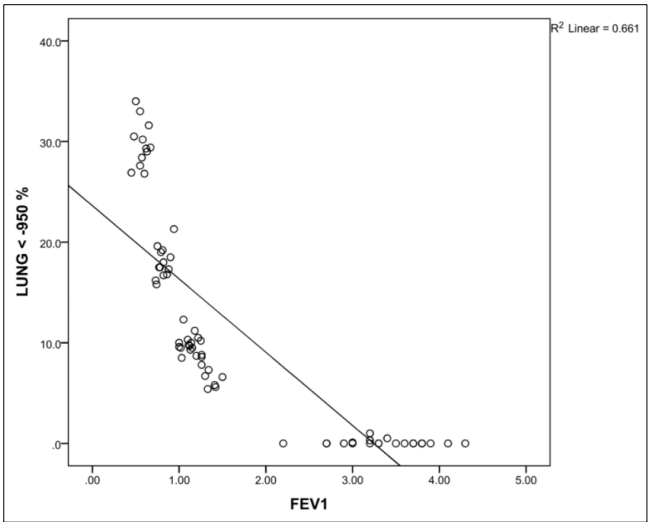


Fig 2: Scatterplot shows percentage of low-attenuation areas ≤ –950 HU on inspiratory CT (LAA-950I) and forced expiratory volume in 1 second (FEV1). Line shows linear correlation.

Limitations of study

Our study was associated with multiple limitations

- The CT attenuation values are affected by variation in inspiratory and expiratory lung volumes and acquisition techniques.
- Limited number of study subjects.
- Poor breath holding by subjects affected the correct measurement of lung volumes (TLC & ERC).
- Manual measurement of 4th generation segmental bronchial measurements.
- Full-body plethysmography was not performed as part of this study; hence, measures such as the diffusion capacity of lung for carbon monoxide and true TLC could not be determined.

Conclusion

We conclude that QCT measurements of inspiratory and expiratory low-attenuation areas are strongly associated with spirometric impairment in subjects with COPD.

QCT of the lung parenchyma uses accurate measures of lung density to generate histogram statistics of the lung to detect lower-density areas of the lung that correspond to emphysema on total lung capacity (TLC) scans and can also look at lower-density areas of the lung that correspond to air trapping on CT scans of the lung obtained at functional residual capacity (FRC) or residual volume (RV). The detection of the emphysema is a direct measure of lung remodelling in COPD, and the detection of air trapping is an indirect measure of small airway disease.

Although univariate correlation between airway measures and spirometric impairment is less strong, inclusion of these measures in the multiple regression model strengthens the correlation.

Air trapping on expiratory imaging measured as LAA-856E strongly correlates with physiologic measurements of airway obstruction.

References

1. Global Initiative for Chronic Obstructive Lung Disease. Global strategy for the diagnosis, management, and prevention of chronic obstructive pulmonary disease. Bethesda, Md: National Heart, Lung, and Blood Institute, World Health Organization; c2008.
2. Murray CJL, Lopez AD. Evidence-based health policy-Lessons from the Global Burden of Disease Study. Science. 1996;274:740-3.
3. Fujimoto K, Kitaguchi Y, Kubo K, Honda T. Clinical analysis of chronic obstructive pulmonary disease phenotypes classified using high-resolution computed tomography. Respirology. 2006;11:731-40.
4. Makita H, NasuharaY, Nagai K, Ito Y, Hasegawa M, Betsuyaku T, *et al*. Characterisation of phenotypes based on severity of emphysema in chronic obstructive pulmonary disease. Thorax. 2007;62:932-7.
5. Webb WR, Muller NL, Naidich DP. High-resolution CT of the lung. 4th ed. Philadelphia, Pa: Lippincott Williams & Wilkins; c2009.
6. Coxson HO, Rogers RM. Quantitative computed tomography of chronic obstructive pulmonary disease. Acad Radiol. 2005;12:1457-1463.
7. Gevenois PA, De Maertelaer V, De Vuyst P, Zanen J, Yernault JC. Comparison of computed density and macroscopic morphometry in pulmonary emphysema. Am J Respir Crit Care Med. 1995;152:653-657.
8. Gevenois PA, De Vuyst P, De Maertelaer V, *et al*. Comparison of computed density and microscopic morphometry in pulmonary emphysema. Am J Respir Crit Care Med. 1996;154:187-192.
9. Müller NL, Staples CA, Miller RR, Abboud RT. -Density mask‖: an objective method to quantitate emphysema using computed tomography. Chest. 1988;94:782-787.
10. John D Newell JR. Quantitative Computed Tomography of Lung Parenchyma in Chronic Obstructive Pulmonary Disease-An Overview. Proc Am Thorac Soc. 2008;5:915-918.
11. Fujimoto K, Kitaguchi Y, Kubo K, Honda T. Clinical analysis of chronic obstructive pulmonary disease phenotypes classified using high-resolution computed tomography. Respirology. 2006;11:731-740.
12. Makita H, Nasuhara Y, Nagai K, *et al*. Characterisation of phenotypes based on severity of emphysema in chronic obstructive pulmonary disease. Thorax. 2007;62:932-937.
13. Larsen, William J. Human embryology (3. ed.). Philadelphia, Pa.: Churchill Livingstone; c2001. p. 143. ISBN 0-443-06583-7.
14. Sadler T. Langman's medical embryology (11th ed.). Philadelphia: Lippincott William & Wilkins; c2010. p. 202-204. ISBN 978-0-7817-9069-7.
15. Pauwels RA, Buist AS, Ma P, Jenkins CR, Hurd SS. Global strategy for the diagnosis, management, and prevention of chronic obstructive pulmonary disease: National Heart, Lung, and Blood Institute and World Health Organization Global Initiative for Chronic Obstructive Lung Disease (GOLD): executive summary. Respir Care. 2001;46(8):798-825.
16. Jones PW. Health status measurement in chronic obstructive pulmonary disease. Thorax. 2001;56(11):880-7.
17. Harrison 19th Edition, Dennis Casper, Anthony Fauci, Stephen Hauser, Dan Longo, J.Larry Jameson, Joseph Loscalzo.
18. Saetta M, Ghezzo H, Kim WD, *et al*. Loss of alveolar attachments in smokers: a morphometric correlate of lung function impairment. Am Rev Respir Dis. 1985;132:894-900.

19. Gelb AF, Hogg JC, Muller NL, *et al*. Contribution of emphysema and small airways in COPD. Chest. 1996;109:353-359.
20. Hogg JC, Wright JL, Wiggs BR, Coxson HO, Opazo Saez A, Pare PD. Lung structure and function in cigarette smokers. Thorax. 1994;49:473-478.
21. Petty TL, Silvers GW, Stanford RE. Radial traction and small airways disease in excised human lungs. Am Rev Respir Dis. 1986;133:132-135.
22. Lamb D, McLean A, Gillooly M, *et al*. Relation between distal airspace size, bronchiolar attachments, and lung function. Thorax. 1993;48:1012-1017.
23. Mannino DM, Watt G, Hole D, *et al*. The natural history of chronic obstructive pulmonary disease. Eur Respir J. 2006;27:627-43.