MEASUREMENT OF PULMONARY PARENCHYMAL ATTENUATION IN HEALTHY THAI SUBJECTS: USE OF SPIROMETRIC GATING WITH QUANTITATIVE CT.

Ponglada SUBHANNACHART, Sutarat TUNGSAGUNWATTANA, Sumnieng ATHTAWET

ABSTRACT

Objectives: To measure lung attenuation quantitatively in normal healthy Thai people and to measure the attenuation in various areas of the normal lung with quantitative high resolution CT.

Materials and Methods: The subjects in this study were 154 healthy Thai volunteers. High resolution computerized tomography of the lung with spirometric gating (Pulmo CT) were obtained at level of the carina, 5 cm. above and 5 cm. below the carina. Scans were obtained at 50% vital capacity. Overall attenuation of the lungs and attenuation in various areas of the lungs were measured by using automatic fast contour tracing algorithms.

Results: The mean attenuation of the lung parenchyma decreased when age increased. The mean attenuation of total lung parenchyma of healthy Thai subjects was –811 ± 28 HU. The attenuation of anterior and posterior segments of the lung were not statistically different. The attenuation of the central part of the lung was more than in the peripheral part of the lung.

Conclusions: Quantitative high resolution CT or Pulmo CT is non-invasive method for measurement lung tissue attenuation. This method is useful in early detection of diffuse lung lesions and in follow up study.

Keyword: Pulmo CT, Lung Attenuation, Attenuation Values, Quantitative

INTRODUCTION

High resolution CT imaging of the lung parenchyma constitutes a wide-spread clinical application both in diagnosis of diffuse lung lesions and in follow up after treatment.[1] Diagnosis is usually based on a subjective, qualitatives assessment of changes in morphology and density of the lung parenchyma by an experienced radiologist. The problems commonly found are difficulties in the comparison of degree of impairment of the diseases because of different inspiratory level and difficulty in detection of early change or very mild cases of diffuse lung lesions. Factor influence accuracy of radiologist interpretation includes inconstancy of lung inflation.[2] A 10% change in inspirational status resulted on average in a change of about 16 HU of lung

Department of Radiology, Chest Disease Institute, Nonthabury 11000, Thailand

attenuation.[3] Quantitative evaluation of CT images with spirometric gating was developed to overcome this factor.

Quantitative High Resolution CT or Pulmo CT is high resolution computed tomography (HRCT) with constant lung inflation, controlling by spirometry and same mA, KV technique. This method is very useful in 3 major ways. The first way is detection of early change or mild degree of diffuse lung lesions [4] because abnormal attenuation in HRCT could be detected earlier than abnormal pulmonary function and could pointed the most affected area of the lung.[5] This method provides objective quantitative data that reflect changes of pulmonary structures corresponding to lung function impairment.[6,7] The second way is differentiation of diffuse lung lesion into 2 major groups of diseases, the decreased lung attenuation group and the increased lung attenuation group. The third way is to follow up patient's HRCT image and detection of improvement or progression of the lung lesions, comparison with previous study.

Attenuation of the lung in healthy European, using this technique, were reported in many studies but very few in Asian and none in Thai. Very few reports compared lung attenuation in different regions of the lung. It is very important to know normal lung attenuation in healthy Thai people and to know whether the attenuation of lung in different regions are the same or not.

OBJECTIVES

1. To study lung parenchymal attenuation in normal healthy Thai people.
2. To compare lung parenchymal attenuation in different age groups.
3. To compare lung parenchymal attenuation in male and female.
4. To find relationship between vital capacity from spirometry alone and from spirometry gated high resolution computed tomography (Pulmo CT).
5. To compare lung parenchymal attenuation in different lung regions.

MATERIAL AND METHOD

The study was performed in 154 healthy adult Thai volunteers, age between 20-69 years.

41 cases were in age group of 20-29 years, 16 males and 25 females.

47 cases were in age group of 30-39 years, 18 males and 29 females.

34 cases were in age group of 40-49 years, 12 males and 22 females.

19 cases were in age group of 50-59 years, 4 males and 15 females.

13 cases were in age group of 60-69 years, 6 males and 7 females.

The subjects included in this study must reach the following criteria.

1. nonsmoker or smoker not more than 1 pack–year.
2. healthy person who have no history of previous lung diseases or previous thoracic surgery.
3. no chest symptom such as cough, dyspnea, chest pain.
4. had normal chest film performing within the same day.
5. had normal lung function study within the same day. The HRCT studies of the lung were performed using Siemens Somatom plus 40 machine.

Vital capacity from CT scan (CTVC) were measured 3 times in each subject with 3 minutes interval between each time. The highest CTVC was used. The thin section HRCT of the lung were performed with spirometric gating at 50% CTVC.[7,9] (Figure 1) The scan parameters were 1 millimeter slice thickness, 1 second scan time, 275 mA tube current and 137 kV voltage.The patients were positioned supine on the CT couch and instructed to breath through a small hand-held pocket spirometry connected to a microcomputer (Figure 2). When the 50% CTVC of the subject was reached, the scan was triggered by respiratory gating device and airflow inhibited for the duration of the scan. Three lung levels were examined in each subject, the carinal level, 5 cm. above carina and 5 cm. below carina (Figure 3).

To reduce operator-related reproducibility errors, evaluation of lung parenchyma was based on automatic fast contour tracing algorithms that isolated the left and right lung parenchyma in each HRCT section. The machine automatically rejected extrapulmonary tissue by excluding all pixels outside the range –999 to –350 HU.[10] (Figure 4)

Histogram was determined for the left lung, right lung and both lungs. In the analysis; mean value of lung attenuation and standard deviation were calculated (Figure 5). Lung parenchyma attenuation values were determined by divided lung in anterior-posterior segmentation into 5 segments (Figure 6) and by central-peripheral segmentation into 2 segments (peripheral segment was the lung from subpleural area to 2 cm. distant from the pleura) (Figure 7).

RESULTS

The vital capacity from pulmo CT (CTVC) had linear correlation with vital capacity from spirometry (PFVC). The CTVC is about 0.847 of PFVC ($r=0.847$).

The mean attenuation of the lung parenchyma related with age in both male and female. ($p<0.05$).

Mean attenuation of the lung decreased (became more negative) when age increased. The mean attenuation of the lung parenchyma in healthy female subject was – 810 ± 29 HU and – 813 ± 25 HU in male which are not statistically different. ($p<0.05$) (Figure 8)

The mean attenuation of the left and right lung were not statistically different ($p<0.05$).

The mean attenuation of total lung parenchyma of healthy Thai volunteers was –811 ± 28 HU (range from –716.4 to –847.3 HU) (Figure 9). The attenuation of the lung parenchyma at carinal level and 5 cm. above caina were –816 and –813 HU respectively which were not statistically different ($p<0.05$). The attenuation at 5 cm. below carinal level is –803 HU which was more (less negative) than in the two upper levels.

When compared between the 5 segments (divided equally from anterior to posterior location) of the lung at each level, the mean attenuation of all segments were not significantly different ($p<0.05$).

The mean attenuation of lung parenchyma of central and peripheral segments were –811.9 ± 34 HU and –832.5 ± 29 HU respectively. The mean attenuation of the central part was more than in the peripheral part of the lung (central part had less negative value) ($p<0.05$).

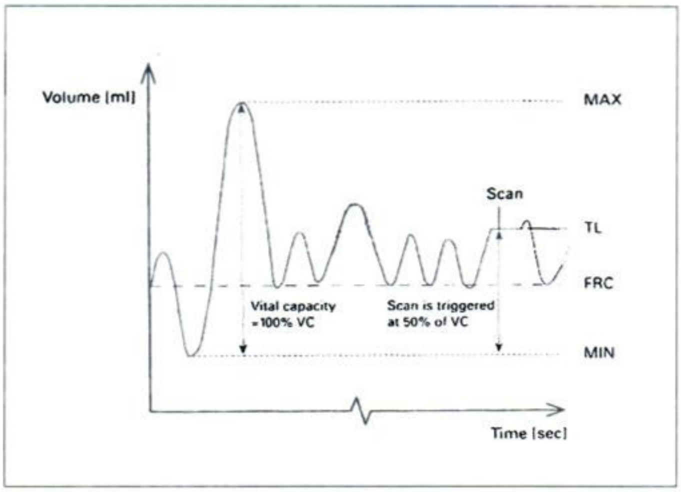


Fig. 1. Example of a breathing curve used to obtain CT scans under respiratory control.

Fig. 2. The spirometer gating device with application in a volunteer study.

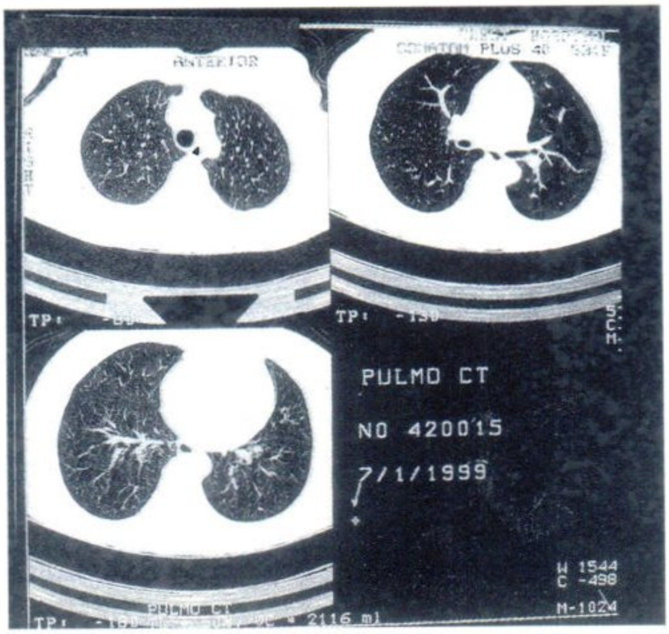
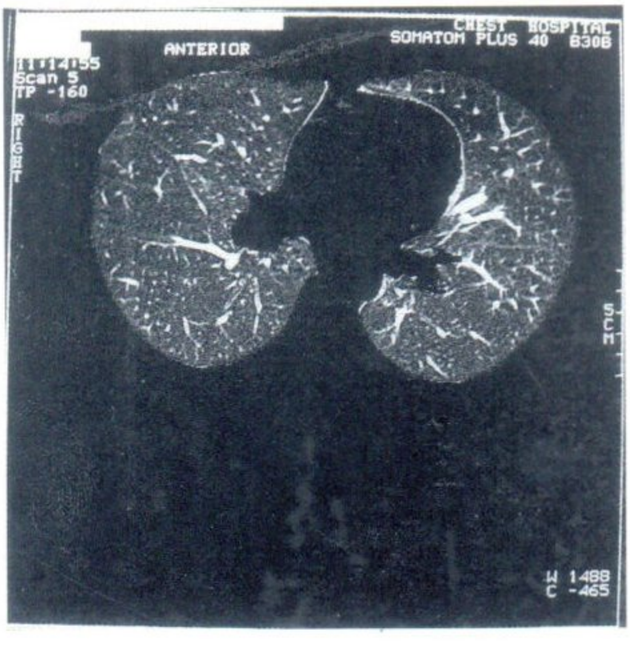


Fig. 3. Three examined lung levels: 5 cm. above carina, carinal level and 5 cm. below carina



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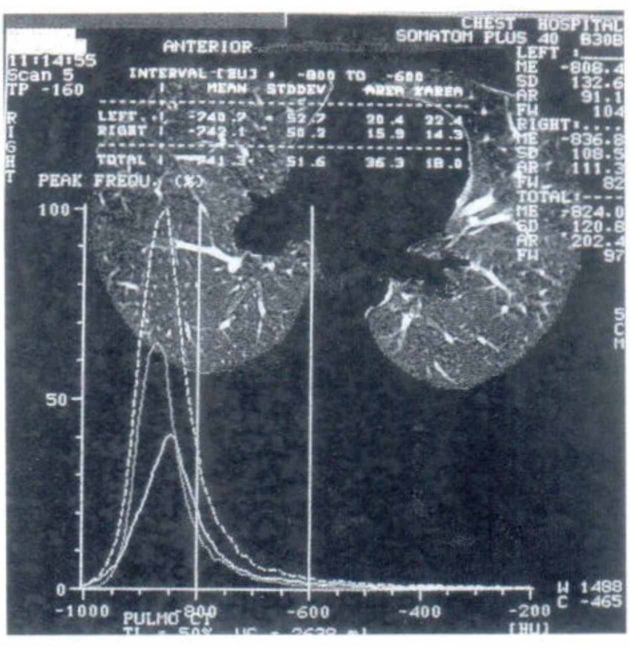

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Fig. 4. Scan of isolated lung parenchyma and corresponding histograms.

(a) isolated left and right lung parenchyma using automatic fast contour tracing algorithm.

(b) Histograms correspond with the left, right and total lung.

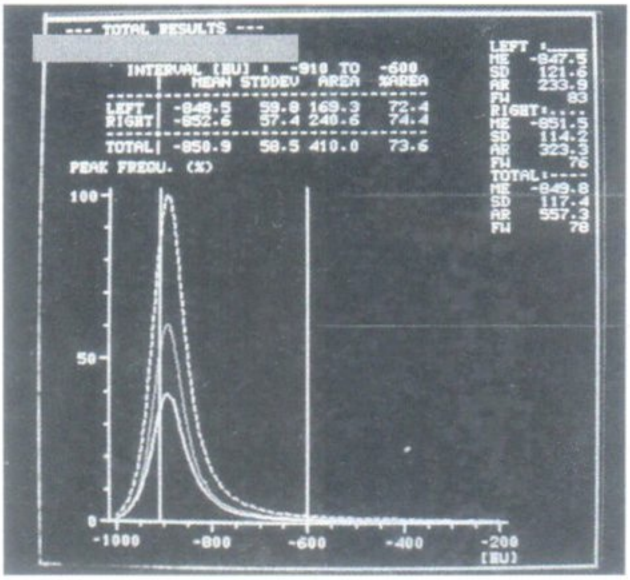


Fig. 5. Histogram and mean attenuation values of the left lung, right lung and both lungs.

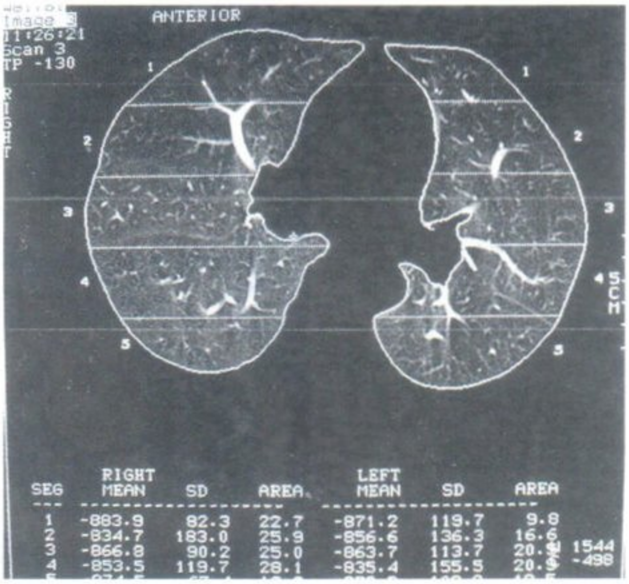
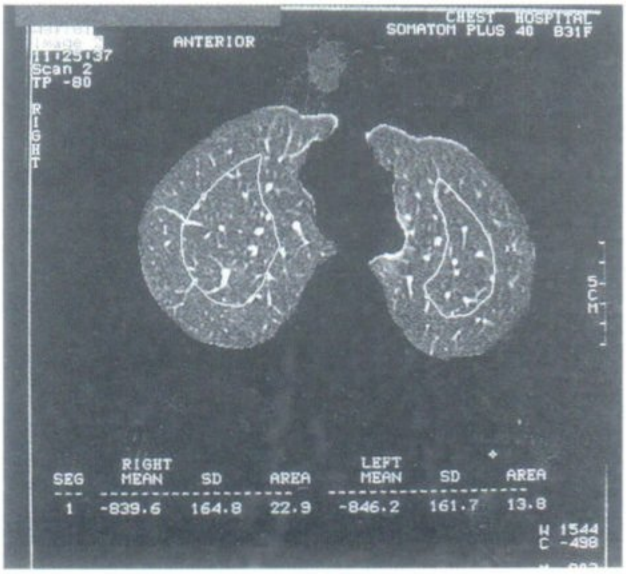


Fig. 6. Lung parenchyma attenuation values of the 5 antero-posterior segments.



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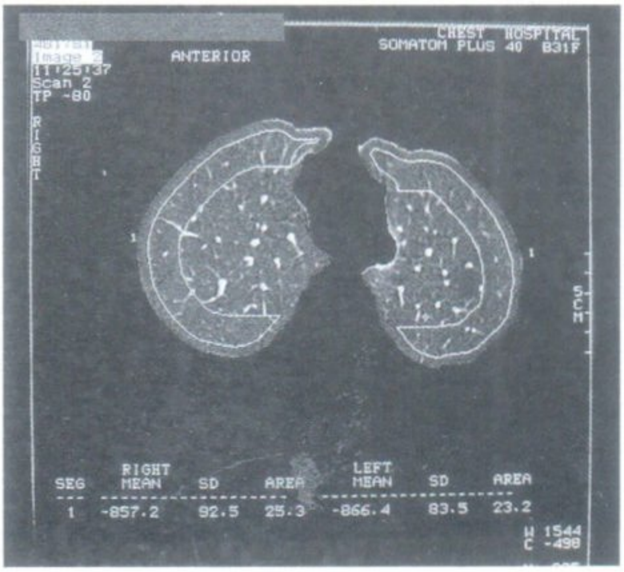

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Fig. 7. Lung parenchyma attenuation values (a) central segment (b) peripheral segment

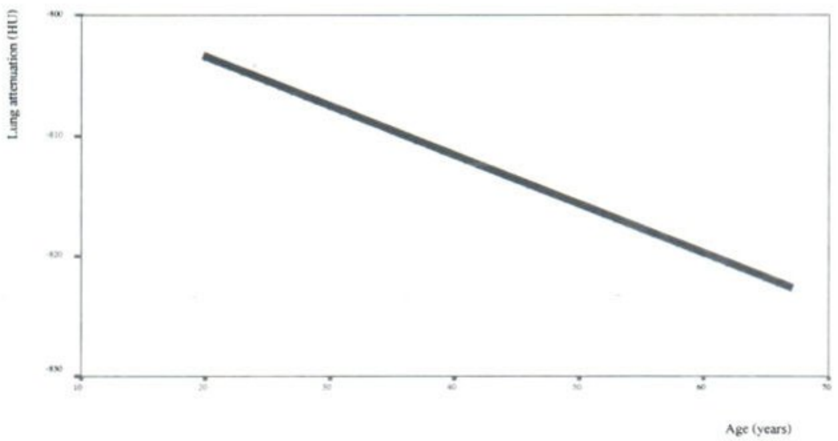

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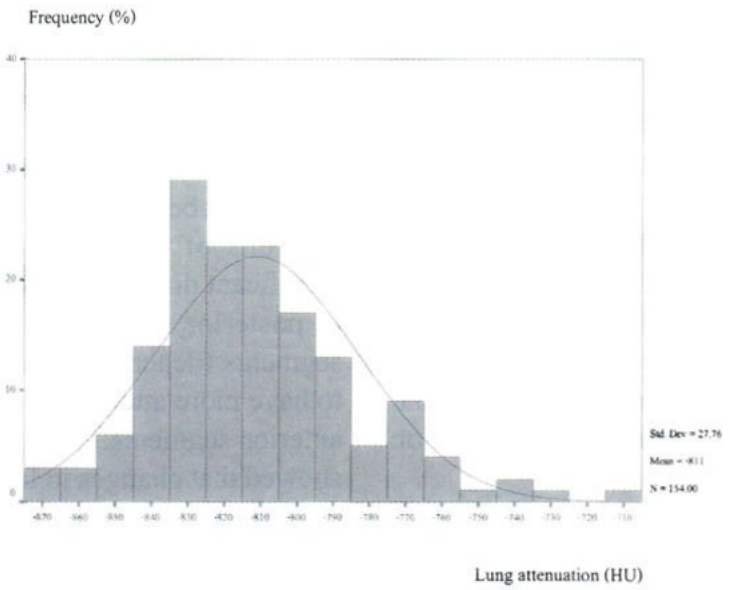
Fig. 8. Reference values for mean lung attenuation and histogram at 50% vital capacity
(a) Lung attenuation decreases as age increases



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(b) Reference histogram, averaged over all age groups.

DISCUSSION

The mean attenuation of the lung parenchyma in normal healthy Thai subjects is –811 ± 28 HU which is not different between male and female. The mean attenuation of the lung is age-dependent. It will decrease (turn more negative) when age increase. These results are the same as the study of Kalender.[11]

In comparison with other studies, the mean attenuation of lung parenchyma of normal healthy Thai subjects is not different from normal healthy foreigners which are –817 HU,[12] –819 ± 3 HU,[9] –820 ± 4 HU[7] and –829.8 HU[13] (range between –770 to –875).[14] We can use –811 ± 28 HU to be the reference of normal lung attenuation in Thai.

Many studies divided the abnormal attenuation of lung into two major groups.[6] The first is group of decrease lung attenuation such as pulmonary emphysema, air-trapping lung lesion. The other is group of increase lung attenuation such as pulmonary fibrosis, interstitial pneumonia etc.

Some studies used –900 and –910 HU to be the upper value of normal lung (emphysematous index). [5,7,14] Some used –700 HU to be the lower value of normal lung (fibrosis index).[7]

In pulmonary emphysema, expiratory quantitative CT is not as accurate as inspiratory CT for quantifying pulmonary emphysema and probably reflects air trapping more than reduction in the alveolar wall surface.[8]

There is significant linear correlation between the vital capacity from CT (CTVC) and the vital capacity from spirometry (PFVC). CTVC is 0.847 times of PFVC which is the same as the study of Rienmuller [15] ($r=0.84$, $p<0.001$).

CTVC is less than PFVC because the CTVC is performed in supine position. Because of linear correlation between them, we can predict patient VC (PFVC) from pulmo CT. We can also detect area of airway obstruction by detection of air trapping area in expiratory HRCT [16] (air trapping area is area of different attenuation of lung less than 100 HU between full inspiration and full expiration).

The advantage of HRCT with pulmo CT over spirometry is the ability to detect the location of abnormal or pathological area of the lung.

The attenuation of lung parenchyma in right and left lungs and in different lung levels of each lung are not statistically different. By this result, in the follow up study of diffuse lung patient, we can use the average mean attenuation of healthy subject lung as the normal value in comparison with any abnormal lung area of the patient with or without comparison with the mean lung parenchyma of the patient to determine improvement or progression of the lesion.

To determine the difference in lung attenuation between dependent and non-dependent portions of the lung, this study showed no significant difference in the 5 segments (anterior to posterior segments) but the more posterior segments (dependent portion of the lung) seems to have more attenuation (less negative) than the anterior segments. The study of Verschakelen[17] showed that changes in lung volume have effects on change in lung density in dependent and non-dependent parts of the lung.

The gradient decreases as lung volume increases. The gradient was significantly smaller at lung volume of 90% and 50% of VC than at 10% of VC.[17] So if the lesion mostly located at posterior segment of the lung (such as in asbestosis), the pulmo CT done in prone position might give more accurate lung attenuation value.

The attenuation of lung parenchyma is significantly different between central and peripheral part of the lung. Although HRCT is used to determine abnormality of diffuse lung lesion, some lesions have more profusion at central lung portion such as in sarcoidosis, pulmonary emphysema.[18,19] Some have more profusion at periphery of the lung such as in pulmonary fibrosis, interstitial pneumonitis.[19] In these cases we should also interest in both mean lung attenuation and abnormal attenuation in peripheral or central lung segments.

CONCLUSIONS

HRCT and Pulmo CT are non-invasive methods to measure lung tissue attenuation and are useful to determine lung pathology.

HRCT and Pulmo CT are very useful in follow up study to determine progression or regression of diffuse lung lesions after treatment.

HRCT and Pulmo CT are useful for clinician to determine mild cases or early cases of abnormal increased or decreased lung attenuation by comparison lung attenuation in suspected area with mean attenuation of normal healthy subject.

CT is very useful but it is still the high cost machine in Thailand though we should use it with proper indication.

REFERENCES

1. Kalender WA, Rienmuller R, Behr J, et al. Quantitative CT of the lung with spirometrically controlled respiratory status and automated evaluation procedures. In : Fuchs W (Ed.) Advances in CT. Berlin : Springer Verlag, 1990; 85-93.
2. Rienmuller RK, Behr J, Kalender WA, et al. Standardized quantitative high resolution CT in lung diseases. Journal of Computer Assisted Tomography 1991; 15(5): 742-749.
3. Kalender WA, Rienmuller R, Seissler W, et al. Measurement of pulmonary parenchymal attenuation: Use of spirometric gating with quantitative CT. Radiology 1990; 175: 265-268.
4. Pelinkovic D, Lorcher U, Chow KU, et al. Spirometric gated quantitative computed tomography of the lung in healthy smokers and nonsmokers. Invest Radiol 1997: 32(6): 335-343.
5. Gevenois PA, De Vuyst P, Littani M, et al. CT quantification of preliminary emphysema-correlation with pulmonary function tests: preliminary results on 15 patients. In: Felix R, Langr M (Eds.)
6. Advances in CT II, Springer, Berlin Heidelberg New York, 1992; 3-7.
7. Rienmuller R, Behr J, Beinert T, et al. Evaluation of CT histograms determined by spirometrically standardized high resolution CT studies of the lung in man. In: Felix R, Langr M (Eds.) Advances in CT II, Springer, Berlin Heidelberg New York, 1992; 17-24.
8. Beinert T, Behr J, Mehnert F, et al. Quantitative computerized tomography of the lung-respiration controlled diagnosis of diffuse lung diseases. Pneumologie 1995; 49(12) : 678-683.
9. Gevenois PA, De Vuyst P, Sy M, et al. Pulmonary emphysema: quantitative CT during expiration. Radiology 1996; 199(3) : 825-829.
10. Beinert T, Behr J, Mehnert F, et al. Spirometrically controlled quantitative CT for assessing diffuse parenchymal lung disease. J Comput Assist Tomogr 1995; 19(6): 924-931.

11. Guenard H, Diallo M, Laurent F, et al. Lung density and lung mass in emphysema. Chest 1992: 102:198-203.
12. Kalender WA, Fichte H, Bautz W, et al. Reference values for lung density and structure measured by quantitative CT. In: Pokieser H, Lechner G (Eds.) Advances in CT III, Springer-Verlag, Berlin Heidelberg New York, 1994; 290-298.
13. Adam H, Bernard MS, Mc Connochie K. An appraisal of CT pulmonary density mapping in normal subjects. Clin Radiol 1991; 43: 238-242.
14. Reuter M, Holling I, Emde L, et al. Quantitative assessment of lung density by CT in Navy personnel exposed to asbestos. In: Pokieser H, Lechner G (Eds.) Advances in CT III, Springer-Verlag, Berlin Heidelberg New York, 1994; 308-314.
15. Bae KT, Slone RM, Gierada DS, et al. Patients with emphysema: quantitative CT analysis before and after lung volume reduction surgery. Radiology 1997; 203: 705-714.
16. Rienmuller R, Altmann I, Behr J, et al. Spirometrically standardized quantitative high resolution CT of interstitial lung diseases. In: Fuchs W (Ed.) Advances in CT. Berlin: Springer Verlag, 1990; 102-108.
17. Webb WR, Muller NL, Naidich DP. Diseases characterized primarily by cysts and emphysema. In: High-Resolution CT of the Lung. 3 rd ed. Lippincott Williams & Wilkins, 2001: 455.
18. Verschakelen Ja, Van fraeyenhoven L, Laureys G, et al. Differences in CT density between dependent and nondependent portions of the lung: influence of lung volume. AJR 1993; 161: 713-717.
19. Nakano Y, Sakai H, Muro S, et al. Comparison of low attenuation areas on computed tomographic scans between inner and outer segments of the lung in patients with chronic obstructive pulmonary disease: incidence and contribution to lung Function. Thorax 1999; 54(5): 384-389.
20. Webb WR, Muller NL, Naidich DP. High resolution computed tomography findings of lung disease. In: High-Resolution CT of the Lung. 3 rd ed. Lippincott Williams & Wilkins, 2001: 184-185.