ISSN: 2572-3235

Won-Bin et al. Int J Radiol Imaging Technol 2019, 5:055
DOI: 10.23937/2572-3235.1510055
Volume 5 | Issue 2
Open Access

International Journal of
Radiology and Imaging Technology

ORIGINAL ARTICLE

Study on the Variations of Image Density Index of MDCT for Healthy Lungs

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Abstract

We selected several image density indices to establish CAD for prediction of biopsy in lung diseases. Our results suggested that significant difference was not observed in the image density indices between bilateral lungs at each slice level. Our own designed image indices may be reliable parameters in the establishment of CAD system and pathologic diagnosis for lung disease [1,2].

Keywords

CAD, Density index, Histogram, Frequency, Entropy

Introduction

There has been a rapid progress in the modality of CT since it was developed by Mr. Hounsfield. The earlier CT had been upgraded to the helical CT and for the time being the MDCT is widely used in the radiology practice. The up-to-dated MDCT is supported by the detectors of 64 rows or more [3-5].

The slice thickness of CT has been reached to 0.1 mm, based on the noble high resolution it reflects the indirect the pathological findings and enables working on the algorithm and image density index anticipating the pathological diagnosis. Some researchers reported the characteristics of image density in healthy lungs using the various indices including the mean value, standard deviation, maximum in the region of interesting [6-8].

Recently, the free service of MDCT is provided for diagnosis of patients at some health facilities. Taking the advantage of the high resolution, we have selected the new quantitative index of image density other than HU and obtained the basic data for CAD and prediction of the pathological findings in lung diseases [9,10].

Materials and Methods

We analyzed the CT findings of 40 males and 40 females without respiratory symptoms and abnormal X-ray findings.

The findings of target group was disaggregated by sex and analyzed.

And we selected the image density index and compare the index results of the bilateral lungs at the level of vertebrae thoracales from No. 1 to 8.

Each image density indices were evaluated when setting range of HU from 0 to 5000 instead of -1000 to 4000.

Result

1. The indices were selected to quantitatively evaluate the image density.

Density grade is Density ratio of interior half and exterior half of healthy lung (Table 1, Table 2, Table 3 and Table 4)

Average value of energy (Table 5 and Table 6)

$M_f = S_f/L_y$

S_f: Integration of quarter division of spectrum

L_y: Area of quarter division of spectrum

Average range ratio of high frequency and low frequency

Citation: Won-Bin C, Sok-Chan Y, Chan-Ung R, Chol-Ho C (2019) Study on the Variations of Image Density Index of MDCT for Healthy Lungs. Int J Radiol Imaging Technol 5:055. doi.org/10.23937/2572-3235.1510055

Accepted: October 19, 2019: **Published:** October 21, 2019

Table 1: Density grades in male group.

Height / Location	Th1	Th2	Th3	Th4	Th5	Th6	Th7	Th8
Right lung	2.69 ± 0.99	3.75 ± 0.18	1.80 ± 0.06	1.27 ± 0.09	1.02 ± 0.08	0.75 ± 0.01	0.61 ± 0.02	0.47 ± 0.02
Left lung	2.64 ± 0.86	3.92 ± 0.12	1.86 ± 0.06	1.23 ± 0.08	0.96 ± 0.05	0.73 ± 0.02	0.59 ± 0.03	0.45 ± 0.02

Table 2: Density grades in female group.

Height / Location	Th1	Th2	Th3	Th4	Th5	Th6	Th7	Th8
Right lung	2.68 ± 1.04	3.82 ± 0.12	1.83 ± 0.16	1.25 ± 0.12	1.01 ± 0.04	0.56 ± 0.01	0.59 ± 0.03	0.47 ± 0.02
Left lung	2.67 ± 0.90	3.92 ± 0.13	1.88 ± 0.15	1.21 ± 0.29	0.97 ± 0.16	0.55 ± 0.01	0.57 ± 0.03	0.45 ± 0.01

Table 3: Average range ratio of high frequency and low frequency in male group.

Height / Location	Th1	Th2	Th3	Th4	Th5	Th6	Th7	Th8
Right lung	2.72 ± 0.15	3.00 ± 0.13	2.95 ± 0.12	2.67 ± 0.19	2.58 ± 0.08	2.90 ± 0.11	3.46 ± 0.18	2.96 ± 0.10
Left lung	2.68 ± 0.17	2.84 ± 0.19	2.94 ± 0.09	2.66 ± 0.16	2.52 ± 0.15	3.01 ± 0.11	3.37 ± 0.16	3.04 ± 0.17

Table 4: Average range ratio of high frequency and low frequency in female group.

Height / Location	Th1	Th2	Th3	Th4	Th5	Th6	Th7	Th8
Right lung	2.67 ± 0.17	2.90 ± 0.15	2.93 ± 0.13	2.60 ± 0.11	2.52 ± 0.11	3.04 ± 0.13	3.41 ± 0.14	3.10 ± 0.14
Left lung	2.69 ± 0.13	2.87 ± 0.15	2.94 ± 0.16	2.61 ± 0.19	2.44 ± 0.13	3.08 ± 0.13	3.30 ± 0.12	3.04 ± 0.10

Table 5: Average value of energy in male group.

Height / Location	Th1	Th2	Th3	Th4	Th5	Th6	Th7	Th8
Right lung	51.93 ± 1.17	76.15 ± 1.37	117.03 ± 2.48	138.52 ± 2.71	147.43 ± 1.83	157.65 ± 1.88	161.34 ± 1.14	152.34 ± 2.33
Left lung	50.73 ± 1.44	77.43 ± 1.24	115.08 ± 2.73	140.23 ± 2.49	146.25 ± 2.19	156.49 ± 2.78	162.43 ± 2.34	154.62 ± 1.58

Table 6: Average value of energy in female group.

Height / Location	Th1	Th2	Th3	Th4	Th5	Th6	Th7	Th8
Right lung	51.72 ± 1.75	67.27 ± 2.69	118.3 ± 1.41	140.72 ± 1.90	145.95 ± 2.82	156.51 ± 3.18	165.40 ± 2.79	156.04 ± 2.50
Left lung	50.84 ± 1.93	70.25 ± 2.57	117.21 ± 1.75	139.42 ± 1.83	147.50 ± 2.61	157.55 ± 3.01	163.98 ± 2.87	155.71 ± 2.71

Table 7: Histogram of parenchyma of healthy lungs in male group.

Height / Location	Th1	Th2	Th3	Th4	Th5	Th6	Th7	Th8
Right lung	28.90 ± 1.36	58.66 ± 1.95	71.84 ± 1.34	74.09 ± 1.01	75.2 ± 1.33	70.19 ± 2.38	77.10 ± 1.22	77.86 ± 1.46
Left lung	28.59 ± 1.32	59.76 ± 1.16	71.36 ± 1.30	74.34 ± 1.29	74.05 ± 1.47	71.82 ± 2.04	76.83 ± 1.44	77.10 ± 1.20

$C_f = H_f/L_f$ (Table 3 and Table 4)

C_f is the average range ratio of high frequency and low frequency of the regions in healthy lungs.

H_f: Average range of high frequency

L_f: Average range of low frequency

Histogram of parenchyma of healthy lungs (Table 7

and Table 8)

$R_h = H_{max} - H_{min}$

H_{max}: Maximum density of histogram

H_{min}: Minimum density of histogram

Average histogram value of healthy lung parenchyma (Table 9 and Table 10)

$M_h = T_h/R_h$

T_h: Total value of histogram

R_h: Range of histogram

Entropy (Table 11 and Table 12)

Entropy = $\sum_{It=0}^{L-1} p(Zi) \log 2P(Zi)$

2. The value of image density indices of bilateral lungs at each level of vertebrae thoracales are shown in the tables below.

As mentioned above, the quantitative indices have been newly identified to indicate the characteristics of image density of healthy lungs. Subsequently the diagnostic algorithm was drafted to compare the image density of ill lung and healthy lung at slice levels.

According to the results of study on image density of healthy lungs at the level of vertebrae thoracales from No. 1 to 8, the significant deviation was observed in the histogram at the level of vertebrae thoracales from No. 4 to 8, though not observed in the density grade, ratio of high frequency and low frequency, average frequency, histogram and entropy.

We could note that the comparison of image density of healthy and ill lungs at the appropriate slice level would be one of key approaches to anticipate the pathological diagnosis regarding the values of the indices vary from disease to disease.

Conclusion

The quantitative indices have been newly identified to indicate the characteristics of image density of healthy lungs. The significant deviation was observed in the histogram at the level of vertebrae thoracales from No. 4 to 8, though not observed in the density grade, ratio of high frequency and low frequency, average frequency, histogram and entropy.

Table 8: Histogram of parenchyma of healthy lungs in female group.

Height / Location	Th1	Th2	Th3	Th4	Th5	Th6	Th7	Th8
Right lung	28.66 ± 1.26	58.08 ± 1.28	72.82 ± 1.28	74.16 ± 1.2	75.94 ± 2.41	71.88 ± 1.18	76.35 ± 2.26	76.56 ± 2.22
Left lung	29.50 ± 1.16	59.16 ± 1.31	72.66 ± 1.24	75.33 ± 1.19	74.00 ± 2.23	70.83 ± 1.12	74.16 ± 2.14	75.66 ± 2.17

Table 9: Average histogram value of healthy lung parenchyma in male group.

Height / Location	Th1	Th2	Th3	Th4	Th5	Th6	Th7	Th8
Right lung	79.78 ± 3.82	173.77 ± 3.75	271.51 ± 3.24	441.13 ± 3.16*	435.21 ± 4.14*	452.85 ± 3.51*	469.59 ± 4.28*	434.78 ± 4.61*
Left lung	79.47 ± 3.84	174.87 ± 3.78	272.44 ± 4.45	344.32 ± 3.78*	335.73 ± 3.81*	345.78 ± 3.74*	309.07 ± 4.99*	359.54 ± 3.98*

($p < 0.05$)

Table 10: Histogram value of healthy lung parenchyma in female group.

Height / Location	Th1	Th2	Th3	Th4	Th5	Th6	Th7	Th8
Right lung	78.97 ± 2.29	175.28 ± 2.88	270.38 ± 3.79	345.18 ± 3.90*	437.31 ± 3.89*	466.55 ± 3.12*	468.44 ± 3.54*	435.44 ± 3.35*
Left lung	78.37 ± 2.25	177.06 ± 2.59	274.29 ± 3.61	342.38 ± 4.09*	358.48 ± 3.93*	346.90 ± 3.54*	303.11 ± 3.21*	352.68 ± 3.61*

($p < 0.05$)

Table 11: Entropy in male group.

Height / location	Th1	Th2	Th3	Th4	Th5	Th6	Th7	Th8
Right lung	-11.75 ± 0.33	-18.15 ± 1.35	-13.33 ± 1.61	-11.40 ± 1.58	-9.96 ± 1.24	-9.75 ± 1.23	-9.51 ± 1.47	-10.68 ± 1.58
Left lung	-11.64 ± 0.21	-19.41 ± 1.48	-13.84 ± 1.61	-11.81 ± 1.45	-10.73 ± 1.58	-11.72 ± 1.74	-11.87 ± 1.40	-12.00 ± 1.48

Table 12: Entropy in female group.

Height / Location	Th1	Th2	Th3	Th4	Th5	Th6	Th7	Th8
Right lung	-11.81 ± 0.47	-18.15 ± 1.34	-13.34 ± 1.62	-11.27 ± 1.25	-10.09 ± 1.52	-9.75 ± 1.23	-9.42 ± 1.24	-10.68 ± 1.58
Left lung	-12.73 ± 0.46	-19.41 ± 1.49	-13.84 ± 1.61	-11.81 ± 1.46	-10.64 ± 1.45	-11.56 ± 1.47	-11.87 ± 1.40	-11.91 ± 1.24

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