◎原 著

Correlation between low attenuation area (LAA) of the lungs in high-resolution computed tomography (HRCT) and mean CT number in bronchial asthma

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Summary : The maximal percent low attenuation area < −950 HU (%LAA) among three anatomic lung levels on high resolution computed tomography (HRCT) was examined in patients with asthma, classified by the degree of %LAA, in relation to the mean CT number, %FVC of the predicted value, and FEV 1/FVC (FEV1%).

1. The mean CT number was closely related to the degree of %LAA of the lungs. The mean CT number was significantly lower in patients with high %LAA (mean CT number-915.3HU, %LAA 37.6%) than in those with low %LAA (−852.9HU, 4.7%).

2. The FEV1% value was significantly lower in patients with high %LAA (47.8%) than in those with low %LAA (62.2%)($p<0.05$). The %FVC value was also significantly lower in patients with high %LAA (77.1%) compared to the value in those with low %LAA (101.2%). The results suggest that a large volume of LAA<−950HU of the lungs can be observed in patients with asthma, and the %LAA is closely correlated with mean CT number and the values of FEV1% and %FVC.

Key words : bronchial asthma, %LAA, mean CT number, FEV1, FVC

Introduction

Asthma is a disease characterized by airway inflammation, in which various inflammatory cells, especially activated T cells and eosinophils[1,2], and chemical mediators such as histamine and leukotrienes[3] and various cytokines relesased from these cells play important roles in the allergic reaction sites of the airways. Thus, remodelling of the airways, such as bronchial dilatation and bronchiectasis, has been observed in patients with asthma by high-resolution computed tomography (HRCT)[4,5]. It has been shown that patients with nonallergic asthma have a more extensive remodelling of the airways than those with allergic asthma[6].

In contrast, the relative area of the lungs

with attenuation values lower than −950 Housfield Unit (HU)(LAA, low attenuation area) can be a measurement of pulmonary emphysema. The relative areas of the lungs that has attenuation values lower than −950 HU on high-resolution CT scans obtained at full inspiration is an objective measure of the extent of pulmonary emphysema[7,8]. However, the significance of percent LAA of the lungs on HRCT scans has been not defined in patients with asthma.

In the present study, a correlation between the percentage of lung area with CT numbers < −950HU (%LAA) and the mean CT number in HU was examined in patients with asthma.

Subjects and Methods

The subjects in this study were 20 patients (2 females and 18 males) with asthma. The patients were 53 to 79 yr of age (mean, 66.1 yr). IgE antibodies against house dust mite (HDm) were observed in 16 of 20 patients (80.0%). Thirteen patients were long-term cigarette smokers with an average smoking history of 37 ± 21 pack-years (mean ± 1SD). An informed consent for study protocol was obtained from all the patients. Asthma was defined according to the criteria of the International Consensus on Diagnosis and Management of Asthma[9]. All patients showed reversible airway response with a difference between prebronchodilator and postbronchodilator values of FEV1 exceeding 15%.

CT scans were performed on a TOSHIBA Xpeed scanner (2.7s, 200mAS, 120kVp) without infusion of contrast medium. using 2 − mm collimation (HRCT) in patients breathholding at full inspiration. The lungs were scanned as preselected three anatomic levels ; (1) top of the aortic arch, (2) origin of the lower lobe bronchus, (3) three cm above the top of the diaphragm, as reported by Miniati M, et al.[10]. Inspiratory HRCT scans were evaluated quantitatively by measuring the percentage of lung area with CT number < −950HU (%LAA)(Fig. 1) and the mean CT number in HU. The maximal low attenuation area (<−950HU) among three different levels of the lung was expressed as %LAA in each patient with asthma. The mean CT number was calculated from the CT numbers of three anatomical lung levels.

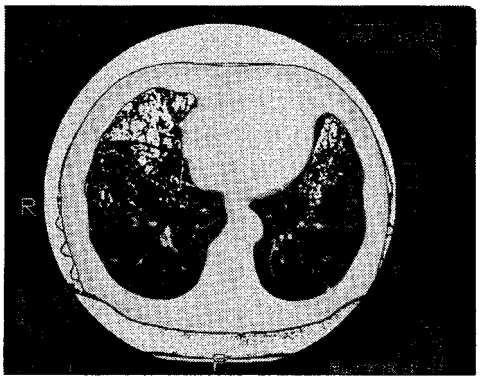

Fig. 1. Representative scan of a patient with mild asthma (79 years old, female). The percentage of low attenuation area < −950 HU on HRCT was 15.6% and the mean CT number was −885.3HU

Pulmonary function tests, forced vital capacity (FVC) and forced expiratory volume in one second (FEV_1), were performed by a CHESTAC33 (Chest Co) linked to a computer, when they were attack-free. The subjects were divided into 4 groups according to the degree of %LAA ; 0−9.9% (A), 10.0−19.9 % (B), 20.0−29.9% (C), and 30.0%+(D).

IgE antibodies were evaluated by radioallergosorbent test (RAST) and serum level

of total IgE was measured by radioimmunosorbent test (RIST).

Statistically significant differences of the mean were estimated using the unpaired Student's test. Ap value of < 0.05 was regarded as significant.

Results

Table 1 represents the characteristics of asthma patients classified by the degree of maximal percent of low attenuation area <−950HU (%LAA) among the three anatomic lung levels. The mean age was over 60 yr in all groups. The level of serum IgE was highest in group D (%LAA, 30%<), and the frequency of a positive RAST score for house dust mite (HDm) was high (60−100%) in all study groups. The mean %LAA of the lungs was 4.7±2.9% (mean±1SD) in group A, 16.5±3.7% in group B, 23.1±2.0% in group C, and 37.6±8.6% in group D.

Table 1. Characteristics of patients with asthma studied

%LAA	No of patients	Age (years)	Age at onset (years)	Serum IgE (IU/ml)	RAST for HDm
A	5	68.6	41.0	944 (80-2298)	4/5
B	5	65.8	58.0	331 (71-904)	3/5
C	5	68.8	45.6	622 (318-1016)	5/5
D	5	61.2	51.8	732 (113-2564)	4/5

HDm, house dust mite. %LAA, A: 0-9.9%, b:10.0-19.9%, C:20.0-29.9%, and D:30.0<

The mean CT number was closely correlated with the degree of maximal %LAA, and showed a tendency to decrease as the maximal %LAA was higher. The mean CT number was significantly higher in group A (−852.9±17.5HU) than in group B (−899.4±5.2HU) ($p<0.02$), in group B than in group C (−903.7±8.7HU)($P<0.001$), and in group C than in group D (−913.3±7.6HU)($p<0.05$) (Fig. 2).

The mean value of FEV1/FVC (FEV1%) was significantly lower in group D (47.8±8.6%) compared to the value in group B (67.7±5.0%)($p<0.01$) and in group A (62.2±7.9%)($p<0.05$), as shown in Fig. 3. However, the difference in FEV 1% value between group D and group C was not significant.

The mean %FVC of predicted value was significantly lower in group D (77.1±8.8%) than in group A (101.2±12.5%)($p<0.01$) (Fig. 4). However, the differences in %FVC were not significantly different among groups A, B, and C.

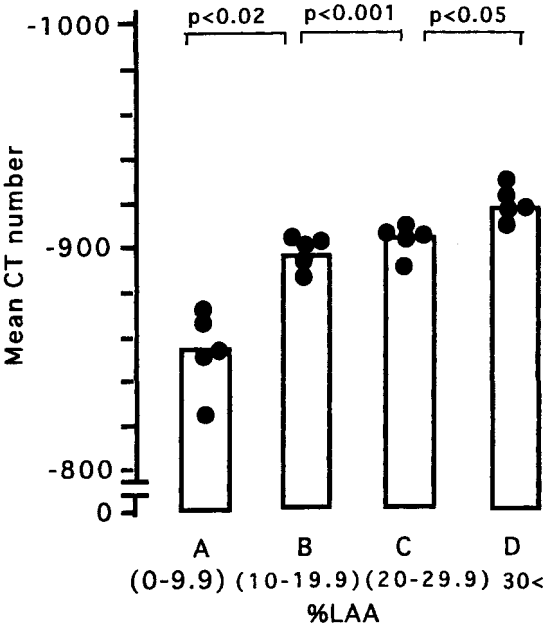

Fig. 2. Correlation between maximal %LAA of the lungs and mean CT number in asthma

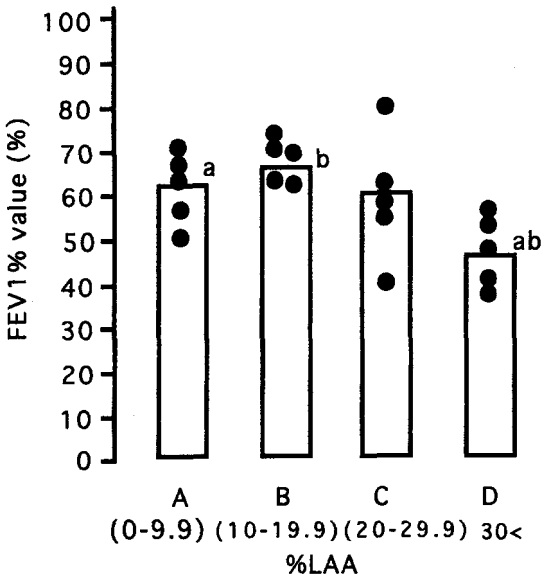

Fig. 3. Correlation between Maximal %LAA of the lungs and FEV 1 % values in asthma. a<0.05, b<0.01

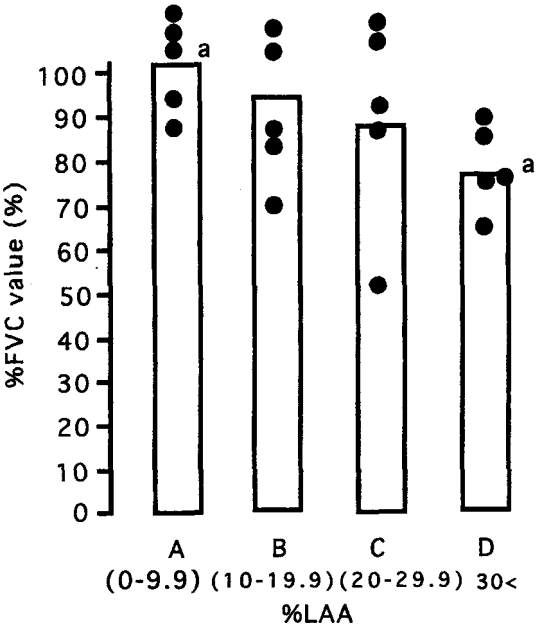

Fig. 4. Correlation between maximal %LAA of the lungs and %FVC values in asthma. a<0.01

Discussion

The analysis of computed tomography (CT) images compared with the pathologic evaluatioin of emphysema in autopsy or surgical lung specimens has strongly suggested that CT is the most acurate imaging method for diagnosing emphysema[11-16]. The relative area of the lung with attenuation values < −950 HU on HRCT scans can be applied for evaluation and diagnosis of emphysema[7,8]. Thus, it is generally agreed that CT scanning is a sensitive technique of detecting emphysematous lesions[17], however, the possiblle influences of hyperinflation and of nonemphysematous expiratory airflow limitation on the CT quantification of pulmonary emphysema has not been investigated[18].

It has been observed in HRCT that patients with asthma show more abnormalities related to airways remodelling than do normal subjects[4,5], and that airways remodelling is more often found in patients with nonallergic asthma than in those with allergic asthma[6]. The significance of measuring low attenuation area of the lungs on HRCT has been controversial in asthma. Gevenois PA, et al. did not find any significant change in CT lung density parameters by measuring low attenuation area (LAA) of the lungs <−950 HU during allergen challenge tests, despite the decrease in FEV_1 of 0.91 associated with an increase in RV and FRC of about same volume. They concluded that hyperinflation and airflow obstruction without emphysematous lung destruction would not influence densitometoric measurements obtained from inspiratory scans[19]. Newman KB, et al. founf no significant difference between asthmatic patients and control subjects for the inspiratory HRCT scans obtained in the lower

areas (the level of diaphragm, LLA $<$ $-$900 HU), however, difference was significant for the upper area (the level of transverse aorta, LLA $<$ $-$950HU)[20].

In this study, maximal %LAA among the three anatomic lung levels was examined in patients with asthma. The results obtained here demonstrated that the maximal %LAA was closely related to the mean CT number in asthma patients. The mean CT number is lineally related to the fraction of air in the lungs, showing the ratio between the volume of air and the volume of air plus the volume of tissue[21]. The %LAA was also associated with the values of FEV 1 % and %FVC. This suggests that the measurement of both the mean CT number and the percent of lung area with attenuation values $<$ $-$950HU can be applied for evaluation and management of asthma.

These results might suggest that the percentage of lung area associated with LAA $<$ $-$ 950HU is correlated with airways remodelling of asthma. Gevenois PA, et al. showed that aging was significantly related to an increase in %LAA $<$ $-$950HU, however, a significant correlation was not observed between an increase in %LAA and changes in total lung capacity (TLC)[19]. In this study, it might be speculated that aging did not influence our results, because the mean age was over 60 yr, and no significant difference was found among four groups.

Our results reveal that large percent of LAA (30%$<$) of the lungs on HRCT could be observed in patients with asthma, in whom the values of FEV 1 % and %FVC were significantly lower than in those with low %LAA. This suggests that high %LAA shows a more extensive remodelling of the airways than in low %LAA in asthma.

It is unclear whether high %LAA in asthma is due to hyperinflation and nonemphysematous inspiratory airflow limitation, or due to emphysematous lesions. Further studies are necessary to clarify the influences of hyperinflation and airflow lomitation in the CT quantification of asthma.

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気管支喘息におけるHRCTによるLow attenuation area（LAA）と平均CT numberとの関連

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HRCT（high resolution computed tomography）により，－950HU以下のlow attenuation area（LAA）を3つの高さの肺野レベルで観察し，そのなかの最も高い値をmaximal%LAAとして表し，この値と平均CT number，%FVCおよびFEV1.0%の値と比較検討した。1．平均CT numberは，maximal%LAAと密接な関連を示した。そして，平均CT numberは，%LAAが低い症例（%LAA：4.7%，mean CT number：－852.9HU）に比べ，%LAAが高い症例（%LAA：37.6%，mean CT number：－915.3HU）において低い傾向が見られた。2．FEV1.0%値は，%LAA値が低い症例（62.2%）に比べ%LAA値が高い症例（47.8%）において有意に低い値を示した（P＜0.05）。%FVC値も同様%LAA値が低い症例（101.2%）に比べ高い症例（77.1%）で低い値を示したが両群間に有意の差は見られなかった。これらの結果より，気管支喘息においても，HRCT上肺野で－950HU以下のLow attenuation area（LAA）を示す症例が見られること，そして，%LAAは，mean CT number，FEV1.0%や%FVC値とある程度関連していることが示唆された。