Correlation of Functional and Radiological Findings of Lung in Asymptomatic Smokers

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Abstract

Background: Pulmonary damage induced by smoking acts slowly and may show no symptom until pulmonary functions are decreased.

Objectives: To correlate findings on chest X-ray (CXR), pulmonary function tests (PFTs), and thoracal high resolution computed tomography (HRCT) scans for determining whether these findings may be useful in an early diagnosis of pulmonary damage in asymptomatic smokers.

Methods: Sixty smokers were questionnaired about pulmonary symptoms. Among them 50 asymptomatic volunteers, underwent CXR, PFTs (spirometry, lung volumes and DLCO) both inspiratory and expiratory thoracal HRCT. Air trapping on HRCT scan was calculated using a visual score method. These scores were correlated with CXR and PFTs.

Results: PFTs showed an obstructive pattern in only 3(%6) of patients. FEV1/FVC values were decreased as cumulative smoking increased. FEV1 and DLCO values were significantly lower in subjects with the history of parental smoking than the other subjects. All CXRs were normal but various degrees of air trapping were seen in all patients on expiratory HRCTs. Total and mean pulmonary scores assesing air trapping were higher in the group who were smoking more than 20 packs/year. Although correlation between PFT parameters and air trapping scores was expected, this correlation was not found.

Conclusion: We concluded that even asymptomatic smokers may have pulmonary damage. The expiratory thoracal HRCT may be more useful than both CXR and PFTs in detecting air trapping as a clue for early pulmonary damage in asymptomatic smokers.

Key words: Air trapping, cigarette smokers, high-resolution computed tomography, pulmonary function tests, visual score

Received: 17.04.2007 Accepted: 22.01.2008

INTRODUCTION

Cigarette smoking produces inflammatory changes in small airways, especially in respiratory bronchioles. This pathological process leads to dilatation and destruction of the small airways, characterized as emphysema [1-3]. Unfortunately, the pulmonary damage induced by smoking acts slowly and may show no symptom until pulmonary functions are lost. Voluntary spirometric screening of a high-risk population of smokers gives a very high yield of subjects presenting with spirometric signs of airway obstruction [4]. Although various ventilatory tests to detect functional abnormalities caused by smoking have been the center of attention, they are of limited value for direct estimation of structural abnormalities at the lung peripheries. HRCT has been shown to be more sensitive than the chest X-ray in the detection of lung parenchymal abnormalities such as air trapping for emphysema [5].

The aim of this study was to determine the correlation between PFTs and radiological findings in assessing the early diagnosis of pulmonary damage in asymptomatic smokers.

MATERIALS AND METHODS

We asked 60 subjects for participating this study. Four subjects refused to participate and 6 subjects did not undergo thoracal HRCT. Fifty current smokers, 25 men and 25 women, were included in the study after providing written informed consent. None of the subjects had pulmonary symptoms or any coexisting disease. This study included only adults, but there was no upper limit on age. The study was approved by the local ethics committee.

Evaluation included age, body mass index, both own and parental smoking history, CXR, PFTs, inspiratory and expiratory thoracal HRCT. Subjects were classified according to cumulative cigarette consumption using the Brinkman smoking index (BI), defined as packs of cigarettes/day x years [6]. Subjects with a BI < 20 (n = 31, 62%) and BI ≥ 20 (n = 19, 38%) were defined as mild and heavy smokers, respectively.

The whole pulmonary function tests were performed with a flow-sensitive spirometer (Sensormedics, Vmax 229, Yorba Linda, CA). Forced expiratory volume in 1 second (FEV_1), forced vital capacity (FVC), FEV_1/FVC, and forced mid-expiratory flow (FEF_{25-75}) were measured and expressed as a percentage of the predicted value. While determining airflow obstruction, Global Obstructive Lung Disease (GOLD) criteria was used. A FEV_1 value greater than 80% of predicted value and a FEV_1/FVC value greater than 70% of predicted value were considered as normal. Functional residual capacity (FRC) was measured by nitrogen wash-out method. Total lung capacity (TLC) and resid-

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ual volume (RV) were calculated from the lung volumes. The diffusing capacity of the lung for carbon monoxide (DLCO) was measured by single-breath method. The ratio of DLCO to alveolar volume (VA) was also calculated and expressed as a percentage of the predicted value. Subjects were divided into three groups according to PFTs: group 1 with normal PFTs; group 2 with $FEV_1 > 80\%$ and $DLCO < 80\%$; group 3 with $FEV_1 < 80\%$ and $DLCO < 80\%$ [7].

Both inspiratory and expiratory thoracal HRCT were performed on subjects at the radiology department of our hospital, using a helical CT scanner (Hitachi, Pratico, Korea). HRCT scans were obtained with 1 mm collimation at a window level of -700 Hounsfield units (HU) and a window width of 1200 HU using a high-frequency reconstruction algorithm. In all subjects, both end-inspiratory and end-expiratory scans were obtained at three levels: 3 cm below the apex, at the hilus, and 3 cm above the dome of the diaphragm. All radiographs were independently evaluated by two experienced radiologists that were blinded to all clinical and functional data; they also evaluated the presence of air trapping. Air trapping was identified as areas of low attenuation and hypovascular regions in the lungs. In the assessment of air trapping by visual score, a five-point scale was used as follows: 0 point, no air trapping; 1 point, 1-25% involvement; 2 points, 26-50% involvement; 3 points, 51-75% involvement; 4 points, 76-100% involvement [7]. The total pulmonary score for each individual was calculated by summing the points for each scanning level (0-24 points). The mean pulmonary score was calculated by dividing the total score by 6.

The data in the text, tables, and figures are presented as means ± standard deviations (SD). Kruskal-Wallis and Mann-Whitney-U tests were used to examine the significance of differences between groups. A p value of < 0.05 was considered statistically significant.

RESULTS

Subject profiles including age, body mass index and all functional measurements are summarized according to smoking history in Table 1.

Table 1. Characteristics of subjects

	<20pack.years n=31	≥20pack.years n=19	p
Mean Age±SEM (years)	32.16±1,03	42.42±1.01	0.0001
Body Mass Index (BMI)	24.06±0.78	25.2±0.76	0.23
Mean Brinkman Index (pack-years)	10.84±0.65	29.89±2.46	0.0001
FEV_1 (% predicted)	96.94±2.04	94.26±3.24	0.26
FVC (% predicted)	101.19±2.4	99.63±2.76	0.81
FEV_1/FVC (%)	82.13±1.29	78.79±1.42	0.08
FEF_{25-75} (% predicted)	84.29±3.95	78.05±5.67	0.39
PEF (% predicted)	96.97±2.78	92.68±4.74	0.52
RV/TLC (%)	25.42±1.26	27.95±2.05	0.21
DLCO (% predicted)	80.48±2.32	82.53±4.97	0.81
DLCO/VA (%)	84.13±2.66	87.58±4.35	0.39

PFTs showed an obstructive pattern in only 3(6%) subjects. Seventeen subjects (34%) had low values of FEF_{25-75}, among them 3(6%) had also obstructive pattern in PFT. The DLCO values of 27 (54%) subjects were decreased. RV/TLC values were increased in 28 (56%) subjects.

According to PFTs, 23 (46%) subjects were in group 1, 24 (48%) subjects were in group 2 and 3 (6%) subjects were in group 3. Parental and subjects' own smoking history of these three groups are shown in Table 2.

Table 2. Parental and own smoking history according to pulmonary function test groups

PFT groups	Parental smoking history (n)	Own smoking history BI (pack-yrs)
Group 1 (n = 23, 46%)	13 (56%)	16.7 (5-48)
Group 2 (n = 24, 48%)	17 (70%)	18.8 (5-52)
Group 3 (n = 3, 6%)	3 (100%)	26.6 (10-37)

All CXRs were normal. Air trapping was not evident on inspiratory HRCT scans, but various degrees of air trapping were detected on expiratory HRCT scans in all subjects. Air trapping in expiratoy HRCT was in 1 scanning level in 3 (6%) patients, 2 to 5 scanning levels in 43 (86%) patients and 6 scanning levels in 4 (%8) patients.The dominant site of air trapping was the lower lobes of the lungs. The means of total pulmonary scores and mean pulmonary scores according to smoking history are shown in Figure 1 and 2. Total pulmonary scores of heavy smokers were significantly higher than mild smokers. Similarly, heavy smokers had significantly higher mean pulmonary scores

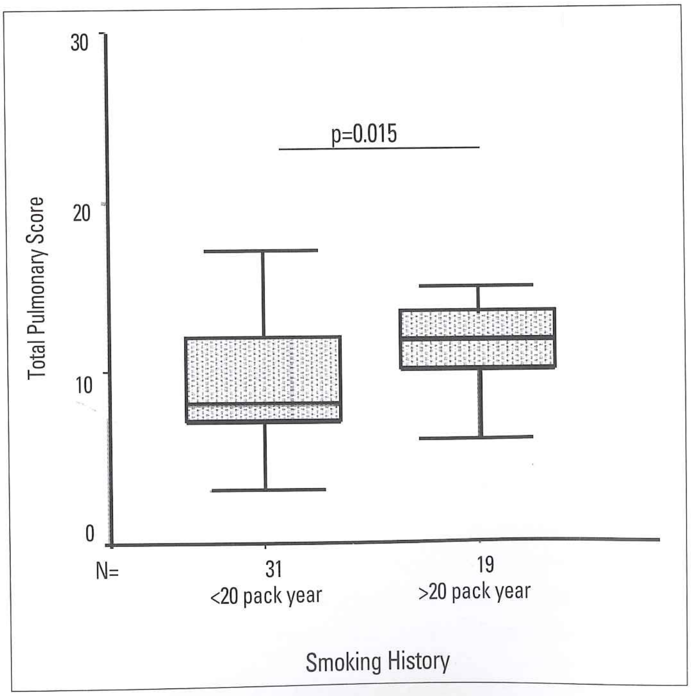

Figure 1. Correlation between total pulmonary scores and smoking history

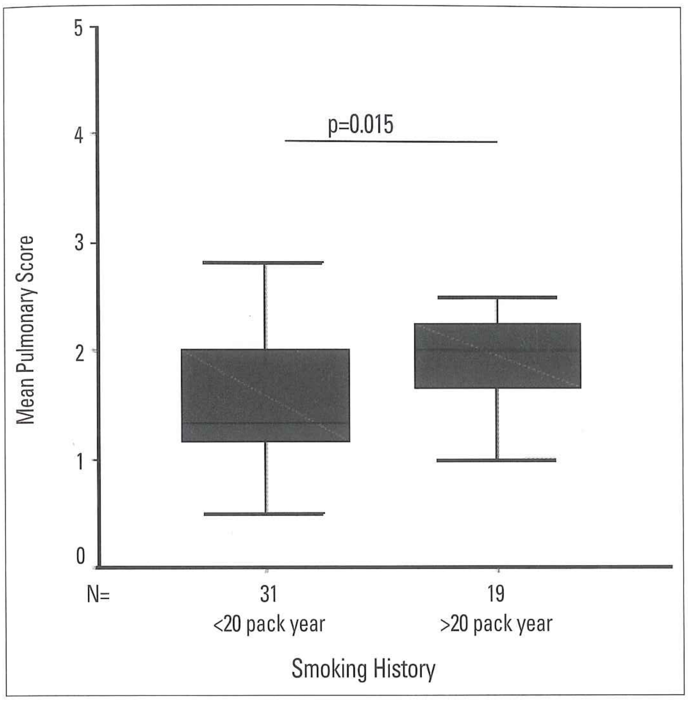

Figure 2. Correlation between mean pulmonary scores and smoking history

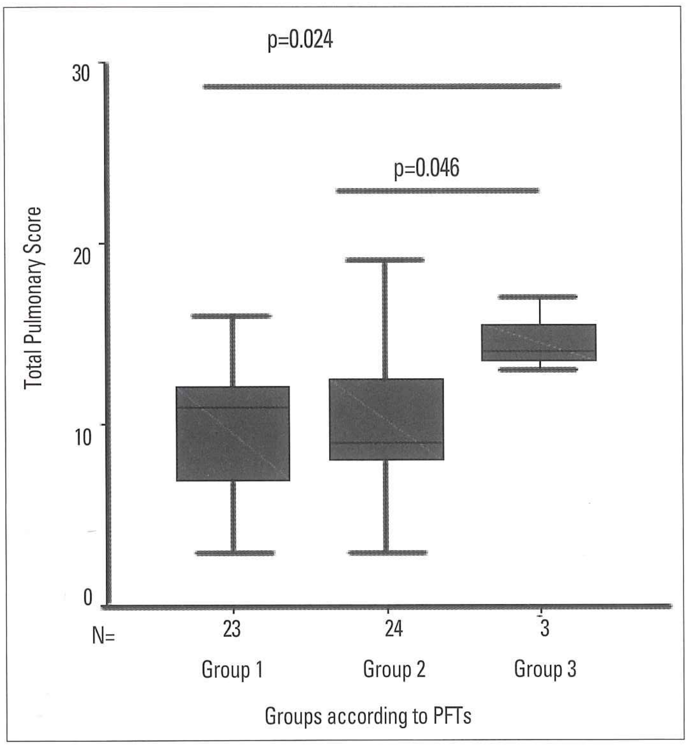

Figure 3. Correlation between total pulmonary scores and PFT groups

than mild smokers. The means of total pulmonary scores and mean pulmonary scores according to PFT groups are also shown in Figure 3 and 4. Patients in group 3 had significantly higher total and mean pulmonary scores than group 1 and group 2. This correlation was not found between group 1 and group patients.

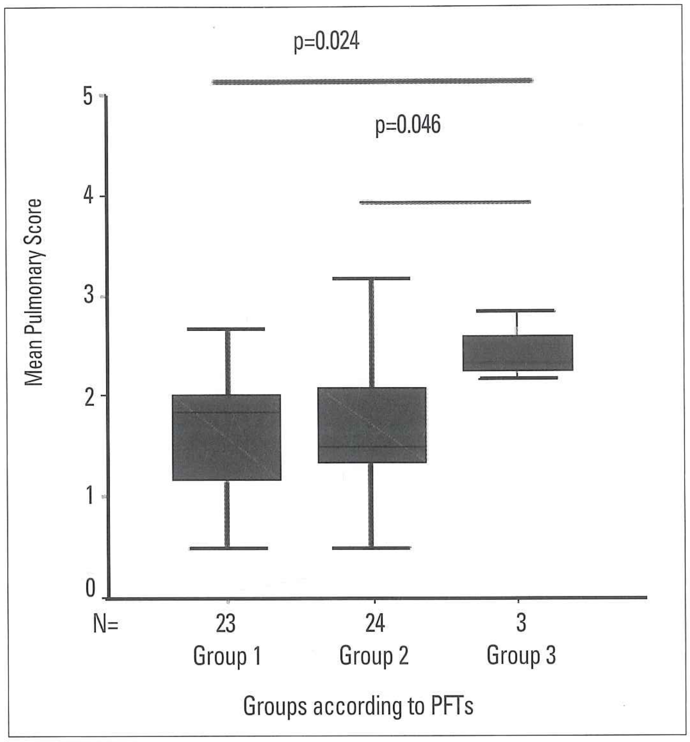

Figure 4. Correlation between mean pulmonary scores and smoking history

We also detected other coexisting pulmonary pathologies such as pulmonary nodules in 15 (30%) subjects, interstitial irregularities in 11 (22%) subjects, parenchymal band formation in 7 (14%) subjects, cyst formation in 4 (8%) subjects and bronchiectasis in 2 (4%) subjects.

FEV_1 and DLCO values were significantly lower in subjects with a history of parental smoking than the subjects without parental smoking history (Figure 5). There was also inverse correlation between cumulative smoking and FEV_1/FVC (Figure 6). As the FEF_{25-75} values decreased, total and mean pulmonary scores increased, but this correlation was not statistically significant ($p > 0.05$). No other PFT parameters showed correlation with air trapping scores.

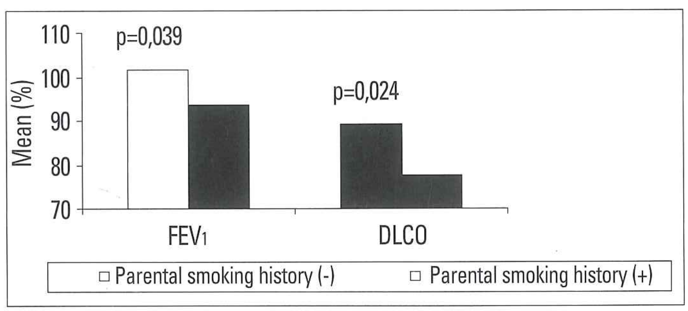

Figure 5. Correlation between parenteral smoking history and FEV_1 and DLCO

DISCUSSION

The aim of this study was to investigate correlation of radiological and functional alterations of lung in asymptomatic smokers. We showed that both radiological and func-

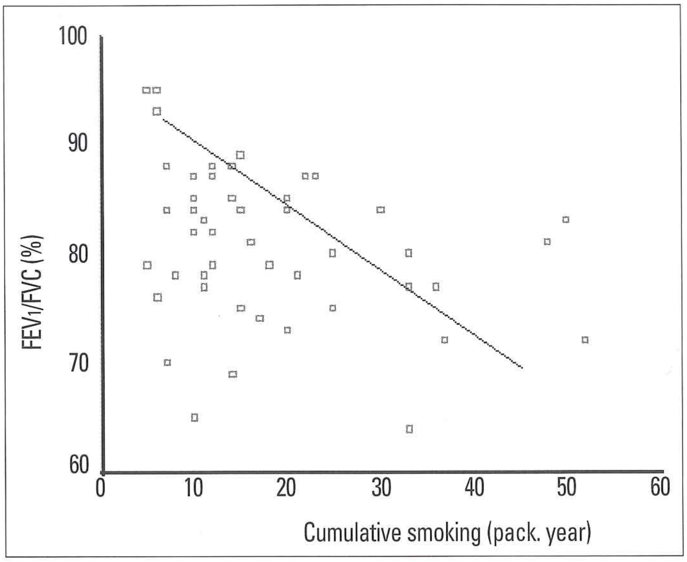

Figure 6. Correlation between FEV1/FVC and cumulative smoking

tional deterioration in lung may occur even in asymptomatic smokers. Various degrees of air trapping were detected on expiratory HRCT scans, whereas all inspiratory HRCT scans were normal. The dominant site of air trapping was the superior segment of the lower lobes. We found a significant positive correlation between visual scores on thoracal HRCT and smoking but not between PFTs and visual scores.

It is reported that smoking accelerates the loss of pulmonary function in adults [8,9]. Zielinski et al. reported 24.3% airway obstruction indicated by PFTs in 11,000 smokers, especially in the elderly and heavy smokers [4]. Parental tobacco smoking is also related to poor lung function and pulmonary functions are decreased proportionally with passive exposure to tobacco smoke [10-12]. In our study, FEV_1/FVC value decreases as cumulative smoking history increases even the subjects are asymptomatic. FEV1 and DLCO values were also significantly low in subjects with a history of parental smoking. On the other hand, as our subjects were current smokers, it is not clear whether the low values of FEV_1 and DLCO were due to own or parental smoking history.

It is obviously known that CXR is the first choice in order to determine pathological changes in the lungs. CXR has a sensitivity of 24-81% and a specificity of 50-90% in detecting air trapping [13]. Some recent reports have indicated that CT scans obtained at full expiration show areas of emphysema and air trapping with great clarity and may, therefore, allow the early detection of obstructive lung function impairment[14-16]. In our study, although air trapping was detected in expiratory thoracal HRCT, CXRs were normal in all subjects confirming its low sensitivity.

Air trapping on HRCT scans can also be detected in asymptomatic smokers [17]. Remy-Jardin et al. performed thorax HRCT on 98 current smokers, 26 ex-smokers, and 51 non-smokers. They found air trapping in 21% of current smokers and 8% of ex-smokers. Their data support the concept that parenchymal abnormalities can be detected in healthy smokers with normal findings on chest radiography and PFTs [18].

Betsuyaku et al. reported that asymptomatic smokers with air trapping on HRCT scans, show significantly low values for FEV_1, DLCO and DLCO/VA [19]. Lucidarme et al. found that air trapping is more common in patients with severe obstruction in PFTs than the patients with normal PFTs [20]. On the other hand, Mastora et al. investigated the correlation between HRCT scans and PFTs in 250 volunteer smokers. They concluded that there was a significant relationship between segmental and lobar air trapping and cigarette consumption, but that lobular air trapping did not reflect functional impairment at the small airway level [21]. Like Mastora et al., Vikgren et al. found that neither diffuse nor focal air trapping is a sensitive indicator of small airway disease in smokers [22].

One of the limitations of this study was the number of participants. Due to study design (PFTs, HRCT both in inspirium and expirium), it was difficult to find a volunteer participant. As we did not have a chance to follow up these subjects for years, we can not comment if the subjects with air trapping on HRCT would develop COPD in the future. Another limitation was the absence of a subject group consisting of non-smoker volunteers.

As a result, we conclude that expiratory HRCT scans may reflect the air trapping induced by small airway obstruction, regardless of the functional characteristics of air trapping, and may be useful in the early estimation of pulmonary damage in asymptomatic cigarette smokers. Further studies on larger populations of both smokers and non-smokers are needed.

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