CT Assessment of Subtypes of Pulmonary Emphysema in Smokers*

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Objective: To determine the incidence of subtypes of pulmonary emphysema (PE) identified by CT imaging in male patients who have a significant smoking history.

Patients and setting: We reviewed 945 subjects (619 men and 326 women) who had undergone CT scanning. However, only the data for male subjects were analyzed due to there being too few female subjects. The male subjects were divided into the following two age groups: group A (age, < 50 years) and group B (> 50 years). There were two subtypes of PE found: centrilobular emphysema (CLE) and paraseptal emphysema (PSE). Based on these subtypes, PE was divided into the following three categories: I (CLE or CLE-predominant); II (CLE and PSE of equal extent); and III (PSE or PSE-predominant).

Results: PE was found in 270 of 516 male smokers (10 of 38 female smokers had PE). Among male subjects, in age group A there were 53 subjects with some degree of PE (category I, 12 subjects [22.6%]; category II, 7 subjects [13.2%]; and category III, 34 subjects [64.2%]). Among men in age group B, there were 217 subjects with some degree of PE (category I, 109 subjects [50.2%]; category II, 23 subjects [10.6%]; and category III, 85 subjects [39.2%]).

Conclusion: In age group A, men < 50 years of age who were in category III (PSE or PSE-predominant PE) predominated (34 of 53 subjects; 64.2%). In age group B, men > 50 years of age who were in category I (CLE or CLE-predominant PE) predominated (109 of 217 subjects; 50.2%).

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Key words: cigarette smoking; CT; emphysema; pulmonary

Abbreviations: CLE = centrilobular emphysema; HU = Hounsfield unit; LAA = low-attenuation area; PE = pulmonary emphysema; PSE = paraseptal emphysema

Pulmonary emphysema (PE) is defined pathologically as a group of diseases that demonstrate “an anatomic alteration of lung characterized by enlargement of airspaces distal to the terminal bronchiole, accompanied by destructive changes of alveolar walls.”1 PE is one of the most important diseases related to cigarette smoking, and a large proportion of cases of PE is caused by smoking. PE has been observed in more than half of Japanese male smokers.2 In the present study, subtypes of PE were identified by CT scanning according to the age of the subjects.

Materials and Methods

Materials

We reviewed 945 subjects (619 men and 326 women, ranging in age from 21 to 91 years) from the Kagawa Prefectural Cancer Detecting Center and Numakuma Hospital, who had undergone CT scanning between December 1997 and June 1999 because of suspected lung disease seen on chest radiographs or because of respiratory complaints. Because there were too few female smokers, only the data for male smokers were analyzed. PE was diagnosed by the presence of low-attenuation areas (LAAs) on CT scans and not by pulmonary function test results. Subjects were divided into the following two age groups: group A (≤ 50 years); and group B (> 50 years).

PE is usually classified into the following three main subtypes: centrilobular emphysema (CLE); panlobular emphysema; and paraseptal emphysema (PSE).3 In the present study, there were no subjects with PLE, so PE was classified into the following three categories based on the presence of CLE and PSE: I (CLE or CLE-predominant); II (CLE and PSE of equal extent); and III (PSE or PSE-predominant). Ex-smokers were included with current smokers. The data on cigarette consumption in number of pack-years for male subjects according to age group are shown in Table 1. Patients with conditions such as silicosis were
different age groups was analyzed by prevalence of PEs according to different categories between significant differences in cigarette consumption in had PE). In male smokers, there were no statistically in 270 of 516 male smokers (10 of 38 female smokers
than PE (lung cancer, 10 subjects; interstitial pneumo-
was only 41 (4.3%) with pulmonary disease other
excluded because of focal lung destruction that was found
NR, Japan [used at 120 kV and 100 mA]; and Lemage SX/E; Yokogawa; Tokyo, Japan [used at 120 kV and 100 mA]) were used. In all cases, contiguous 1-cm sections encompassed the entire thorax without using high-resolution reconstruction. Hard-copy images were photographed at a 400-Hounsfield unit (HU) window width and a −200-HU window level (Toshiba 700S) and at a 1,500-HU window level and a −620 window level (Yokogawa Lemage SX/E).

According to the extent of LAAs in the peripheral lung fields, the CT findings were classified into the following five grades: grade 0, no LAAs; grade 1, sparse, scattered small LAAs up to 5 mm in diameter; grade 2, adjacent LAAs up to 10 mm in diameter; grade 3, LAAs > 10 mm that were adjacent to or indistinguishable from each other; and grade 4, absence of normal lung parenchyma.4 The CT scans were reviewed independently by two radiologists (K.S. and T.K.). When there was a conflict in evaluation, they discussed the problem together to reach a conclusion. As judged by the two radiologists, the image quality in the present study was not different between the two CT machines with respect to the presence or absence of LAAs in CT scans with 1-cm collimation without high-resolution reconstruction.

Statistical Analysis

For comparison of the number of pack-years smoked according to CT grade within each group, the Student’s t test was used. The prevalence of PEs according to different categories between different age groups was analyzed by χ² test.

RESULTS

Of 945 total subjects in the present study, there were only 41 (4.3%) with pulmonary disease other than PE (lung cancer, 10 subjects; interstitial pneumonia, 8 subjects; pneumoconiosis, 8 subjects; inflammatory change including tuberculosis, 9 subjects; and bronchiectasis, 6 subjects). PE was found in 270 of 516 male smokers (10 of 38 female smokers had PE). In male smokers, there were no statistically significant differences in cigarette consumption in

![Table 1—Cigarette Consumption by CT Grade in Men According to Age Group*](image)

![Figure 1. The prevalence of grade and category subtypes of PE in male subjects according to age groups. Asterisks indicate significance in the prevalence of categories I and II combined and of category III between the respective age groups as indicated by connecting lines. * = p = 0.005. ** = p < 0.0001. *** = p < 0.0005 (χ² test).](image)
Among subjects with grade 3 PE, there were 9 subjects in group A (category I, 5 subjects; category II, 1 subject; and category III, 3 subjects) and 40 subjects in group B (category I, 30 subjects; category II, 2 subjects; and category III, 8 subjects). Among subjects with grade 4 PE, there were 10 subjects in group A (category I, 1 subject; and category III, 9 subjects) and 36 subjects in group B (category I, 16 subjects; category II, 5 subjects; and category III, 15 subjects).

The prevalence of PE in men according to age is shown in Figure 1. The prevalence of CLE was greater in older men. Thus, category I or II (ie, CLE-predominant or CLE equal to PSE) was found in 4 of 14 subjects (28.6%) who were <40 years of age, in 15 of 39 subjects (38.5%) who were in their 40s, in 31 of 64 subjects (48.4%) who were in their 50s, in 50 of 91 subjects (54.9%) who were in their 60s, and in 51 of 62 subjects (79.9%) who were >70 years of age (these figures combine all grades >0). Especially with respect to the prevalence of subjects in categories I and II combined and category III in each age

category III, 24 subjects). Among subjects with grade 3 PE, there were 9 subjects in group A (category I, 5 subjects; category II, 1 subject; and category III, 3 subjects) and 40 subjects in group B (category I, 30 subjects; category II, 2 subjects; and category III, 8 subjects). Among subjects with grade 4 PE, there were 10 subjects in group A (category I, 1 subject; and category III, 9 subjects) and 36 subjects in group B (category I, 16 subjects; category II, 5 subjects; and category III, 15 subjects).

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CT scans of three typical subjects with grades 2, 3, and 4 PE are shown in Figures 2, 3, and 4, respectively.

**Figure 2.** CT scan of subject with grade 2, category III PE (a 39-year-old man, smoking 50 pack-years of cigarettes). LAAs (arrows) adjacent to the chest wall are seen from the apex to the upper lobes.

**Figure 3.** CT scan of subject with grade 3, category II PE (a 36-year-old man, smoking 17 pack-years of cigarettes). Both types of LAAs of PE are seen (CLE, arrow heads; and PSE, arrows).

**Figure 4.** CT scan of subject with grade 4, category I PE (a 52-year-old man, smoking 40 pack-years of cigarettes). Both types of LAAs of PE are seen (CLE, arrow heads; and PSE, arrows).

**Discussion**

CLE is by far the most common form of emphysema and has a proven association with cigarette smoking. PSE can occur as an isolated phenomenon in young adults. Bullae can develop in association with any type of PE but are most common with PSE or CLE. A bulla, by definition, is a sharply demarcated area of PE measuring ≥1 cm in diameter and possessing a wall <1 mm in thickness. PSE can occur in older patients with CLE.

At least some degree of PE is recognized in more than half of Japanese male smokers. In male smokers <50 years of age, PE is found in 43.8%. Even in subjects <40 years of age, PE is found in 35.0%. The prevalence of CLE rises as age increases from <40 years to >70 years. CLE-predominant subtypes were found in 4 of 14 subjects (28.6%) who were <40 years of age and in 15 of 39 subjects (38.5%) who were in their 40s.

Category III (PSE-predominant) PE in the present study was found not only in younger subjects but also in older subjects. In subjects ≥50 years of age, category III showed a high incidence, while in subjects who were in their 50s and 60s, the prevalence in category III was the same as in category I.
No significant differences between the high-resolution CT scores and pathology scores were found in patients with mild-to-moderate PE. Although there is a good correlation between the CT visual scores and pathologic scores of PE extent, mild PE can be missed on high-resolution CT scans. Objective or quantitative assessment of PE has been described. The ability to diagnose PE, however, is influenced by factors such as scanner type, collimation, window setting, and interobserver variability and intraobserver variability. Measurements of attenuation can vary to scanner type, calibration, kilovoltage, reconstruction algorithm, volume averaging, patient size, location, environment, and size of the area being assessed. In the present study, the method of evaluation and classification of PE that was used was a subjective one based on visual judgment. This method is simple and is available in any hospital because all CT scanners are not able to quantitatively measure CT values.

**Conclusion**

CLE (or CLE mixed with PSE) can be found in young subjects (i.e., those ≤ 50 years of age), and even in those < 40 years of age. In older subjects (i.e., those > 50 years of age), CLE predominates. Although PSE can occur in nonsmokers, both CLE and PSE are strongly related to smoking. Both types progress with age and the cumulative cigarette smoking dose. PE was found in more than half of male smokers. A high incidence of PE was found even in younger subjects.

**REFERENCES**


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