Computer aided diagnosis for severity assessment of pneumoconiosis using CT images

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ABSTRACT

240,000 participants have a screening for diagnosis of pneumoconiosis every year in Japan. Radiograph is used for staging of severity in pneumoconiosis worldwide. This paper presents a method for quantitative assessment of severity in pneumoconiosis using both size and frequency of lung nodules that detected by thin-section CT images. This method consists of three steps. First, thoracic organs (body, ribs, spine, trachea, bronchi, lungs, heart, and pulmonary blood vessels) are segmented. Second, lung nodules that have radius over 1.5mm are detected. These steps used functions of our developed computer aided detection system of chest CT images. Third, severity in pneumoconiosis is quantified using size and frequency of lung nodules. This method was applied to nine pneumoconiosis patients. The initial results showed that proposed method can assess severity in pneumoconiosis quantitatively. This paper demonstrates effectiveness of our method in diagnosis and prognosis of pneumoconiosis in CT screening.

Keywords: pneumoconiosis, computed tomography, computer aided diagnosis

INTRODUCTION

240,000 participants have a screening for diagnosis of pneumoconiosis every year in Japan. Radiograph is used for staging of severity in pneumoconiosis worldwide. The International Labor Office (ILO) provides a staging of pneumoconiosis using radiographs [1]. Its advantages are relatively low cost, low radiation dose, and wide availability. However, the chest radiograph is relatively insensitive for detecting early pneumoconiosis [2]. Chest CT scans are more sensitive than routine radiographs in detecting pneumoconiosis. However, CT scans are not recommended for routine surveillance due to the increased radiation exposure and the lack of scoring scheme [3]. Since 1992, several classification or coding systems for evaluating pneumoconiosis in CT studies have been reported [4]. It is important to develop quantitative severity assessment of pneumoconiosis. This paper presents a method for quantitative assessment of severity in pneumoconiosis using both size and frequency of lung nodules that detected by thin-section CT images. This method was applied to nine pneumoconiosis patients. The results showed that proposed method can assess severity in pneumoconiosis quantitatively. This paper demonstrates effectiveness of our method in diagnosis and prognosis of pneumoconiosis in CT screening.

MATERIALS AND METHODS

Materials

This study was approved by institutional review board in Nagasaki University. The scanning was carried out with 120 kV, 240mA, 1mm slice thickness, 512x512 matrix, pixel size of 0.625mm or 0.781mm, 1mm reconstruction interval, and FC13-H convolution kernel. CT images of pneumoconiosis by each stage are shown in Fig.1. Private information that was contained in DICOM header information is replaced by a DICOM anonymization system [5].
Pneumoconiosis was classified into 15 stages based on a guideline defined by Ministry of Health, Labour and Welfare in Japan: 0/-, 0/0, 0/1, 1/0, 1/1, 1/2, 2/1, 2/2, 2/3, 3/2, 3/3, 3/+, 4A, 4B, 4C. The total number of patients is nine: stage 0/1 is three, 1/0 is three, stage 1/2 is two, and stage 4A is one. In this study, the stages were certified by consensual decision of physicians.

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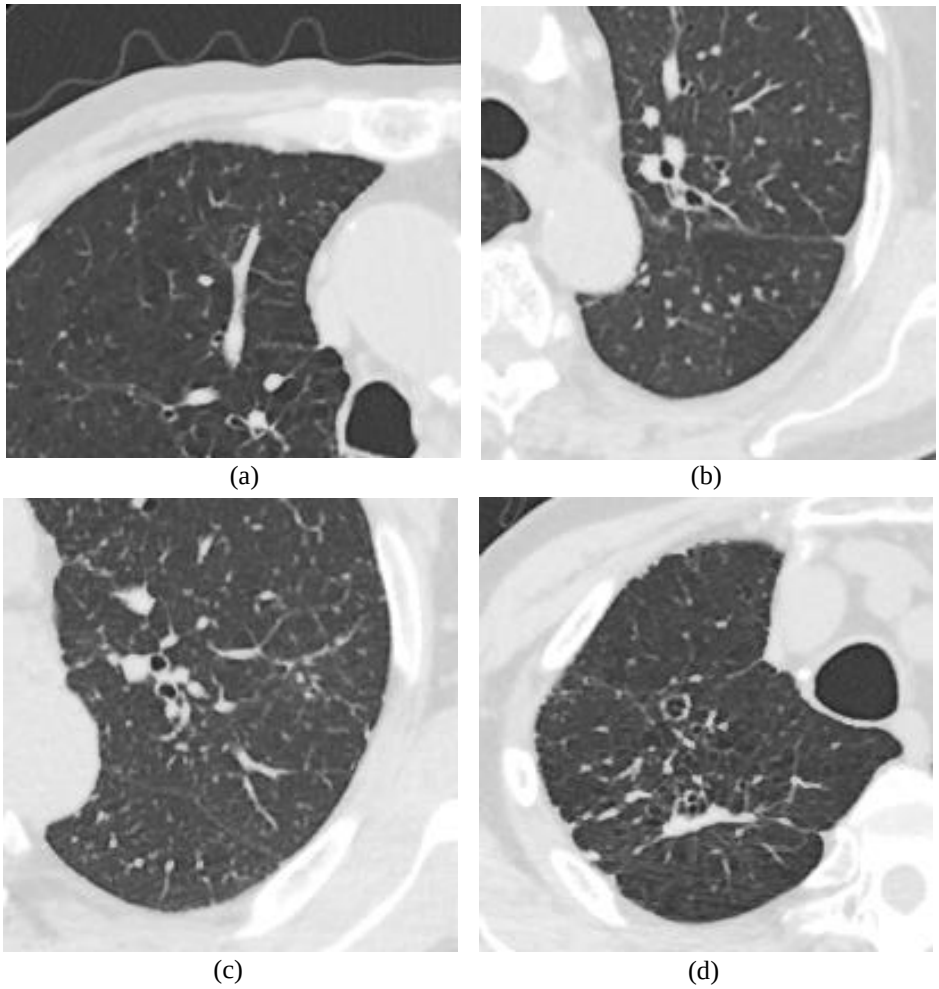
Methods

1) Segmentation of thoracic organs.

Our group has developed computer aided detection (CADe) and computer aided diagnosis (CADx) systems for lung cancer CT screening [6][7]. This CADe system has graphical user interface and four modules, (1) DICOM Query/Retrieve function, (2) thoracic organ analysis (body, rib, spine, lungs, trachea, bronchi, pulmonary blood vessel, and aorta), (3) detection (lung nodule, low attenuation volume, and osteoporosis), and (4) comparative reading assistance. Using a function of the CADe, thoracic organs, body, bone, trachea, bronchi, lungs, heart, and pulmonary blood vessel are segmented as illustrated in Fig.2. The organs are extracted using anatomical rule based methods. The rules are described by CT value histogram and shape features that were derived by four dimensional curvature. Then, lungs are segmented into five lung lobes using the interlobar fissures as the borders of lobes as described in [8].

2) Detection of lung nodules

Our CADe has detection functions for multi diseases; lung nodules, pleural diseases, emphysema, and osteoporosis [9][10][11]. The CADe detects nodules from lungs that excluded vascular regions (bronchi, and pulmonary blood vessel). In early stage of pneumoconiosis, a lot of small nodules occur. Threshold value for detected nodule size was defined as the diameter over 1.5mm. Fig.3 shows axial images with nodule detection result.

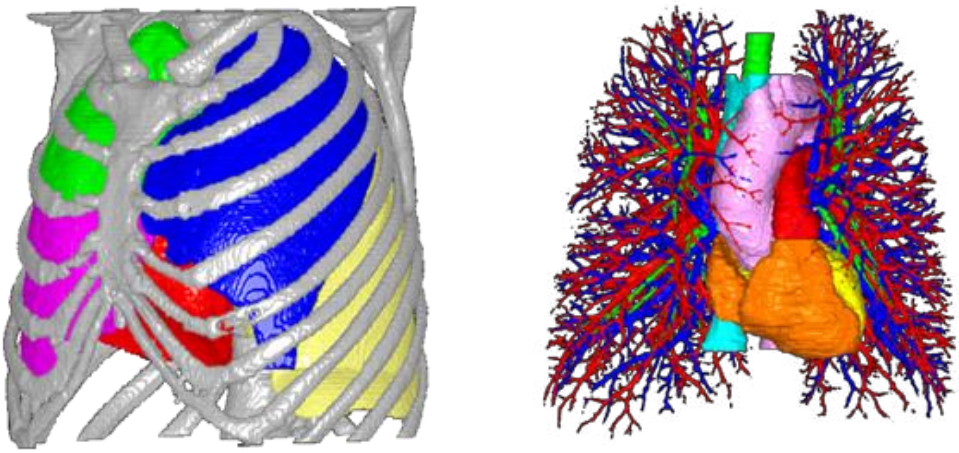


(a) (b) (c) (d)

Fig.1 CT images of pneumoconiosis. (a)PR0/1, (b)PR1/0, (c)PR1/2, (d)PR4A.

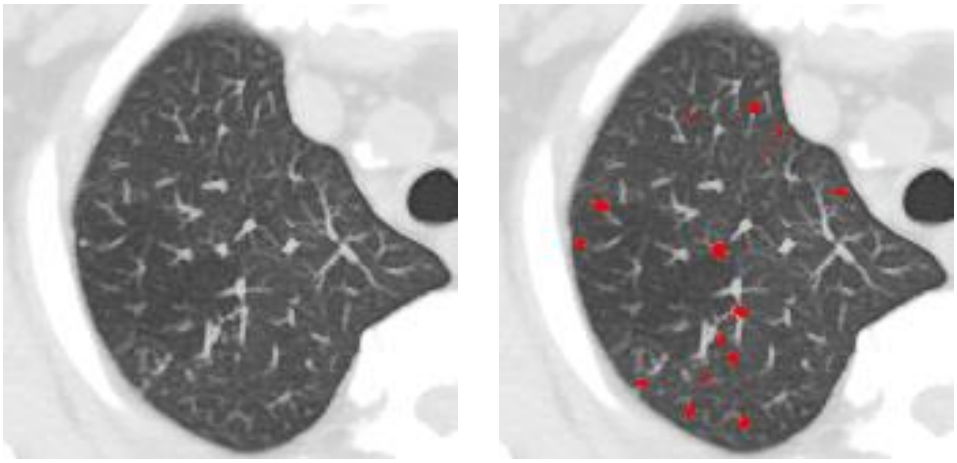
3) Quantitative assessment of severity in pneumoconiosis

Severity in pneumoconiosis was assessed by both size and frequency of lung nodules. Assuming that the nodules have spherical shape, nodule size is defined by the diameter that was computed from nodule volume. The number of nodules was counted by three dimensional labeling method.



(a) (b)

Fig.2 An extraction result of thoracic organs. (a)Bone and lung lobes. Green color is right upper lobe, magenta color is right middle lobe, and red color is right lower lobe. (b)Trachea, bronchi, pulmonary artery, pulmonary vein, aorta, and heart regions.

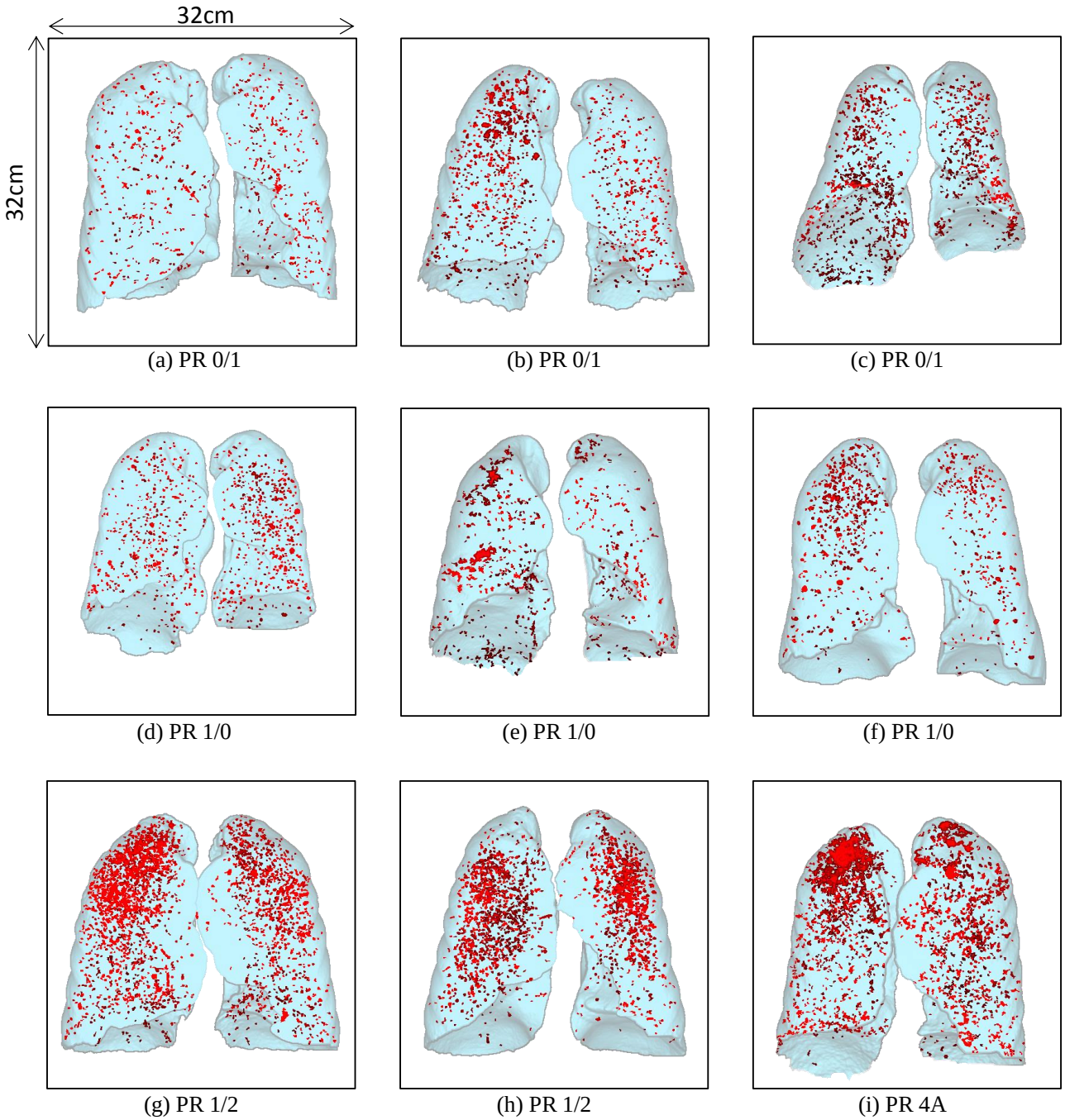


(a) (b)

Fig.3 Axial image with detection result of pulmonary nodules of PR1/0 participant. (a) Maximum intensity projection of original CT image (3mm width), (b) detected nodule regions are colored by red.

RESULTS

Fig.4 shows three dimensional distributions of lung nodules that detected by our CADe. In Fig.4, (a)(b)(c) are PR0/1, (d)(e)(f) are PR1/0, (g)(h) are PR1/2, and (i) is PR4A. Especially, amount of nodule in upper lobes are greater than amount of nodule in lower lobes. Fig.5 shows relationship between radius and cumulative frequency of nodules. Along with increase of severity, frequency of nodules increased. The slope angle in the graph could represent severity in pneumoconiosis.



(a) PR 0/1 (b) PR 0/1 (c) PR 0/1

(d) PR 1/0 (e) PR 1/0 (f) PR 1/0

(g) PR 1/2 (h) PR 1/2 (i) PR 4A

Fig.4 Nodule detection results.

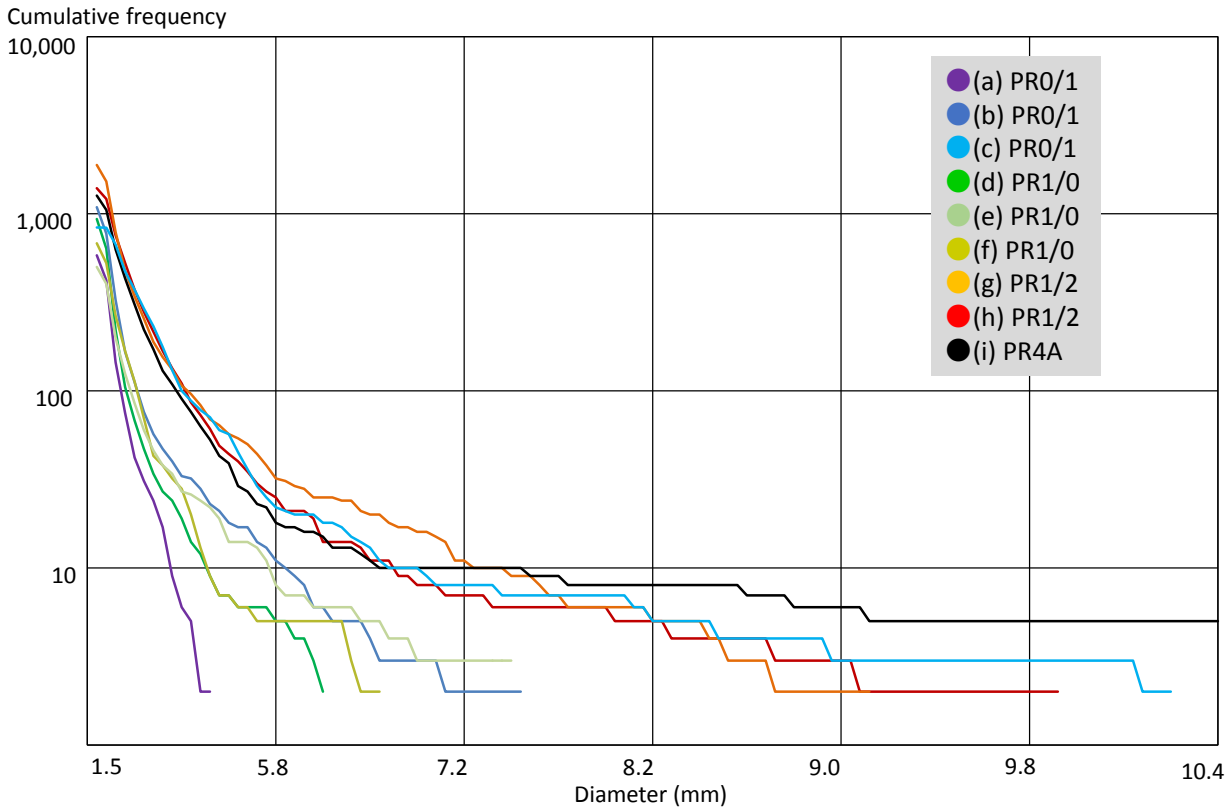


Fig.5 Relationship between diameter and cumulative frequency of nodule.

CONCLUSIONS

This paper presented a method for quantitative assessment of severity in pneumoconiosis using both size and frequency of lung nodules that detected by thin-section CT images. CT screening is useful for certifying workers' compensation by accurate diagnosis of pneumoconiosis. The proposed method could quantify severity of pneumoconiosis in CT screening.

ACKNOWLEDGEMENT

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