



Inter-observer agreement in identifying traction bronchiectasis on computed tomography: its improvement with the use of the additional criteria for chronic fibrosing interstitial pneumonia

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Abstract

Purpose To assess inter-observer variability in identifying traction bronchiectasis on computed tomography (CT) using additional criteria for chronic fibrosing interstitial pneumonia.

Methods Seven experts categorized CT image set representing 39 patients into three groups on the basis of the presence of traction bronchiectasis, using a three-point scale: 3—definitely/probably yes; 2—possibly yes; and 1—definitely/probably no. This scale served as a reference standard. The image set included cases of chronic fibrosing interstitial pneumonia, non-interstitial lung disease, and difficult-to-determine cases. Forty-eight observers similarly assessed the same image set, first according to the Fleischner Society definition, and second with additional criteria, in which traction bronchiectasis was observed exclusively in chronic fibrosing interstitial pneumonia. The agreement level between the reference standard and each observer's evaluation in each session was calculated using weighted kappa values which were compared between the two sessions using a paired *t* test.

Results The mean weighted kappa value for all observers was significantly higher in the second reading session (mean 0.75) than in the first reading session (mean 0.62) ($p < 0.001$).

Conclusion Inter-observer agreement in identifying traction bronchiectasis improves when using the additional criteria which specify chronic fibrosing interstitial pneumonia as the underlying disease.

Keywords Interstitial pneumonia · Traction bronchiectasis · Computed tomography

Introduction

Traction bronchiectasis is defined as an irregular bronchial dilatation caused by surrounding retractile pulmonary fibrosis on computed tomography (CT) according to the Fleischner Society definition [1]. The finding is observed in advanced pulmonary fibrosis in patients with chronic fibrosing interstitial pneumonia such as idiopathic pulmonary

fibrosis/usual interstitial pneumonia (IPF/UIP) [2–8], non-specific interstitial pneumonia (NSIP) [5–7, 9], chronic hypersensitivity pneumonia [6, 10, 11], asbestosis [8], and sarcoidosis with fibrosis [12].

Current IPF guidelines recommend classifying cases of clinically suspected IPF into four categories, based on high-resolution CT (HRCT) findings: UIP pattern, probable UIP pattern, indeterminate pattern, and alternative diagnosis [13]. Honeycombing is a distinguishing feature in UIP pattern and must be present for a definite HRCT diagnosis of UIP to be made. However, it should be noted that observer agreement in identifying honeycombing is moderate and it is not always reliable [14]. Subpleural basal predominance reticular abnormalities with peripheral traction bronchiectasis or bronchiolectasis should be regarded as probable UIP.

The members of the Study Group of Diffuse Interstitial Lung Disease in Japan are listed in the Acknowledgements section.

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Thus, traction bronchiectasis is a key imaging finding for cases of probable UIP.

Several studies have reported that the extent of traction bronchiectasis is correlated with fibrosis stage in interstitial lung diseases [9, 10]. Moreover, several studies have demonstrated that severity of traction bronchiectasis, which was scored by generation of the most proximal bronchial branches involved or by coarseness of the coexisting parenchymal fibrosis, is associated with increased mortality in patient with fibrotic or chronic interstitial lung diseases [2, 10, 11, 15, 16].

Therefore, recognition of the presence of traction bronchiectasis is important for both the diagnosis of chronic fibrosing interstitial pneumonia and for predicting patients' prognosis. However, there is no description of chronic fibrosing interstitial pneumonia in the Fleischner Society definition for traction bronchiectasis. We inferred that if observer agreement in identifying traction bronchiectasis improved on implementing the additional criteria for chronic fibrosing interstitial pneumonia, its clinical importance would increase.

Thus, the purpose of the present study was to quantify inter-observers' variability in identifying traction bronchiectasis on CT with the use of the additional criteria which specified chronic fibrosing interstitial pneumonia as underlying disease.

Materials and methods

Materials

The relevant Institutional Review Boards approved the multi-institutional and multinational retrospective study and waived the requirement for patient approval or informed consent for retrospective analysis of anonymous images. Seven advisory committee members, including six chest radiologists and one pulmonologist with 22–33 years' experience, planned and executed the study. These members had a special interest in diffuse interstitial lung diseases.

Twenty-two chest radiologists and 11 pulmonologists submitted anonymized thin-section CT images depicting traction bronchiectasis and other forms of bronchial dilatation (e.g., bronchiectasis caused by airway disease), with at least three cases per presenter. Images were presented in electronic format (JPEG) at a resolution of 72 or 300 pixels/inch. Information was included on clinical course (i.e., acute, subacute, or chronic course) and the clinical diagnosis. One hundred and twenty-seven cases were submitted. In addition, reconstructed coronal images were submitted for 24 (19%) cases. Up to three contiguous transverse images, which included bronchial branches with representative prominent dilatation, were selected per case. A single

region on the axial image was circled to indicate the target bronchus for an evaluation. Reconstructed coronal images, when available, were also selected. Coronal images were not available for some cases, and thus the target bronchus was not specifically circled on coronal images.

The advisory committee members independently evaluated all 127 image sets for the presence of traction bronchiectasis. Each member was asked to assign a grade from 1 to 3 (definitely or probably no, grade 1/low-confidence; possibly yes, grade 2/moderate-confidence; probably or definitely yes, grade 3/high-confidence), reflecting subjecting scores for the presence of traction bronchiectasis. The Fleischner Society definition was used for the evaluations: Traction bronchiectasis represents irregular bronchial dilatation caused by surrounding retractile pulmonary fibrosis [1]. For the purpose of the study, additional criteria, described below, were also included on the standard evaluation sheets, based on advisory committee members' consensus view of underlying disease related to traction bronchiectasis:

1. Traction bronchiectasis occurs exclusively with chronic fibrosing interstitial pneumonia.
2. Dilatation of the airway within airspace consolidation, focal lesions, and bronchiectasis due to airway diseases must be excluded.
3. Traction bronchiectasis occurs near or within a pulmonary lesion.

After the evaluations by each advisory committee member, all members re-evaluated images together by consensus, with the same three-point scale used in consideration of diseases harboring bronchial dilatation, on the basis of both the Fleischner Society definition and the additional criteria. Subsequently, advisory committee members discussed CT findings and clinical information; they classified each case into one of the following categories on the basis of the underlying disease related to bronchial dilatation: (1) chronic fibrosing interstitial pneumonia, (2) non-interstitial lung disease, and (3) difficult-to-determine cases. Cases with bronchial dilatation in chronic fibrosing interstitial pneumonia, non-interstitial lung disease, and difficult-to-determine cases were further classified into grade 3/high-confidence, grade 1/low-confidence case, and grade 2/moderate-confidence case groups in terms of the presence of traction bronchiectasis, respectively. The results of scoring among advisory committee members served as the reference standard.

For observer performance portion of this study, 39 cases with unanimously consistent judgement among committee members were selected (grade 3/high-confidence case group, 16 cases; grade 2/moderate-confidence case group, 6 cases; and grade 1/low-confidence case group, 17 cases).

Image evaluation

Forty-eight observers participated in the observer performance portion of the study. The group comprised of 31 chest radiologists, 4 non-chest radiologists (i.e., 2 neuroradiologists, 1 gastrointestinal radiologist, and 1 interventional radiologist), 5 radiology training residents, and 8 pulmonologists who were specialized in diffuse interstitial lung disease. They collectively represented 38 institutions from 7 countries. To recruit as many participants as possible, no limit was placed on the number of observers. Accordingly, the number of observers in each group differed: e.g., the number of observers in the chest radiologist group was 31, whereas that in non-chest radiologist group was four.

The observer performance portion of the study contained two steps for the imaging evaluation: first reading session and subsequent second reading session in order.

The observers independently evaluated 39 cases solely by the Fleischner Society definition in the first reading session. They rated their confidence regarding the presence of traction bronchiectasis using the same three-point scale adopted by the advisory committee members. The observers were blinded to all clinical data.

The second reading session was performed after an interval of at least 30 days to minimize the influence of the first reading session (i.e., recall bias). In the second reading session, images were evaluated using both the Fleischner Society definition and the additional criteria described above.

Data analysis

The level of agreement between the reference standard and each observer's evaluation was calculated with the weighted kappa (κ_w). The observers' κ_w values were compared between the first and second reading sessions with paired *t* test. Individual differences were calculated by subtracting the κ_w value of the first reading session from that of the second reading session for each observer.

Correlation between the κ_w values of the first reading session and the individual differences was analyzed to assess changes in the individual evaluation after including the additional criteria by using Spearman's rank correlation coefficient for all observers.

For all tests, $p < 0.05$ indicated statistical significance. R version 3.2.4 for Windows (R Development Core Team, Vienna, Austria) was used for data analysis.

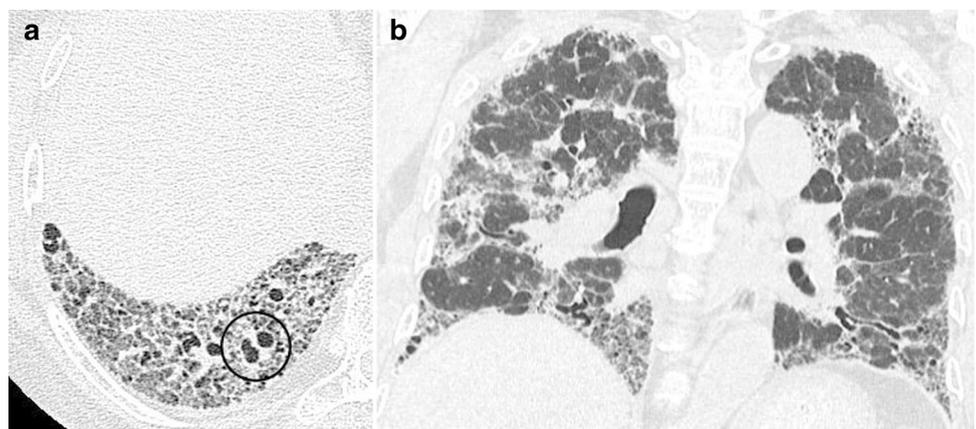
Results

The reference standard for the data analysis

For the reference standard, subject cases were classified into the following three categories:

1. Grade 3/high-confidence case group: chronic fibrosing interstitial pneumonia showing a reticular pattern and/or honeycombing, with chronic clinical course: 16 cases (41%) (Fig. 1).
2. Grade 1/low-confidence case group: non-interstitial lung disease, 17 cases (44%), e.g., bronchiectasis caused by airway disease, 14 cases (Fig. 2); pulmonary emphysema/chronic obstructive pulmonary diseases, three cases. Bronchial dilatation in these diseases differs from traction bronchiectasis in that the former results from direct injury of bronchi rather than from indirect traction by the surrounding parenchyma fibrosis.
3. Grade 2/moderate-confidence case group: difficult-to-determine cases, six cases (15%), e.g., airway dilatation with interstitial pneumonia combined with bronchiectasis caused by airway disease, in which both bronchial dilatation with parenchymal reticular opacity and that with few abnormal opacity in background parenchyma coexist, four cases; airway dilatation that was difficult to distinguish from honeycombing, two cases (Fig. 3). It

Fig. 1 A case of chronic fibrosing interstitial pneumonia. Computed tomography shows a dilated bronchus with prominent reticular opacities in the transverse image (a) and the reconstructed coronal image (b). This patient was classified into the grade 3/high confidence case group as a reference standard



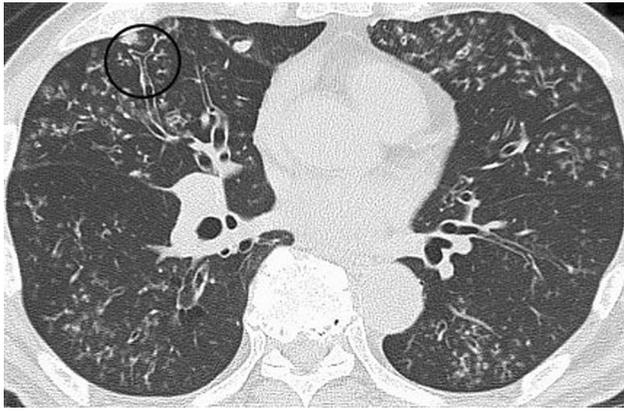


Fig. 2 A case of non-interstitial lung disease in which airway disease caused bronchiectasis. Computed tomography shows dilated bronchi with thickened walls, but few abnormal opacity in the background lung parenchyma. This case is suspected to have bronchiectasis caused by airway disease. This patient was classified into grade 1/low confidence case group as a reference standard



Fig. 3 A case of difficult-to-determine cases for which airway dilatation is difficult to distinguish from honeycombing. Computed tomography shows cystic structures grouped in a layer. It is difficult to determine whether the cystic structures result from tangential view of the airways or from honeycombing. The patient was classified into grade 2/moderate confidence case group as a reference standard

was difficult to determine whether the bronchial dilatation in this category should be judged as traction bronchiectasis.

Level of agreement between the reference standard and the observers' evaluations

Table 1 shows the level of agreement between the reference standard and the observers' evaluations of the presence of traction bronchiectasis. The κ_w values of the first reading session ranged from 0.10 to 0.91, and those of the second reading session ranged from 0.47 to 0.97. Forty (83%) of the 48 observers showed higher κ_w values in the second reading session than in the first reading session, whereas six (13%) observers had a lower value in the second reading session. The mean κ_w value for all observers in the second reading session [0.75; standard deviation (SD) 0.11] was higher than that in the first reading session (0.62; SD, 0.20). The κ_w values were significantly different between the first and second reading sessions ($p < 0.001$).

The individual differences calculated by subtracting the κ_w value of the first reading session from that of the second reading session for each observer, ranged from -0.17 to 0.64 . The κ_w values of the first reading session were negatively correlated with the individual differences (Spearman $r = -0.763$, $p < 0.001$; Fig. 4).

Discussion

Observer agreement in identifying traction bronchiectasis in the first reading session based on the Fleischner Society definition alone was relatively low; however, it improved in the second reading session with using the additional criteria which specified chronic fibrosing interstitial pneumonia as underlying disease related to traction bronchiectasis. This result suggests that definition of traction bronchiectasis on CT should be implemented with the additional criteria.

With regard to changes in the observers' judgments, the κ_w values of the first reading session were negatively correlated with the individual differences that were calculated by subtracting the κ_w values of the first reading session from those of the second reading session. This indicated that observers with poorer agreement in identifying traction bronchiectasis in the first reading session had greater potential for improvement in the second reading session. Use of the additional criteria may contribute to increasing the level of agreement in identifying traction bronchiectasis. These results suggest that traction bronchiectasis is identified consistently and appropriately among observers with various ability levels, regardless of their experience and specialty in the diagnosis of chronic fibrosing interstitial pneumonia.

Previous studies, in which CT images of chronic or fibrosing interstitial pneumonia were evaluated by two observers, showed moderate to good inter-observer agreement in identifying traction bronchiectasis ($\kappa_w = 0.58$ – 0.69) [11, 15, 16]. Walsh et al. [15] examined the association between

Table 1 Level of agreement (weighted kappa values) between the reference standards and the observers’ evaluations

Observer	The first reading session	The second reading session	The individual difference
A1	0.78	0.62	−0.16
A2	0.67	0.67	0.00
A3	0.51	0.73	0.22
A4	0.77	0.86	0.09
A5	0.60	0.75	0.15
A6	0.87	0.70	−0.17
A7	0.91	0.90	−0.01
A8	0.89	0.92	0.03
A9	0.55	0.73	0.18
A10	0.30	0.70	0.40
A11	0.77	0.66	−0.11
A12	0.82	0.85	0.03
A13	0.77	0.78	0.01
A14	0.56	0.86	0.30
A15	0.45	0.74	0.29
A16	0.70	0.97	0.27
A17	0.66	0.70	0.04
A18	0.64	0.81	0.17
A19	0.76	0.81	0.05
A20	0.91	0.87	−0.04
A21	0.77	0.89	0.12
A22	0.82	0.93	0.11
A23	0.64	0.79	0.15
A24	0.77	0.93	0.16
A25	0.48	0.69	0.21
A26	0.51	0.81	0.30
A27	0.51	0.70	0.19
A28	0.64	0.81	0.17
A29	0.47	0.49	0.02
A30	0.58	0.67	0.09
A31	0.64	0.75	0.11
B1	0.46	0.51	0.05
B2	0.12	0.66	0.54
B3	0.63	0.69	0.06
B4	0.79	0.89	0.10
C1	0.27	0.47	0.20
C2	0.20	0.62	0.42
C3	0.80	0.80	0.00
C4	0.69	0.74	0.05
C5	0.80	0.78	−0.02
D1	0.49	0.65	0.16
D2	0.10	0.74	0.64
D3	0.75	0.77	0.02
D4	0.58	0.66	0.08
D5	0.33	0.75	0.42
D6	0.41	0.77	0.36
D7	0.70	0.78	0.08

Table 1 (continued)

Observer	The first reading session	The second reading session	The individual difference
D8	0.66	0.75	0.09
Mean	0.62	0.75	0.14
SD	0.20	0.11	0.17

Observers A1–A31 are chest radiologists; observers B1–B4, non-chest radiologists; observers C1–C5, radiology training residents; and observers D1–D8, pulmonologists specializing in diffuse interstitial lung diseases. The values in the first reading session and the second reading session columns are the weighted kappa (κ_w) values. The values in the individual difference column were calculated by subtracting the κ_w values of the first reading session from those of the second reading session. The values in the mean row and the SD row are the means and the standard deviations of all 48 observers for both reading sessions and the individual difference, respectively

SD standard deviation

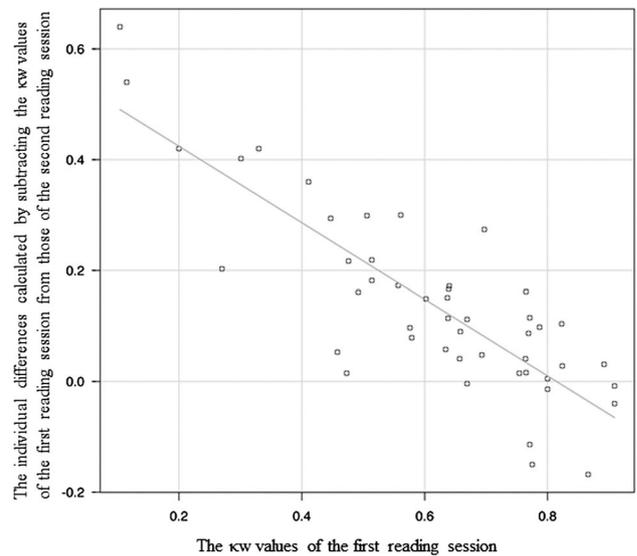


Fig. 4 Correlation between the κ_w values of the first reading session and the individual differences calculated by subtracting the κ_w values of the first reading session from those of the second reading session. Spearman’s rank correlation coefficient (r) is -0.763 ($p < 0.001$). κ_w weighted kappa

CT findings and mortality in patients with connective tissue disease-related fibrotic lung disease. In their study, increasing severity of traction bronchiectasis and increasing extent of honeycombing were independently associated with increased mortality. In a subgroup analysis, these results remained independently associated with increased mortality in patients with a radiological diagnosis of NSIP and in those with a radiological diagnosis of UIP. Moreover, inter-observer agreement for traction bronchiectasis ($\kappa_w = 0.68$) was higher than that for honeycombing ($\kappa_w = 0.50$) [15].

They asserted that traction bronchiectasis may be a superior alternative CT sign to honeycombing for predicting patients' prognoses. Watadani et al. [14] quantified inter-observer agreement for the presence of honeycombing on CT. Their study included images of not only typical honeycombing but also of emphysema. They showed that there was only moderate agreement in the identification of honeycombing ($\kappa_w = 0.40\text{--}0.58$). The present study also included images of not only typical traction bronchiectasis, but also non-interstitial lung disease such as airway disease. Compared with the study of Watadani et al. [14], inter-observer agreement on the presence of traction bronchiectasis was higher in both first and second reading sessions ($\kappa_w = 0.62, 0.75$). However, it should be noted that difference in the methods of image presentation could have influenced the result. The fact that the bronchus was circled in the present study was possibly a source of the increased agreement, which differed from the study of Watadani et al.

The present study had several limitations. First, each observer assessed the same cases twice; therefore, the evaluations in the second reading session could have been influenced by other factors such as learning effect instead. However, the second reading session was performed after an interval of at least 30 days to minimize the influence of the first reading session (i.e., recall bias). Second, validity of the additional criteria and the advisory committee members' reference standards was not examined. Third, the number of samples was relatively small. The use of highly selected 39 cases would degrade the validity of the conclusion of this study. Fourth, a maximum of three sections of transverse CT images were used, and a coronal view was not provided for all cases. Therefore, evaluating bronchi sufficiently was difficult in some patients because of a limited number of contiguous images. Fifth, image quality was not uniform because subject images were provided by multiple facilities, which used different imaging protocols. Finally, a histopathological basis was not established for each patient.

In conclusion, inter-observer agreement in identifying traction bronchiectasis improves with the use of the additional criteria which specify chronic fibrosing interstitial pneumonia as underlying disease.

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Compliance with ethical standards

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