Mod Rheumatol (2002) 12:311–317

ORIGINAL ARTICLE

Tomomasa Izumiyama · Hikaru Hama · Motohiko Miura
Akira Hatakeyama · Yoko Suzuki · Takasi Sawai
Terunobu Saito

Frequency of broncho-bronchiolar disease in rheumatoid arthritis: an examination by high-resolution computed tomography

Received: September 18, 2001 / Accepted: April 30, 2002

Abstract To assess the frequency of pulmonary changes in patients with rheumatoid arthritis (RA), we evaluated a subject group (all outpatients with RA visiting the hospital during a period of three consecutive days) by plain chest radiographs (CRs) and high-resolution computed tomography (HRCT). The study population consisted of 186 patients (32 men, 154 women; mean age 59.8 years), including 6 smokers or exsmokers. Chest radiography was performed on all patients. Seventy (Group A) patients demonstrated abnormal findings and 116 (Group B) did not. HRCT scans were performed on 69 of Group A and 54 of Group B. HRCT demonstrated centrilobular micronodules ($n = 29$; 23.6%), septal lines ($n = 24$; 19.5%), subpleural curvilinear shadows ($n = 24$; 19.5%), bronchiectasis ($n = 21$; 17.1%), dependent opacity ($n = 14$; 11.4%), nodules ($n = 12$; 9.8%), and honeycombing ($n = 11$; 8.9%). Ten (34%) of the patients with centrilobular micronodules also had bronchiectasis. The most frequent disorder was broncho-bronchiolar disease. Contrary to the CRs finding of no abnormality, HRCT detected pulmonary pathological findings in 40 of 54 patients (74.1%). Pulmonary diseases may be frequently latent, and HRCT is useful in evaluating them in patients with RA.

T. Izumiyama (✉) · A. Hatakeyama · Y. Suzuki
Division of Arthritis and Connective Tissue Diseases, Labour Welfare Corporation, Tohoku Rousai Hospital, 4-3-21 Dainohara, Aoba-ku, Sendai 981–8563, Japan
Tel. +81-22-275-1111; Fax +81-22-275-7541
e-mail: to-iz-@tohokuh.rofuku.go.jp

H. Hama
Department of Radiology, Labour Welfare Corporation, Tohoku Rousai Hospital, Sendai, Japan

M. Miura
Department of Respiratory Medicine, Labour Welfare Corporation, Tohoku Rousai Hospital, Sendai, Japan

T. Sawai
Department of Pathology, Iwate Medical University, Morioka, Japan

T. Saito
Institute of Rheumatology, Tokyo Women's Medical University, Tokyo, Japan

Key words Broncho-bronchiolar disease · High-resolution computed tomography (HRCT) · Rheumatoid arthritis (RA)

Introduction

Various pulmonary complications such as interstitial pneumonia, airway disease, and the adverse effects of disease-modifying antirheumatic drugs (DMARDs) are known in patients with rheumatoid arthritis (RA). However, it is difficult to detect slight bronchiolar diseases by plain chest radiographs (CRs), and there are few detailed reports on the frequency of such complications, except for that of Perez et al.[1] describing that air trapping was demonstrated most frequently. We attempted to evaluate the pulmonary changes in RA using high-resolution computed tomography (HRCT), which is excellent in assessing minute parenchymal and bronchiolar lesions.[1–3]

Patients and methods

Patients

The study population consisted of 186 subjects (32 men, 154 women; mean age 59.8 years, range 28–88 years). This corresponds to all the outpatients with RA who visited the hospital and underwent medical examinations during a period of three consecutive days June 7–9, 1999. This represented about 22% of all outpatients with RA in our division. They all fulfilled the American Rheumatism Association criteria for the diagnosis (1987),[4] and only one of them had histologically proven vasculitis. Secondary Sjögren's syndrome was not evaluated. Overlaping syndromes were not included. Radiographic damage in the joints of patients was evaluated by the Steinbrocker staging method (Stages I–IV).[5] There were six smokers or exsmokers. A coal worker was not included.

Chest radiography

Posteroanterior CRs were obtained using Fuji Computed Radiography on all patients; 70 patients had CRs that showed various types of pulmonary involvement (Group A), and the other 116 had normal CRs (Group B).

HRCT

HRCT scans were performed with an electron beam scanner (HiSpeed Advantage, GE, USA) with the patient in a supine position and at full inspiration under the condition of 120 kV, 280 mA, scan acquisition time of 200 ms, and with a 1-mm section thickness by use of a bone algorithm. In principle, 16 slice images equally divided from the lung apices to the costophrenic angles were obtained at window settings suitable for viewing the lung parenchyma (window level of 750 HU, window width of 1200 HU).

We recommended that all patients in both A and B groups be evaluated with HRCT, except for 58 patients who had had HRCT scans within the previous 3 years. Ten of these patients had HRCT films consisting of only 11 slices, but these films were accepted. In all, 123 patients were evaluated with HRCT (Group I), and 63 patients were not (Group II). This implies that 69 of Group A (Group A′) and 54 of Group B (Group B′) were evaluated by HRCT and were included in Group I.

Each of the HRCT signs of the lung was coded as present or absent almost according to the report of M. Remy-Jardin,[6] although codes for subpleural curvilinear shadows (SCLS)[7] and dependent opacity (DO)[7] were added. Septal lines represent thickened interlobular septa, and nonseptal lines are assumed to be traces of inflammatory diseases or thickened blood vessels, although the causes are not clearly understood (Fig.1). Findings of pleura and mediastinum were not coded. All HRCT films and CRs were evaluated by two trainee clinicians (Tomomasa Izumiyama and Motohiko Miura) and one radiologist (Hikaru Hama) who had no knowledge of the patients' clinical information. This study was approved by the Hospital Ethics Committee.

Statistical analysis

We compared the categorical variables using the chi-square test and the calculated means using the Student's t or Z test with Excel Toukei Version 5.0, Esumi, Japan.

Results

Clinical data and radiography analysis

Patients' characteristics are summarized in Table 1. The mean age of 22 male patients in Group I was higher than that of male and female patients in Group II. There were various types of radiographic findings in 70 patients (Group A), including 39 lineal or reticular shadows, 7 silhouette signs, 5 overinflations, 3 calcifications, 3 pleural thicknesses, 2 nodular shadows, and others. In particular, there were many patients with radiographic damage of Stage IV.

Frequency of pathological HRCT findings

The frequency of all HRCT findings for patients in Group I (Group A′ & Group B′) are summarized in Table 2 and examined for each stage, male and female (Fig. 2). The most frequent finding was centrilobular micronodules (mN) especially in Stages II, III, and IV, which were observed in 29 (23.6%) patients, mostly in the middle and lower lobes. Bronchiectasis (BE) was observed in 21 (17.1%) patients, and 10 (47.6%) of them also had mN (Table 3). Septal lines

Table 1. Summary of clinical data and grouping of patients

	Total (n = 186)	Group I (with HRCT)		Group II (without HRCT)	
		Male (n = 22)	Female (n = 101)	Male (n = 10)	Female (n = 53)
Age Mean (years)	59.8	65.9	61.2	58.3*	54.9**
Range (years)	28–88	46–78	29–88	34–71	28–84
Mean disease duration (years)	10.2	12.9	10.1	8.6	9.5
Group A	70	16	53	0	1
Group B	116	6	48	10	52
Stage I[a]	38	4	22	1	11
Stage II[a]	23	1	11	2	9
Stage III[a]	47	7	25	5	10
Stage IV[a]	78	10	43	2	23
Smokers or exsmokers	6	4	2	ND	ND

Total 186 — Abnormal CRs (Group A) 70 — HRCT(+) (Group A′) 69 — Group I; HRCT(−) 1
Total 186 — Normal CRs (Group B) 116 — HRCT(+) (Group B′) 54 — Group I; HRCT(−) 62 — Group II

CRs, chest radiographs; HRCT, high-resolution computed tomography; ND, no data
* $P < 0.05$; ** $P < 0.01$ compared with males of Group I
[a] Stages I–IV, Steinbrocker stage

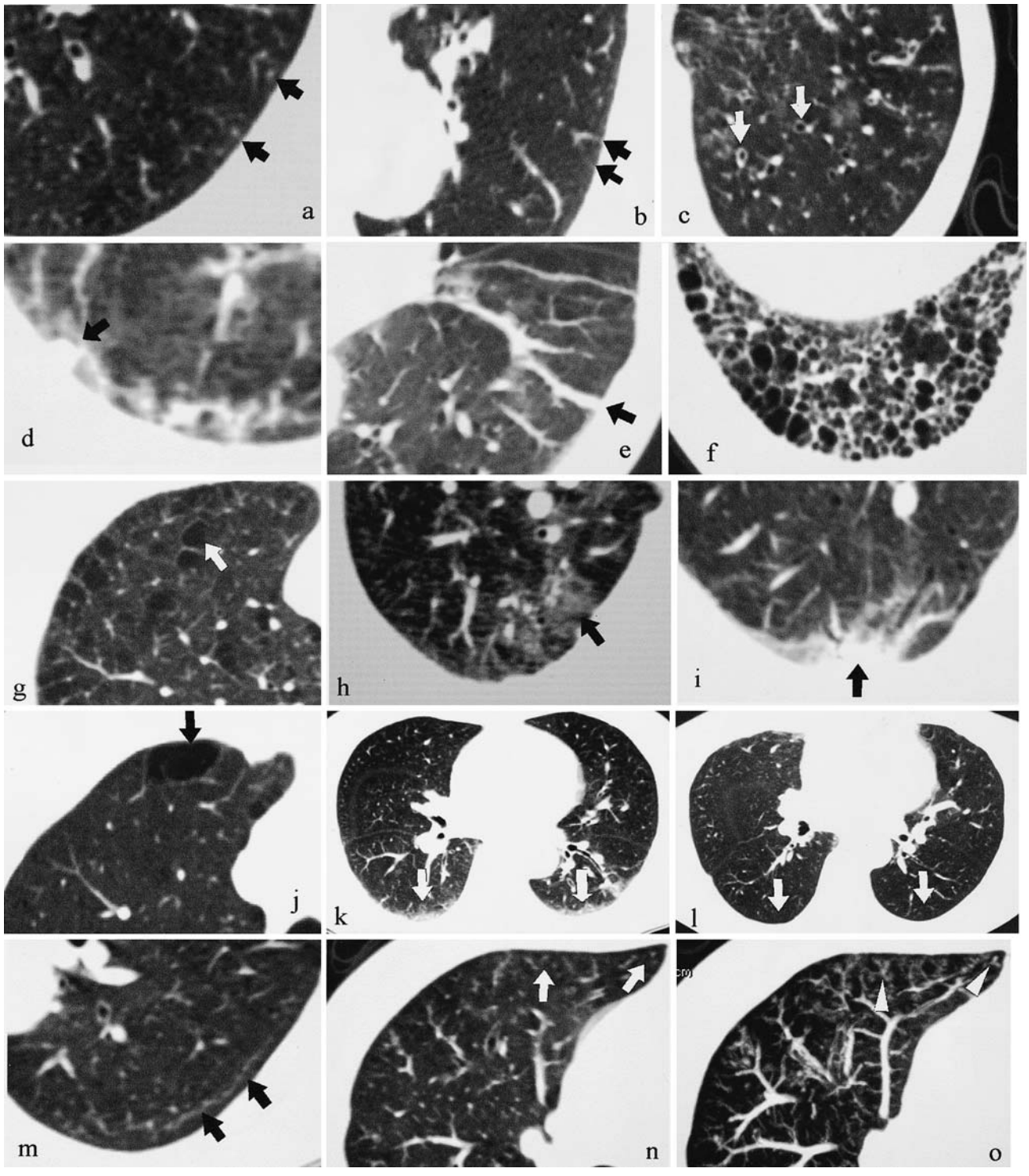

Fig. 1. High-resolution computed tomography (HRCT) images of (**a**) micronodules (mN), (**b**) septal line (Sep.L), (**c**) bronchiectasis (BE), (**d**) nodules (N), (**e**) non-septal line (Non-sep), (**f**) honeycombing (H), (**g**) low attenuation (LA), (**h**) ground glass (GG), (**i**) patchy (P), (**j**) bulla (B), (**k**) dependent opacity (DO) in a supine position, (**l**) disappeared DO in a prone position, and (**m**) subpleural curvilinear shadows (SCLS). Each arrow represents each item. (**n**) Conventional HRCT image of mN (*arrows*) was compared with (**o**) sliding-thin-slab maximum intensity projection (STS-MIP) image, which clearly delineated pathologically thick bronchioles (*arrowheads*)

(Sep.L) were observed in 24 (19.5%) patients and 8 of them also had mN. Subpleural curvilinear shadows (SCLS) were observed in 24 (19.5%) patients and 9 of them also had mN. Nodules (N) were observed in 12 (9.8%) patients. Honeycombing (H), which is the typical HRCT finding of pulmonary fibrosis, was observed in 11 (8.9%) patients. These pathological findings were found frequently in Stages III and IV patients (Fig. 2) and in male patients (Table 2), but were found in almost equal numbers in Groups A′ and B′ (Fig. 3). In particular, male patients had findings of BE,

Table 2. Summary of HRCT findings in groups A′ and B′, male, female, and stages I–IV

	Total $n = 123$	Group A′ $n = 69$	Group B′ $n = 54$	Male $n = 32$	Female $n = 154$	Stage			
						I	II	III	IV
mN no. (%)	29	19 (28)	10 (19)	2 (10)	27 (27)	1	3	8	17
Sep.L no. (%)	24	12 (17)	12 (22)	5 (23)	19 (19)	4	1	6	13
SCLS no. (%)	24	14 (20)	10 (19)	6 (27)	18 (18)	4	4	6	10
BE no. (%)	21	14 (20)	7 (13)	7* (32)	14 (14)	3	0	5	13
GG no. (%)	17	11 (16)	6 (11)	3 (14)	14 (14)	5	1	5	6
DO no. (%)	14	6 (9)	8 (15)	3 (14)	11 (11)	3	0	6	5
N no. (%)	13	7 (10)	6 (11)	3 (14)	10 (10)	1	0	4	8
B no. (%)	12	9 (13)	3 (6)	9* (41)	3 (3)	1	1	5	5
H no. (%)	11	9 (13)	2 (4)	7* (32)	4 (4)	2	2	3	4
LA no. (%)	6	4 (6)	2 (4)	5* (23)	1 (1)	2	0	0	4
P no. (%)	6	5 (7)	1 (2)	2 (10)	4 (4)	0	0	2	4
Non-sep. no. (%)	6	3 (4)	2 (4)	0 (0)	5 (5)	0	1	0	4
Total no. (%)	182	113 (164)	69 (128)	52 (236)	130 (129)	26	13	50	93

mN, micronodules; Sep.L, septal line; SCLS, subpleural curvilinear shadow; BE, bronchiectasis; GG, ground glass; DO, dependent opacity; N, nodules; B, bulla; H, honeycombing; LA, low attenuation; P, patchy consolidation; Non-sep., non-septal line
* $P < 0.05$ compared with females

Table 3. Number of patients with two findings

	mN	BE	SCLS	Sep.L	GG
mN ($n = 29$)	–	10[a]	9[a]	8	6
BE ($n = 21$)	10[a]	–	2	2	5
SCLS ($n = 24$)	9[a]	2	–	11[a]	3
Sep.L ($n = 24$)	8[a]	2	11[a]	–	6
GG ($n = 17$)	6[a]	5	3	6	–

[a] Number exceeds the frequency of 30%

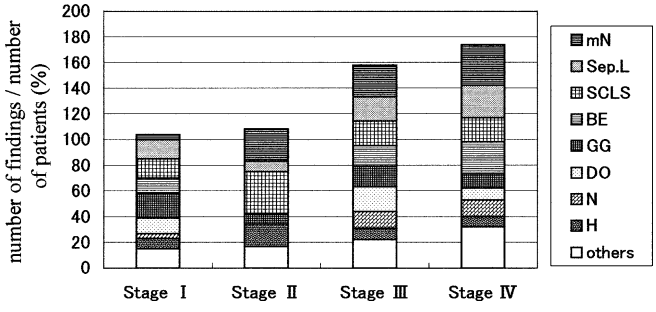

Fig. 2. Frequency of HRCT findings in Stages I–IV. The findings were found more frequently in Stages III and IV than in Stages I and II. The most frequent finding was centrilobular micronodules (mN), especially in Stages II, III, and IV

bulla (B), H, and low attenuation (LA) more frequently ($P < 0.05$) than did female patients.

In the six smoker or exsmoker patients, B was depicted in four male patients and in one female patient, LA in three male patients and in one female patient, H and SCLS in two male patients and in one female patient, BE in three male patients and mN in no patients. Additionally, in those patients with BE, two patients had sinusitis.

Relationship between CT appearance and DMARDs therapy

To determine if the CT appearance was associated with therapy, all DMARDs administered were evaluated. In all,

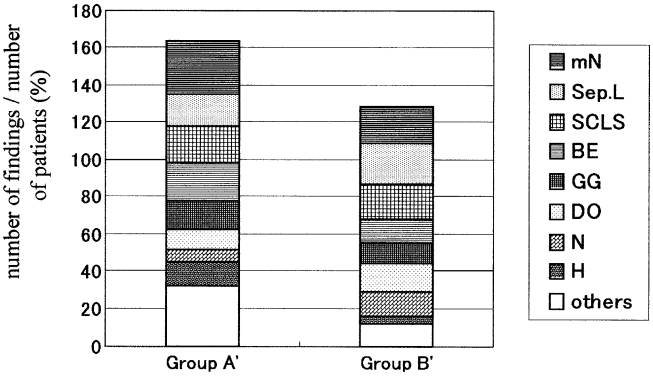

Fig. 3. Frequency of HRCT findings in Groups A′ and B′. The findings were found almost equally in Groups A′ and B′

of the 70 patients taking sodium aurothiomalate, 17 patients (24.3%) had a finding of Sep.L. In patients given methotrexate, there were 10 (34.5%) with mN and 8 (27.6%) with SCLS. In patients given bucillamine, there were 8 (26.7%) with BE and 7 (23.3%) with mN.

Discussion

In this study, we obtained 123 chest HRCT images (Group I) from 186 outpatients, indiscriminately chosen, with RA. Furthermore, 54 patients of Group B′ were from a group of 116 patients without pulmonary involvement, as shown by CRs. This made it possible to presume the frequency of lung involvement in RA.

mN located in the centrilobular area were found in 29 patients, and were often seen as branching structures that were depicted clearly in sliding-thin-slab maximum intensity projection images[8] (Fig. 1). These mN were considered to be a finding of bronchiolitis.[9] Although most of them were countable and looked stable, there were five patients in whom mN were most prominent. We administered eryth-

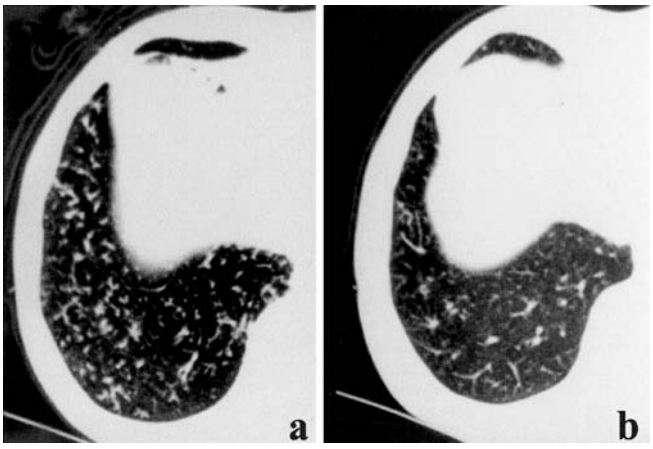

Fig. 4. HRCT findings of diffuse panbronchiolitis (DPB)-like lesion. Multiple centrilobular micronodules before therapy (**a**) disappeared after therapy with erythromycin (**b**), and amounts of sputum also decreased

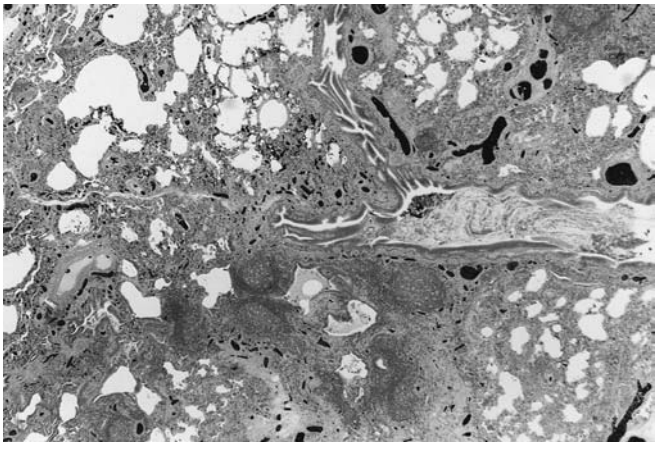

Fig. 5. Follicular bronchiolitis in a 45-year-old woman with classical RA. She complained of no respiratory symptoms, but she had characteristic HRCT findings of high attenuation around the ecstatic bronchioles as well as mN. These were not improved after administration of erythromycin. A video-assisted transcutaneous lung biopsy revealed multiple lymphoid follicles with a germinal center around bronchioles accompanied by diffuse lymphocyte infiltration. Hematoxylin-eosin, ×5 (original magnification)

romycin to these five patients and found an obvious improvement in four of them. They were thought to have had diffuse panbronchiolitis (DPB)-like lesions[10–12] (Fig. 4). The patient without any improvement had characteristic HRCT findings of high attenuation around the ectatic bronchioles as well as mN. A video-assisted transcutaneous lung biopsy revealed follicular bronchiolitis (Fig. 5).

The group of 27 female patients with mN had a longer ($P < 0.01$) mean disease duration than did the 74 female patients without mN (14.1 years and 8.7 years, respectively), and 17 (63.0%) of the former had stage IV radiographic damage. Supposedly mN is associated with RA; however, the mean age of the patients with mN was higher ($P < 0.01$) than that of those without mN (68.1 and 58.6 years old, respectively). Therefore aging also may be associated with the finding in RA patients.

The next most frequent finding of airway diseases was BE. What we call traction bronchiectasis was seen in only one patient. Ten patients had symptoms of a cough or expectoration of sputum, and others were subclinical. In 1994, Remy-Jardin et al.[6] reported that BE was depicted most frequently (30%), which is approximately consistent with our finding. Bronchiolitis and BE were frequently detected simultaneously in our study (Table 3), and they are both thought to be the findings of chronic infection. Bamji and Cooke[13] reported that not only may the RA itself predispose to infection, but also that DMARDs may exacerbate such predisposition. Furthermore, it is reported that untreated or recurrent pneumonia may lead to bronchiectasis in patients with immunodeficiency.[14] Conversely, there is a report that chronic bronchial suppuration preceded the onset of RA.[13] Those reports suggest that susceptibility in RA patients, DMARDs therapy, chronic infection, and the onset of RA may be closely related.

Concerning the frequency of airway involvement in RA patients, Perez et al.[1] used HRCT in patients without radiographic evidence of RA-related lung changes, they reported 16 (32%) patients with air trapping, 15 (30%) with bronchiectasis, and 3 (6%) with centrilobular areas of high attenuation. In their study, centrilobular lesions were detected with an apparently lower frequency than in our study. The reason is not clear, but it is conceivable that bronchiolar lesions may be a Japanese–race or environmental effect where DPB is also frequently noted.[15] However, there are few strict investigations on the frequency of bronchiolitis in RA patients in Japan so far. Fujii et al.[16] reported 5 (5.5%) patients with bronchiolitis, and Sasaka et al.[17] detected centrilobular nodules in 19 (37.3%) patients, but the number of subjects was limited.

Abnormal findings consistent with interstitial lung disease such as Sep.L and ground glass were also depicted frequently. Honeycombing was depicted in 11 patients (5.9% of all patients); its frequency is not very different from previous reports, it is predominant in males. There was one male patient taking methotrexate (MTX) with a finding of H on HRCT. He deteriorated and then successfully recovered with the discontinuance of MTX and the administration of glucocorticoids, sulfamethoxazole with trimethoprim, and ganciclovir, although there was little evidence of infectious pathogens. Later he suddenly relapsed and died when the quantity of glucocorticoids was slowly reduced. There was no obvious cause of his interstitial pneumonia other than RA, although an autopsy was not done. There was no deterioration of interstitial pneumonia in other subjects.

Subpleural curvilinear shadows (SCLS) are thought to reflect the initiation of pulmonary fibrosis leading to the formation of a honeycomb shadow.[18] This represents, histologically, peribronchiolar fibrosis.[18] Kubota et al.[19] used the expression "plate-like atelectasis in the corticomedullary junction" and reported that interstitial infiltration may have caused a check valve effect on the small airways in the cortex and decreased the distensibility of the whole lung. In

any case, the HRCT findings in this study are probably an expression of inflammatory lung disease.

There were several HRCT findings that were detected simultaneously (Table 3). This was presumably because RA was the common cause of these findings. In particular, mN were frequently detected with BE, and these were both findings of airway disease. Similarly, septal lines were seen, especially with SCLS. These were both thought to be a finding of inflammatory diseases. The latter was usually detected posteriorly; thus, it may partially be the result of the effect of gravity.

Other new knowledge derived from this study was that DO was also frequently seen (11.4%). Eight of 14 patients with DO were confirmed by undergoing HRCT in a prone position, and there was no doubt of DO in the others. This phenomenon is explained by a gravity-dependent increase in parenchymal attenuation, and Herold et al.[20] reported that the increased intravascular volume increased the proportion of fluid relative to air in the lung volume. However, cardioechography on a patient with the most prominent DO did not show any deteriorated cardiac functions. The cause of DO is unclear, but mechanical volume loading and/or inflammatory vascular responsiveness may be the cause in RA patients. We found various courses of DO by follow-up HRCT at an average of 2.1 years. Five patients improved, four patients were stable, and one deteriorated.

There were marked differences of HRCT findings between male and female patients. In male patients, B, H, BE, and LA were observed with high frequency, but four patients with B and three with LA were smokers. B and LA are thought to have a causal relationship with smoking,[21] presumably causing these differences between male and female patients. Concerning aging, there were no differences between the mean ages of males (68.3 years) and females (67.5 years) with H. The predominance of H may be a feature of male RA.

It is important to note that pulmonary changes are often unclear in the CRs (Table 1). In CRs, some objects in the lung are projected on two-dimensional displays as cumulative shadows; therefore, reticular shadows are thought to be the cumulative findings of fibrous disorders. Nine of 11 honeycombings were detected as a reticular shadow on CRs. On the other hand, none of Sep.L or SCLS was detected as such, although SCLS may be detected in oblique views in some cases. On the contrary, there were five patients with mild lineal and/or reticular shadows in CRs without any abnormality on HRCT. These are false positives in CRs. That is to say, the findings of CRs were not always consistent with those of HRCT in not only Group B′ but also in Group A′; thus, the frequency of pulmonary involvement in Group B′ was almost equal to that of Group A′ (Fig. 3). This means that subclinical pulmonary involvement may exist with high frequency. HRCT is very useful in evaluating such pulmonary diseases.

Pulmonary function tests are known to be effective in detecting small airway diseases, but their results do not always represent airway diseases directly.[22] On the other hand, mN on HRCT directly means a bronchiole disease. Small airways were called the silent zone before; thus, small amounts of mN were not thought able to impair small airway function. There were two patients with mN who did not show abnormal FEV1%, $\dot{V}50/\dot{V}25$, or $\dot{V}25/HT$, although these tests were not done in all patients.

A video-assisted thoracoscopic lung biopsy was performed on another patient. The pathological diagnosis was lymphocytic interstitial pneumonia.

Although the relationship between lung disease and DMARDs is also important, we judged it impossible to clarify the relationship because the order and period of administration of the DMARDs were very variable. A well-controlled investigation will be necessary.

In conclusion, the present study of chest HRCT revealed that 88.6% of RA patients had various kinds of pulmonary complications, which were very often missed in plain chest radiography. The centrilobular micronodules, which are thought to be an expression of bronchiolitis, were most frequently (23.6%) recognized. Bronchiectasis was also recognized in 21 patients (17.0%). Diffuse panbronchiolitis-like lesions, which may be a most serious state with mN, have the possibility of improvement with erythromycin therapy. Mitchell et al.[23] reported that RA patients showed a marked increase in deaths resulting from infection, and infectious complications were usually located in the lung; therefore, airway problems in RA are as important as, or possibly more important than, interstitial problems.

References

1. Perez T, Remy-Jardin M, Cortet B. Airway involvement in rheumatoid arthritis. Am J Respir Crit Care Med 1998;157:1658–65.
2. Nakata H, Kimoto T, Nakayama T, Kido M, Miyazaki N, Harada S. Diffuse peripheral lung disease: evaluation by high-resolution computed tomography. Radiology 1985;157:181–5.
3. Murata K, Itoh H, Todo G, Kanaoka M, Noma S, Itoh T, et al. Centrilobular lesions of the lung: demonstration by high-resolution CT and pathologic correlation. Radiology 1986;161:641–5.
4. Arnett FC, Edworthy SM, Bloch DA, McShane DJ, Fries JF, Cooper NS, et al. The American Rheumatism Association 1987 revised criteria for the classification of rheumatoid arthritis. Arthritis Rheum 1988;31:315–24.
5. Steinbrocker O, Traeger CH, Batterman RC. Therapeutic criteria in rheumatoid arthritis. JAMA 1949;140:659–62.
6. Remy-Jardin M, Remy J, Cortet B, Mauri F, Dwlcambe B. Lung changes in rheumatoid arthritis: CT findings. Radiology 1994;193: 375–82.
7. Austin JHM, Muller NL, Friedman PJ, Hansell DM, Naidich DP, Remy-Jardin M, et al. Glossary of terms for CT of the lungs: recommendations of the nomenclature committee of the Fleischner society. Radiology 1996;200:327–31.
8. Remy-Jardin M, Remy J, Artaud D, Deschildre F, Duhamel A. Diffuse infiltrative lung disease: clinical value of sliding-thin-slab maximum intensity projection CT scans in the detection of mild micronodular patterns. Radiology 1996;200:333–9.
9. Muller NL, Miller RR. Diseases of the bronchioles: CT and histopathologic findings. Radiology 1995;196:3–12.
10. Hayakawa H, Sato A, Imokawa S, Toyoshima M, Chida K, Iwata M. Bronchiolar disease in rheumatoid arthritis. Am J Respir Crit Care Med 1996;154:531–6.
11. Hayakawa H, Sato A, Imokawa S, Todate A, Chida K, Suzuki K. Diffuse panbronchiolitis and rheumatoid arthritis-associated bronchiolar disease: similarities and differences. Intern Med 1998;37: 504–8.
12. Imokawa S, Sato A, Hayakawa H, Chida K, Toyoshima M, Yositomi A, et al. A clinicopathological study of lung involvement

in patients with rheumatoid arthritis. Jpn J Clin Radiol 1995;141–50.
13. Bamji A, Cooke N. Rheumatoid arthritis and chronic bronchial suppuration. Scand J Rheumatol 1985;14:15–21.
14. Oh YW, Effmann EL, Godwin JD. Pulmonary infections in immunocompromised hosts: the importance of correlating the conventional radiologic appearance with the clinical setting. Radiology 2000;217:647–56.
15. Homma S, Kawabata M, Kishi K, Tsuboi E, Narui K, Nakatani T, et al. Diffuse panbronchiolitis in rheumatoid arthritis. Eur Respir J 1998;12:444–52.
16. Fujii M, Adachi S, Shimizu T, Kono M. Interstitial lung disease in rheumatoid arthritis: assessment with high-resolution computed tomography. J Thorac Imaging 1993;8:54–62.
17. Sasaka K, Nakajima Y, Kase C, Yamada H. Plain film and CT findings of pulmonary involvement in rheumatoid arthritis (in Japanese). Ryumachi 1998;38:705–16.
18. Yoshimura H, Hatakeyama M, Otsuji H, Maeda M, Ohishi H, Uchida H, et al. Pulmonary asbestosis: CT study of subpleural curvilinear shadow. Radiology 1986;158:653–8.
19. Kubota H, Hosoya T, Kato M, Uchimura F, Itagaki T, Yamaguchi K. Plate-like atelectasis at the corticomedullary junction of the lung: CT observation and hypothesis. Radiat Med 1983;1:305–10.
20. Herold CJ, Wetzel RC, Robotham JL, Herold SM, Zerhouni EA. Acute effects of increased intravascular volume and hypoxia on the pulmonary circulation: assessment with high-resolution CT. Radiology 1992;183:655–62.
21. Thurlbeck WM. Chronic airflow obstruction. In: Thurlbeck WM, editor. Pathology of the lung. New York: Thieme MP; 1988. p. 519–75.
22. Izumiyama T, Hida W, Ichinose M, Inoue H, Takishima T, Okazaki T, et al. Small airway involvement in mixed connective tissue disease. Tohoku J Exp Med 1993;170:273–83.
23. Mitchell DM, Spitz PW, Young DY, Bloch DA, McShane DJ, Fries JF. Survival, prognosis, and causes of death in rheumatoid arthritis. Arthritis Rheum 1986;29:706–14.