Sygnatura: © Pol J Radiol, 2008; 73(2): 18-26

Polish Journal of Radiology
www.PolRadiol.com
ORIGINAL ARTICLE

Otrzymano: 2008.01.15
Zaakceptowano: 2008.02.29

High resolution computed tomography in patients with various forms of systemic sclerosis

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The study was financed from a statutory grant of the Medical University of Bialystok No 4-27 560.

Summary

Background: Pulmonary lesions are, besides renal and cardiac complications, one of the main causes of mortality among patients with systemic sclerosis (scleroderma). Pathologic changes in the respiratory system take the form of interstitial fibrosis clinically manifested by progressive exertion dyspnea and abnormalities of respiratory restriction type in functional tests. The aim of the study was systematization of pulmonary lesion symptomatology in conventional chest radiography and high resolution computed tomography (HRCT) in patients with various forms of scleroderma, as well as determination of the frequency and localization of the particular lesion types.

Material/Methods: The study was carried out in a group of 49 patients with systemic sclerosis (47 women and 2 men), who underwent conventional radiography and high resolution computed tomography of the chest.

Results: In patients with systemic sclerosis, HRCT revealed most frequently interstitial changes of ground glass type, as well as linear and reticular opacities, whereas bronchiectasis and honeycombing type lesions were less frequent. Pulmonary lesions were seen with increasing frequency towards the lung base and were localized mainly in the posterior, inferior and peripheral parts of the lungs. Comparison of the patients with limited and diffuse scleroderma demonstrated that the diffuse form is associated with more frequent involvement of the respiratory system and more advanced pulmonary lesions.

Conclusions: The observed characteristics of pulmonary lesions show similarity between interstitial lung disease in the course of systemic sclerosis and nonspecific interstitial pneumonia (NSIP), which supports classification of interstitial lung disease associated with scleroderma as belonging to that group of interstitial inflammations.

Key words: HRCT • systemic sclerosis • scleroderma lung

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Background

Systemic sclerosis (scleroderma) is one of the most serious systemic diseases characterized by progressive fibrosis of the skin and internal organs. Pulmonary lesions are, besides renal and cardiac complications, one of the main causes of mortality among patients with systemic sclerosis. Involvement of the respiratory system is observed in 70-100% of patients with scleroderma, and mortality in this group during 5-year period reaches 50-60%. Pathologic changes in the respiratory system take the form of interstitial fibrosis clinically manifested by progressive exertion dyspnea and abnormalities of respiratory restriction type in functional tests.

Table 1. Demographic and clinical characteristics in the group of patients with systemic sclerosis.

Demographic data	
Age (years)	50.8±13.0 (22-76%)
Sex (F/M)	47/2 (95.92%/4.08%)
Disease dyration (years)	7.05±5.6 (1-25%)
Clinical respiratory symptoms	
Subjective symptoms (Y/N)	31/18 (63.27%/36.73%)
Objective symptoms (Y/N)	26/23 (53.06%/46.94%)
Extrapulmonary involvement	
Muscular system (Y/N)	13/46 (6.12%/93.88%)
Gastrointestinal tract (Y/N)	40/9 (81.63%/18.37%)
Pulmonary hypertension (Y/N)	26/23 (53.06%/46.94%)
Accessory investigations of the respiratory system	
Spirometric abnormalities (n)	23/26 (46.93%/53.06%)
Abnormalities in BALF (n)	35/14 (71.43%/28.57%)
Immunological tests	
anti-Scl 70 (n)	24/25 (48.98%/51.02%)
ACA (n)	7/42 (14.29%/85.71%)
ANA (n)	49/49 (100%/100%)
Imaging results	
Radiographic abnormalities (n)	25/24 (51.02%/48.98%)
Ground glass (n)	5/44 (10.20%/89.80%)
Nodules (n)	15/34 (30.61%/69.39%)
Pleural effusion (n)	1/48 (2.04%/97.96%)
Honeycombing (n)	21/28 (42.86%/57.14%)
HRCT abnormalities (n)	42/7 (85.71%/14.29%)
Ground glass (n)	38/11 (77.55%/22.45%)
Linear and reticular (n)	37/12 (75.51%/24.49%)
Nodules (n)	20/29 (40.82%/59.18%)
Subpleural nodules (n)	14/35 (28.57%/71.43%)
Consolidations (n)	13/36 (26.53%/73.47%)
Pleural thickening (n)	21/28 (42.86%/57.14%)
Pleural effusion (n)	1/48 (2.04%/97.96%)
Lymph node enlargement (n)	16/33 (32.65%/67.35%)
Bronchectasis (n)	30/19 (61.22%/38.78%)
Honeycombing (n)	23/26 (46.94%/53.06%)

BALF – bronchoalveolar lavage fluid, anti-Scl 70 – anti-topoisomerase I antibodies, ACA – anti centromer antibodies, ANA – anti nuclear antibodies, HRCT – high resolution computed tomography, Y/N – yes/no, F/M – females/males.

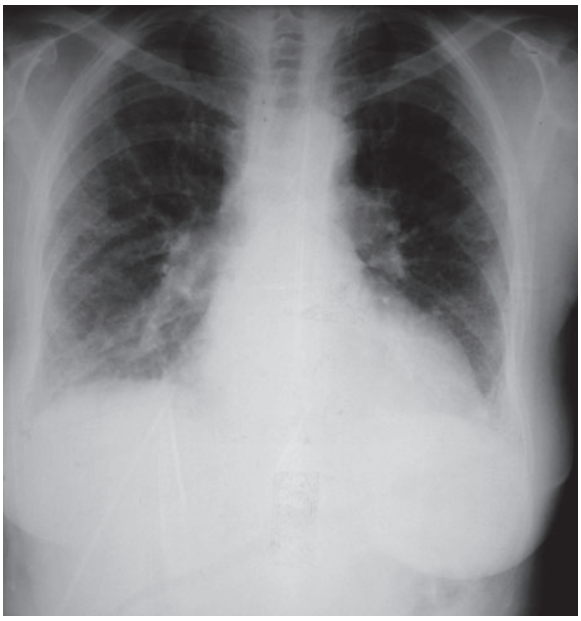

Figure 1. Conventional radiography – Honeycombing type lesions in the lower pulmonary fields, ground glass zones in the central part of the right lung.

Because of high incidence and progressive, often very dynamic, character, interstitial lung disease is an important clinical problem in the group of patients with systemic sclerosis, and early diagnostics is critical, taking into consideration the possibility of treatment for pulmonary pathology. Computed tomography utilizing the high resolution algorithm (HRCT) is currently the basic method in diagnostics, assessment of progression and treatment monitoring in interstitial lung diseases. The aim of the study was systematization of pulmonary lesion symptomatology in conventional radiography and high resolution computed tomography (HRCT) in patients with various forms of scleroderma, as well as determination of the frequency and localization of the particular lesion types. The study was also an attempt to determine the diagnostic potential of conventional radiography and HRCT in assessment of advanced pulmonary lesions.

Materials and methods

Material

The study was carried out in a group of 49 patients with systemic sclerosis (47 women and 2 men), aged 22 – 76 years (mean age: 50.8 ± 13 years). All the patients met the preliminary qualification criteria for systemic sclerosis developed by the American College of Rheumatology (ACR) in 1981 [1]. The study group was divided into 2 subgroups – patients with limited and diffuse forms of scleroderma according to Medsger's classification [2]. The group consisted of 32 patients with limited forms and 17 with diffuse scleroderma.

Methods

Conventional radiography

The patients in the study group underwent plain radiography examinations – chest X-ray in the posteroanterior

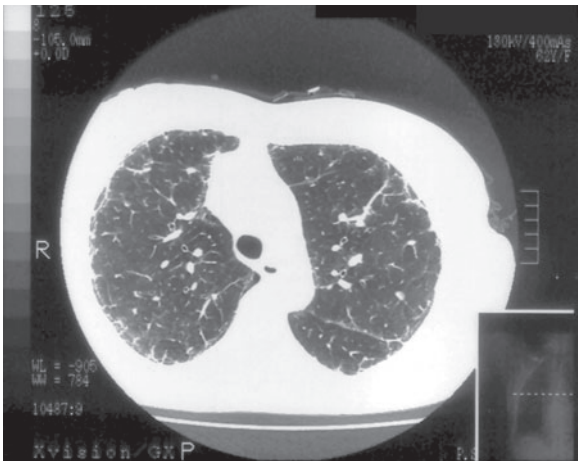

Figure 2. Subpleural linear opacities in HRCT.

and lateral projections, with the following parameters of the unit: voltage - 120 kVp, exposure time – 0.1 s, distance from the examined object – 200 cm.

High resolution computed tomography

HRCT was performed with a Toshiba Xvision GX unit (Toshiba Medical Systems, Japan), with a slice thickness of 2 mm and a slice spacing 10 mm, scanning the area from the lung apexes to the diaphragm. Scans were performed at full inspiration, in the supine position and at the following exposure parameters: lamp voltage 133 kV, lamp current intensity range from 70 to 120 mA, exposure time 2 s, reconstruction matrix 512 x 512 pixels; bone algorithm for reconstruction.

In 15 out of 49 patients, HRCT was additionally performed in prone position, for detailed assessment of ground glass type lesions and exclusion of increased blood flow due to gravity effect [3]. The obtained views were assessed at the following image parameters: Pulmonary window – width 1600 HU and level -600 HU, mediastinal window – width 350 HU and level 50 HU.

Vertical distribution of all lesion types in the lungs was analyzed, taking into consideration the upper, medial and lower fields. Horizontal distribution – in central and peripheral, as well as anterior an posterior fields of both lungs – was also assessed.

Statistical analysis

The obtained results were subjected to statistical analysis, which included calculation of arithmetic means and standard deviations for the measurable characteristics, and of quantitative-percentage distribution for qualitative

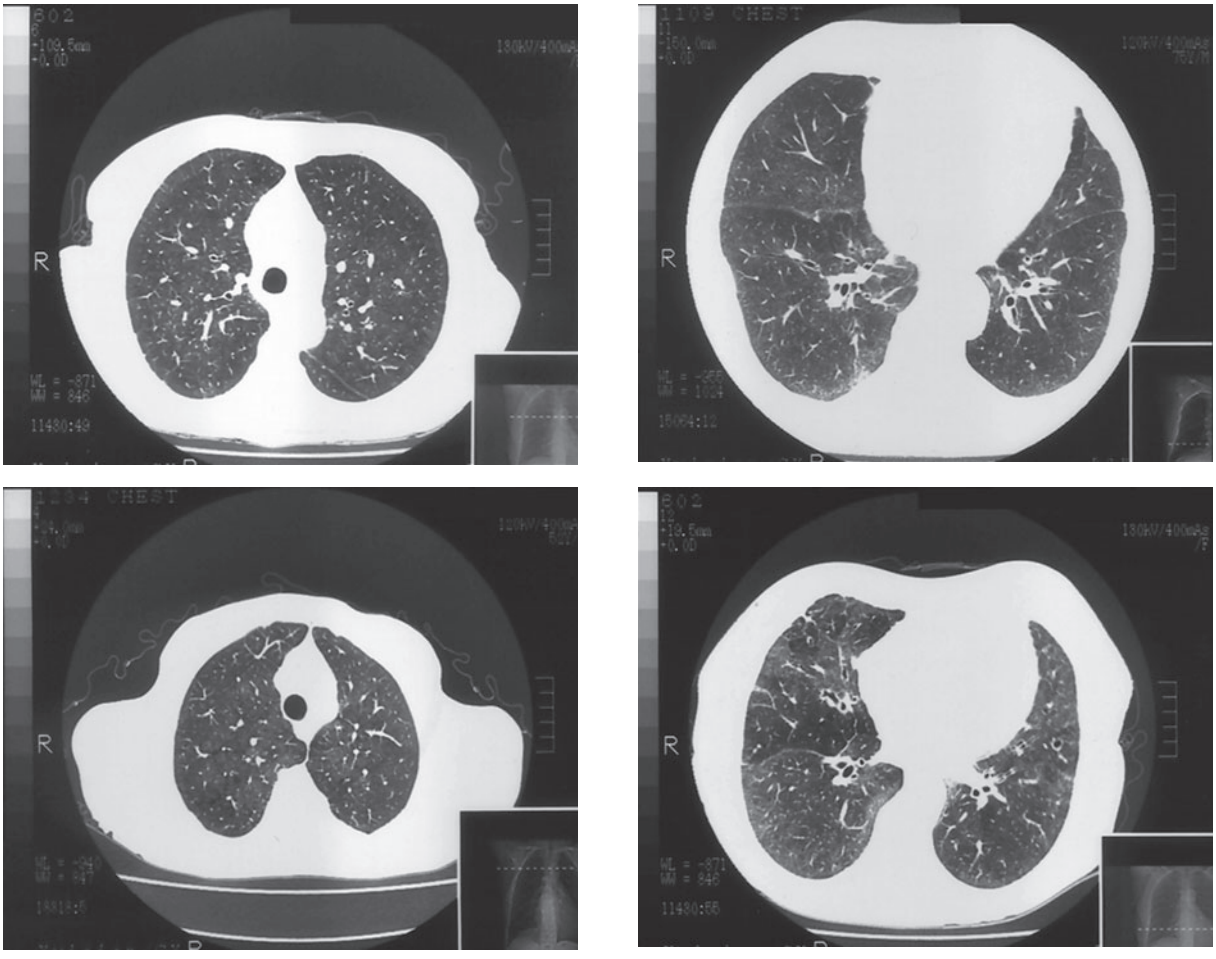

Figure 3. HRCT – ground glass type lesions – central and peripheral; mild in the upper pulmonary fields, more pronounced in the lower fields.

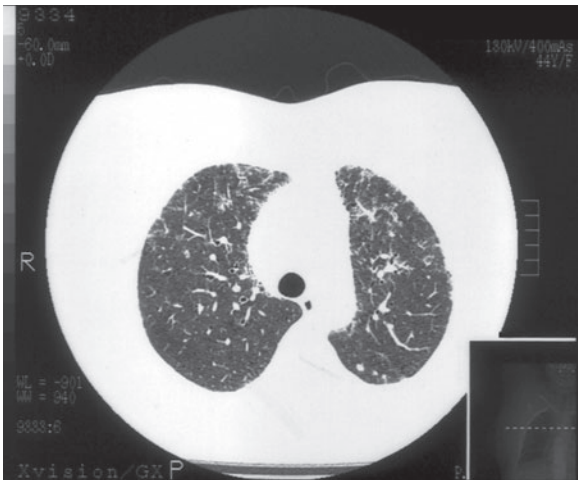

Figure 4. Nodular lesions and subpleural nodules in the upper fields of both lungs in HRCT.

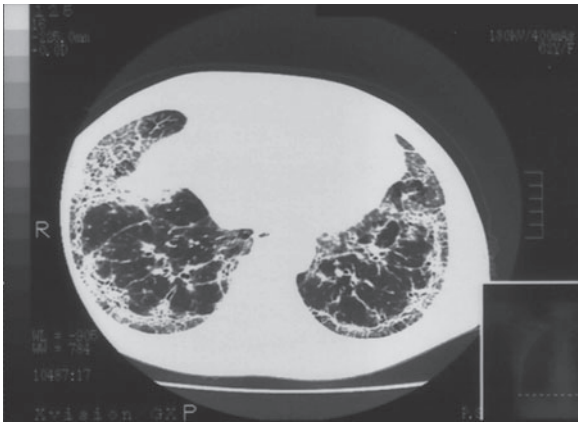

Figure 6. Advanced bronchiectasis with honeycombing in progressive pulmonary scleroderma.

characteristics. Pearson's correlation coefficients were also calculated. Fisher's exact test was used for comparison of qualitative characteristics between groups. The value of $p<0.05$ was regarded as statistical significance level.

Results

Table 1 presents the general characteristics of the studied group of patients. The group consisted of 47 women and 2 men; the mean age of the patients was 50.8±13.0 years, and the mean duration of the disease 7.05±5.6 years. Conventional radiography most frequently revealed the presence of honeycombing type lesions (Fig. 1) and nodules. In HRCT, the most frequent symptoms included: ground glass type abnormalities, linear and reticular opacities (Fig. 2-3). Bronchiectasis, honeycombing areas, pleural thickening and nodules were less frequent (Fig. 4-6). Lymph node enlargement was observed in 38.9% of patients with ground glass type areas and in 52.2% of those with honeycombing type lesions.

Abnormalities in conventional radiograms according to the division of patients into subgroups with restricted and generalized forms of scleroderma are presented in Table 2. Nodular and ground glass type lesions were observed with slightly higher frequency in diffuse scleroderma in comparison with the limited form, but the difference did not reach statistical significance. Also the honeycombing lesion

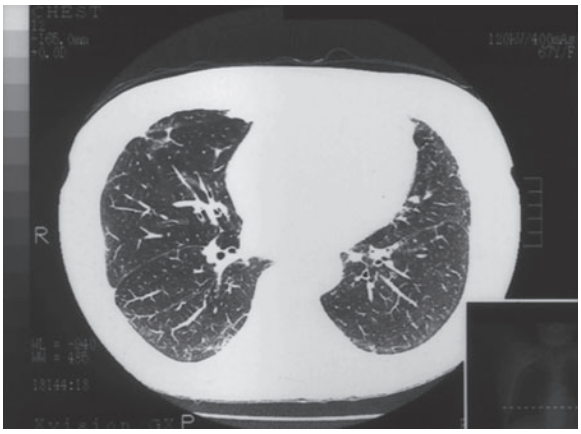

Figure 5. HRCT – single bronchial dilatations in the lower fields of both lungs.

Table 2. Types of abnormalities in conventional radiography in the study group according to the form of the disease.

	Form of the disease		p
	Restricted n=32	Generalized n=17	
Ground glass (n)	3 (9.37%)	2 (11.76%)	p>0.05
Nodules (n)	9 (28.12%)	6 (35.29%)	p>0.05
Pleural effusion (n)	0 (0%)	1 (5.88%)	p>0.05
Honeycombing (n)	12 (37.50%)	9 (52.94%)	p>0.05

Fischer's exact test.

Table 3. Abnormalities in HRCT in the study group according to the form of the disease.

	Form of the disease		p
	Restricted n=32	Generalized n=17	
Ground glass (n)	25 (78.12%)	13 (76.47%)	p>0.05
Linear and reticular (n)	23 (71.87%)	14 (82.35%)	p>0.05
Nodules (n)	12 (37.50%)	8 (47.06%)	p>0.05
Subpleural nodules (n)	8 (25.00%)	6 (35.29%)	p>0.05
Cosolidations (n)	9 (28.12%)	4 (23.53%)	p>0.05
Pleural thickening (n)	12 (37.50%)	9 (52.94%)	p>0.05
Pleural effusion (n)	0 (0%)	1 (5.88%)	p>0.05
Lymph node enlargement (n)	7 (21.87%)	9 (52.94%)	p<0.05
Bronchiectasis (n)	16 (50.00%)	14 (82.35%)	p<0.05
Honeycombing (n)	12 (37.50%)	11 (64.70%)	p>0.05

Pearson's χ^2 test, HRCT – high resolution computed tomography.

Table 4. Vertical distribution of lesions in HRCT in patients with limited scleroderma.

	Right lung			Left lung		
	Upper field	Medial field	Upper field	Medial field	Upper field	Medial field
Ground glass (n)	7	17	21	7	17	21
Linear and reticular (n)	9	14	21	9	15	21
Nodules (n)	6	10	10	5	11	10
Consolidations (n)	3	5	7	1	5	7
Pleural thickening (n)	4	7	12	3	7	10
Subpleural nodules (n)	4	5	3	3	4	3
Bronchiectasis (n)	2	6	15	1	6	15
Honeycombing (n)	1	5	12	2	3	10

HRCT – high resolution computed tomography.

Table 5. Vertical distribution of lesions in HRCT in patients with diffuse scleroderma.

	Right lung			Left lung		
	Upper field	Medial field	Lower field	Upper field	Medial field	Lower field
Ground glass (n)	1	5	11	3	10	12
Linear and reticular (n)	6	13	14	6	12	13
Nodules (n)	4	8	8	3	8	5
Consolidations (n)	1	2	2	0	1	2
Pleural thickening (n)	3	7	9	3	5	8
Subpleural nodules (n)	3	2	2	2	4	1
Bronchiectasis (n)	2	3	13	2	5	14
Honeycombing (n)	0	5	11	3	3	11

HRCT – high resolution computed tomography.

pattern was seen slightly more often in the diffuse scleroderma group, but the difference was not significant statistically.

Table 3 compares the occurrence of pulmonary lesions in HRCT in the groups of patients with diffuse and limited forms of scleroderma. Ground glass areas were observed in both groups with similar frequency. Linear and reticular opacities, consolidations, nodular changes and subpleural nodules were slightly more frequent in patients with diffuse form of the disease, but without statistical significance. However, lymph node enlargement was significantly more frequent in the group with generalized scleroderma. The differences concerning bronchiectasis were also statistically significant.

Vertical distribution of pulmonary lesions in HRCT in patients with limited form of the disease is presented in Table 4. Subpleural nodules are distributed with similar frequency in all the lung fields – upper, medial and lower, whereas the frequency of the remaining lesion types was the lowest in the upper parts and increased progressively towards the lung bases. Similar distribution of changes was observed in the right and the left lung. Also in the diffuse scleroderma group the distribution of lesions was similar. The highest occurrence of lesions was observed in HRCT in the lower fields of both lungs (Table 5).

Figures 7 A, B present horizontal distribution of pulmonary lesions in HRCT in patients with diffuse and limited forms of scleroderma. In patients with the limited form, ground glass areas were slightly more frequent in the peripheral than in central parts of the lungs. Bronchiectasis was localized peripherally and centrally with similar frequency, whereas the remaining lesions were predominantly peripheral. Posterior lung fields were affected more extensively. Similar distribution of lesions was observed in the diffuse scleroderma group, with predominant involvement of the peripheral and posterior areas of the lungs.

Analysis of results and discussion

Conventional radiography in the diagnostics of pulmonary lesions in systemic sclerosis

The diagnostic value of conventional radiography in detection of early pulmonary lesions in patients with systemic sclerosis is controversial. Potente et al. [4] observed no

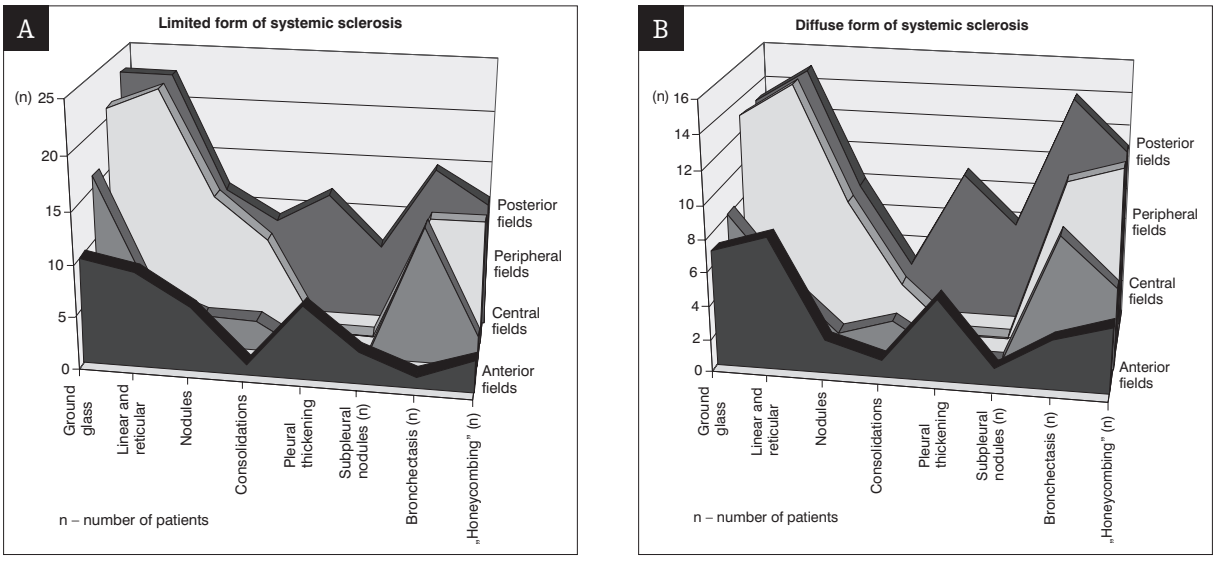

Figure 7 A, B. Horizontal distribution of lesions in HRCT in patients with limited (**A**) and diffuse (**B**) forms of scleroderma.

abnormalities in radiograms of 46% of systemic sclerosis patients. Schurawitzki et al. [5] comparing the diagnostic efficacy of conventional radiograms and HRCT scans in systemic sclerosis, found pulmonary lesions in HRCT in 91% of patients vs. only 39% of cases detected by conventional radiography. Similar results were obtained by Warrick et al. [6], who observed abnormalities in 88% of patients with HRCT and only in 59% with conventional radiography.

According to Strickland et al. [7] , the accuracy of CT in detection of early lung fibrosis in patients with systemic sclerosis is 24% higher than that of conventional radiography. Harrison et al. [8] detected the presence of lesions in HRCT in 44% whose conventional radiograms showed no abnormalities. Low detection of lesions by classic radiography vs. the results of histopathological investigations was confirmed also in many other reports. While pulmonary lesions were visualized by conventional X-ray in 25-44% of patients, the presence of interstitial fibrosis was demonstrated on autopsies even in 74-100% of cases [9].

In own research, changes in conventional chest radiograms were demonstrated with frequency similar to literature data – in 51% of patients, whereas HRCT visualized them in 86% of cases. Thus, our results confirm low value of conventional radiography in the diagnostics of pulmonary lesions associated with systemic sclerosis. In the analyzed group, HRCT revealed in 17 patients (34.7%) various lesion types invisible in conventional radiograms. Classic X-ray revealed ground glass areas only in 51% of cases, whereas HRCT demonstrated their presence in 77.6%. the presence of nodules was also observed significantly more often in HRCT (40.8%), than in X-ray (30.6%). Low value of conventional radiography in comparison with HRCT was also seen in comparison of both methods in scleroderma patients with advanced pulmonary lesions. Honeycombing type lesions were visible in radiograms only in 42.8% of patients vs. 46.9% detected with HRCT.

Low value of conventional radiography result from the fact that radiograms are summary images and contrary to a common belief, their assessment requires considerable experience and accuracy of the observer. The radiologist's experience plays an especially important role in assessment of early, discrete pulmonary abnormalities both in HRCT images and in conventional radiograms. In a study comparing the inter- and intraobserver variability in HRCT and radiography, Collins et al. [10] reported significant differences between experienced and inexperienced independent observers. The study demonstrated also better consistency of diagnoses in case of HRCT than in conventional chest radiography.

High resolution computed tomography in the diagnostics of pulmonary lesions in systemic sclerosis

Characteristics of pulmonary lesions in HRCT imaging

The most frequently described pulmonary abnormalities in HRCT images of patients with systemic sclerosis include linear subpleural opacities – in 74% of cases and honeycombing type lesions – in 30%, as well as band-like interstitial hyperdensity areas observed in 26% of examinations [5]. Seely et al. [11] observed ground glass type lesions in 73% of children with systemic sclerosis, honeycombing in 45%, linear opacities – in 55% and subpleural nodules in 64% of cases. Andonopoulos et al. [12] detected the presence of ground glass areas in 68.2% of patients, signs of fibrosis in 40.9% and bronchiectasis in 59.1%. In the material presented by Italian authors, ground glass sign was seen in 60% of cases, pleural thickening in 56% and linear opacities in 68% [13].

Own material demonstrated the highest frequency of ground glass areas – in 77.55% as well as of linear and reticular opacities – in 75.51%. Bronchiectasis was less frequent – 61.22%, honeycombing type lesions – 46.94% pleural thickening areas – 42.86% and nodules – 40.82%.

Mediastinal lymph node enlargement is observed with varied frequency in the course of interstitial pulmonary diseases. In patients with scleroderma, Warrick et al. [6]

observed lymph node enlargement in 41% of cases, whereas Franquet et al. [14] demonstrated significant differences in the incidence of mediastinal lymph node enlargement dependent on the use of steroid therapy. Own observations demonstrated enlarged lymph nodes in HRCT in 32.65% of cases. Similar frequency of 32% was observed by Garber et al. [15].

The course of interstitial lung disease in patients with systemic sclerosis may also be associeted with development of pulmonary hypertension. Stupi et al. [16] observed pulmonary hypertension in 59 out of 673 patients with systemic sclerosis (9%). The presence of hypertension was associated with significant reduction of gas exchange (DLCO) and was an unfavorable prognostic factor. Young et al. [17] on the basis of autopsies observed moderate or severe abnormalities of the pulmonary arteries in 14 out of 30 assessed cases. In our studies pulmonary hypertension was demonstrated in over a half of the patients 53%, which is consistent with the incidence reported by Young et al. [17]. However, unlike most literature reports, hypertension was observed more frequently in the generalized form of the disease – in 64.7% of patients than in the restricted form – 46.9% [18].

The lesions observed in HRCT images in the course of systemic sclerosis are nonspecific and occur also in other collagenoses. Dawson et al. [19] detected mainly reticular opacities and ground glass type lesions in patients with rheumatoid arthritis (RA). Similar results were reported by Biederer et al. [20], who observed reticular lesions in patients with interstitial lung disease in the course of RA in 75% of cases, and in 30% additionally opaque glass areas. Pulmonary lesions in early ankylosing spondylitis presented most frequently as subpleural nodules and linear opacities [21]. In a study comparing the incidence of the particular symptoms in various collagenoses, Saito et al. [22] observed variable and nonspecific HRCT images. The most common ones includes linear septal thickening, honeycombing or ground glass type lesions. Also Lim et al. [23] reported overlapping of many HRCT symptoms – such as honeycombing or ground glass type lesions and lymph node enlargement in the course of IPF and other interstitial lung diseases.

The group analyzed in our study included only patients with systemic sclerosis. Therefore, direct comparison of the observed symptoms with those of other interstitial pulmonary diseases and differentiation based on own material is impossible. However, similar incidences of the particular types of pulmonary lesions in the examined group of patients indicate that the symptoms observed in systemic sclerosis are nonspecific. Thus, it seems that HRCT does not allow an unequivocal diagnosis of the type of systemic disease. A similar opinion was expressed by Saito et al. [22], who consider differentiation of systemic disease types on the basis of HRCT only to be impossible because of high variability of symptoms observed in connective tissue diseases.

It is assumed that in HRCT the signs most characteristic of interstitial lung disease associated with scleroderma include ground glass type areas as well as linear and reticular opacities, whereas honeycombing type changes are less pronounced. Such observations are based on HRCT verified by biopsies [24]. This was also confirmed by a study of English authors, comparing the groups of patients with systemic sclerosis, idiopathic pulmonary fibrosis (IPF) and nonspecific interstitial pneumonia (NSIP) [25]. In this study, similar severity of fibrosis was observed in the course of systemic sclerosis and NSIP; patients with IPF demonstrated most pronounced fibrous lesions of honeycombing type. The extent of ground glass areas was similar in patients with scleroderma and NSIP, whereas it was smaller in the IPF group. The authors of the cited paper emphasize similarities between interstitial lung disease associated with scleroderma and with NSIP. Also in own research ground glass type zones, linear and reticular changes belonged to the most frequent signs, whereas honeycombing patterns were much less frequent. Thus, it seems that the obtained results constitute a significant argument supporting inclusion of scleroderma-related interstitial lung disease in the group of non-specific interstitial inflammations.

Localization of pulmonary lesions in HRCT

Besides the character of lesions found in imaging studies, their distribution in the pulmonary parenchyma is important. In a study by Schurawitzki et al. [5], linear opacities were found most frequently in peripheral areas of the lungs in scleroderma patients. Such location is confirmed by observations of Bergin et al. [26]. Honeycombing type lesions were localized peripherally in 70% of patients, but in 30% they were observed both in central and peripheral parts of the lungs [5]. Cozzi et al. [13] observed most frequent involvement of the posterobasal lung segments. Strickland et al. [7] observed the presence of changes mainly in the medial and lower lung fields, but they also mention their presence in the anterior parts of the upper segments.

On analysis of distribution of the lesions shown by HRCT based on own material, involvement of the upper lung fields was the least frequent, whereas the occurrence of abnormalities increased progressively towards the lung bases. Only the distribution of subpleural nodules was similar in all lung fields. Most lesions were localized predominantly in the peripheral areas, only bronchiectasis was found centrally and peripherally with similar frequency. The lesions were more frequent in the posterior segments of the lungs. The pattern of lesion distribution is consistent with the results of Remy-Jardin et al. [27], who emphasize that in systemic sclerosis mainly the posterior, inferior and peripheral parts of the lungs are affected.

Pulmonary lesions in various forms of systemic sclerosis

The correlation between respiratory system involvement and the presence of lesions in other organs and systems is a problem mentioned frequently in the literature. Steen et al. [28] in a study carried out in a group of 890 patients with systemic sclerosis did not observe any correlation between the severity of pulmonary lesions and the form of the disease (diffuse/limited). The above observation was also confirmed by Kane et al. [29], who concluded that the

extent of skin lesions does not correlate significantly with the presence of pulmonary changes. Different results were obtained by Tashkin et al. [30], who observed that progression of pulmonary lesions correlates significantly with the extent of skin lesions and involvement of the upper gastrointestinal tract.

In own research, more significant progression of pulmonary lesions was observed in patients with the diffuse form of scleroderma. The changes were visualized more frequently both by classic radiography and by HRCT, but no statistical significance was reached. Ground glass type areas were seen with similar frequency in both forms of scleroderma, whereas linear and reticular opacities, consolidations and nodular lesions were found slightly more often in patients with diffuse form of the disease, but the difference did not reach statistical significance level. The signs differentiating the two forms of scleroderma were pleural thickening and honeycombing type lesions, significantly more frequent in patients with diffuse scleroderma. Patients with diffuse disease demonstrated also higher frequency of lymph node enlargement and bronchiectasis. However, no significant differences in either horizontal or vertical distribution of the lesions between patients with various forms of scleroderma were found.

Some authors report more pronounced progression of pulmonary lesions in diffuse scleroderma. In this group of patients, abnormalities in the lungs were observed more frequently in conventional radiograms [29]. In another study, normal HRCT findings were obtained only in 14% of patients with diffuse systemic sclerosis, whereas in the group with restricted form of the disease normal results were obtained in 43% of cases [31]. In the diffuse form, honeycombing areas were observed more frequently, whereas the frequencies of ground glass type lesions were similar – 14% and 15%, respectively. These observations have been confirmed by own research. The results indicate, that the fibrosis processes are more intensive in patients with diffuse form of scleroderma.

Conclusions

1. Interstitial changes of ground glass type, as well as linear and reticular opacities are most common in patients with systemic sclerosis, whereas bronchiectasis and honeycombing type lesions are less frequent, which supports classification of interstitial lung disease associated with scleroderma as belonging to the group of nonspecific interstitial pneumonias (NSIP).
2. Pulmonary lesions occur with increasing frequency towards the lung base and are localized mainly in the posterior, inferior and peripheral parts of the lungs.
3. The generalized form of scleroderma, in comparison with the restricted forms, is associated with more frequent involvement of the respiratory system and more advanced pulmonary lesions.
4. The study confirms low value of conventional radiography in the diagnostics of pulmonary lesions in the course of systemic sclerosis.

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