



Monaldi Archives for Chest Disease

eISSN 2532-5264

<https://www.monaldi-archives.org/>

Publisher's Disclaimer. E-publishing ahead of print is increasingly important for the rapid dissemination of science. The **Early Access** service lets users access peer-reviewed articles well before print / regular issue publication, significantly reducing the time it takes for critical findings to reach the research community.

These articles are searchable and citable by their DOI (Digital Object Identifier).

The **Monaldi Archives for Chest Disease** is, therefore, e-publishing PDF files of an early version of manuscripts that have undergone a regular peer review and have been accepted for publication, but have not been through the typesetting, pagination and proofreading processes, which may lead to differences between this version and the final one.

The final version of the manuscript will then appear in a regular issue of the journal.

E-publishing of this PDF file has been approved by the authors.

All legal disclaimers applicable to the journal apply to this production process as well.

Monaldi Arch Chest Dis 2026 [Online ahead of print]

To cite this Article:

Barman B, Sathees V, Bhattacharya PK, et al. **High-resolution computed tomography imaging of pulmonary changes and relation with disease activity in rheumatoid arthritis.** *Monaldi Arch Chest Dis* doi: 10.4081/monaldi.2026.3869

Submitted: 26-12-2025

Accepted: 14-10-2026



©The Author(s), 2026
Licensee [PAGEPress](#), Italy

Note: The publisher is not responsible for the content or functionality of any supporting information supplied by the authors. Any queries should be directed to the corresponding author for the article.

All claims expressed in this article are solely those of the authors and do not necessarily represent those of their affiliated organizations, or those of the publisher, the editors and the reviewers. Any product that may be evaluated in this article or claim that may be made by its manufacturer is not guaranteed or endorsed by the publisher.

High-resolution computed tomography imaging of pulmonary changes and relation with disease activity in rheumatoid arthritis

Bhupen Barman,¹ Varsha Sathees,² Prasanta Kumar Bhattacharya,² K G Lynrah,²
Kalyan Sarman,¹ Anomitro Chakrabarty,² Jayanta Das¹

¹All India Institute of Medical Sciences, Guwahati; ²North Eastern Indira Gandhi Regional Institute of Health and Medical Sciences, Shillong, India

Correspondence: Bhupen Barman, All India Institute of Medical Sciences, Guwahati, India.
E-mail: drbhupenb@gmail.com

Contributions: Varsha Sathees: data collection, investigation, and writing of the original manuscript draft. Bhupen Barman: conceptualization, study design, supervision, and critical review and editing of the manuscript. Prasanta Kumar Bhattacharya: critical revision of the manuscript and final approval of the version to be published. K. G. Lynrah: critical review, revision, and editing of the manuscript. Kalyan Sarma: Radiological image collection, image review, and manuscript editing. Anomitro Chakrabarty: Radiological image collection, analysis and interpretation of imaging findings, and contribution to results analysis. Jayanta Das: statistical analysis, interpretation of results, and critical review and editing of the manuscript. All authors reviewed and approved the final version of the manuscript and agree to be accountable for their respective contributions to the work.

Conflict of interest: the authors declare that they have no conflicts of interest relevant to this study.

Ethics approval and consent to participate: the study was approved by the Institute Ethics Committee (Human Studies), North Eastern Indira Gandhi Regional Institute of Health and Medical Sciences (NEIGRIHMS), Shillong, India (Approval No. NEIGR/IEC/M11/P13/21). Written informed consent was obtained from all participants before enrolment in the study. The study was conducted in accordance with the principles of the Declaration of Helsinki and the ethical guidelines of the Indian Council of Medical Research (ICMR).

Informed consent: written informed consent was obtained from all participants before their inclusion in the study.

Patient consent for publication: all clinical and radiological data were anonymized to protect patient confidentiality. Written informed consent for publication of anonymized radiological images was obtained from the relevant participants.

Availability of data and materials: the datasets generated and analysed during the current study are available from the corresponding author upon reasonable request, subject to institutional ethical and data-sharing regulations.

Funding: the authors received no specific funding for this research from any funding agency in the public, commercial, or not-for-profit sectors.

Declaration of generative artificial intelligence and artificial intelligence-assisted technologies in the writing process: during revision of this manuscript, the authors used ChatGPT (OpenAI; GPT-5.6 Sol) for language editing, grammatical refinement, organization of the manuscript and assistance in checking the statistical presentation. All analyses, interpretations and AI-assisted text were reviewed and verified by the authors, who take full responsibility for the final manuscript. The AI tool was not used to generate or fabricate study data.

Abstract

Rheumatoid arthritis (RA) is a chronic systemic inflammatory disease with a wide spectrum of pulmonary manifestations, some of which may remain clinically occult. High-resolution computed tomography (HRCT) is an important imaging modality for detecting and characterizing these abnormalities. This study aimed to evaluate the spectrum of thoracic HRCT abnormalities in patients with RA and examine their association with disease activity and inflammatory markers. A prospective, analytical, hospital-based cross-sectional study was conducted from January 2021 to January 2022, including 63 adults with RA fulfilling the 2010 American College of Rheumatology/European Alliance of Associations for Rheumatology classification criteria. Clinical characteristics, disease activity assessed using the Disease Activity Score 28-erythrocyte sedimentation rate (DAS28-ESR), inflammatory markers, and thoracic HRCT findings were recorded and analyzed. Of the 63 patients, 45 (71.4%) were women, and the mean age was 45.3 ± 13.4 years. HRCT abnormalities were detected in 36 (57.1%) patients, with usual interstitial pneumonia-pattern interstitial lung disease (22.2%) and ground-glass opacities (19.0%) being the most frequent findings. Patients with abnormal HRCT findings had significantly higher DAS28-ESR scores, elevated erythrocyte sedimentation rates, and longer disease duration compared with those with normal HRCT findings (all $p < 0.001$). C-reactive protein positivity ($p < 0.001$) and anti-cyclic citrullinated peptide antibody positivity ($p = 0.012$) were also significantly associated with HRCT abnormalities, whereas age and sex showed no significant associations. Pulmonary abnormalities detected by HRCT were common in patients with RA and were associated with greater disease activity, systemic inflammation, and longer disease duration. These findings highlight the importance of respiratory assessment in patients with RA, particularly those with active disease.

Key words: rheumatoid arthritis, interstitial lung disease, HRCT imaging, disease activity assessment.

Introduction

Rheumatoid arthritis (RA) is a chronic systemic inflammatory disorder affecting approximately 0.75% of the adult Indian population [1]. It is more common in women than in men, and although articular disease is its principal manifestation, RA is also associated with a broad spectrum of extra-articular manifestations [2,3].

Pulmonary involvement is an important extra-articular manifestation of RA and may affect the lung parenchyma, pleura, airways and pulmonary vasculature. Reported manifestations include interstitial lung disease (ILD), pulmonary nodules, pleuritis and pleural effusion, bronchiolitis, bronchiectasis and pulmonary hypertension [4,5]. These complications contribute substantially to morbidity and mortality in patients with RA.

High-resolution computed tomography (HRCT) is more sensitive than conventional chest radiography for detecting and characterizing pulmonary abnormalities in RA [6-10]. HRCT can demonstrate interstitial patterns, including usual interstitial pneumonia (UIP) and nonspecific interstitial pneumonia (NSIP), as well as airway, pleural and nodular abnormalities. Characterization of these changes may be particularly relevant in patients with active systemic inflammation or respiratory symptoms.

Data on HRCT-defined pulmonary abnormalities in patients with RA from Northeast India remain limited. The present study therefore aimed to describe the spectrum of thoracic HRCT findings in adults with RA attending a tertiary-care hospital in Northeast India and to examine the association of HRCT abnormalities with disease activity and inflammatory markers.

Materials and Methods

This prospective, analytical, hospital-based cross-sectional study was conducted in the Department of General Medicine, North Eastern Indira Gandhi Regional Institute of Health and Medical Sciences (NEIGRIHMS), Shillong, from January 2021 to January 2022. Adult patients (aged ≥ 18 years) with a clinical diagnosis of rheumatoid arthritis (RA) who additionally fulfilled the 2010 American College of Rheumatology/European Alliance of Associations for Rheumatology (ACR/EULAR) classification criteria [11] were recruited consecutively. Patients diagnosed with RA at the index study assessment were categorized as newly diagnosed; those with an established diagnosis before enrolment were categorized as previously diagnosed. Patients were excluded if they were current or former smokers or had pre-existing cardiovascular abnormalities or prior respiratory disease as specified in the study

protocol.

RA was diagnosed clinically by the treating physician on the basis of history, clinical examination, laboratory findings and available imaging, and eligibility additionally required fulfilment of the 2010 ACR/EULAR classification criteria. At study assessment, sociodemographic and clinical information was recorded, disease activity was assessed using DAS28-ESR, and ESR, CRP, anti-cyclic citrullinated peptide (anti-CCP) antibodies and other haematological parameters were recorded. All patients underwent clinical evaluation by the principal investigator at the time of recruitment, including assessment of tender and swollen joint counts involving 28 joints for calculation of the DAS28-ESR score. All laboratory investigations, including ESR and CRP, were performed in the same institutional laboratory. Clinical assessment, blood sampling, and HRCT of the thorax were performed on the same day for each participant to ensure temporal consistency between clinical, biochemical, and radiological assessments.

All participants underwent HRCT of the thorax. Images were assessed for ILD, ground-glass opacities, pneumonitis, pulmonary nodules, bronchiolitis, bronchiectasis, pulmonary arterial enlargement and other thoracic abnormalities. UIP-pattern ILD was recorded separately from isolated ground-glass opacity. Isolated ground-glass opacity was not retrospectively relabelled as NSIP because the available study dataset did not contain sufficient imaging descriptors to establish an NSIP pattern. HRCT of the thorax was performed using a 128-slice multidetector CT scanner (SOMATOM Definition AS+, Siemens Healthineers, Germany) in helical acquisition mode, covering the thorax from the lung apices to the lung bases. All examinations were performed with patients in the supine position. Images were transferred to a Syngo.via workstation (Siemens Healthineers) and evaluated using lung, mediastinal, and bone window settings.

HRCT images were evaluated in the presence of a senior radiologist with at least 10 years of experience in thoracic imaging. Pulmonary abnormalities were described using the standardized thoracic imaging terminology recommended by the Fleischner Society. The radiological findings assessed included ILD, ground-glass opacities, pulmonary nodules, pneumonitis, bronchiolitis, bronchiectasis, pulmonary arterial enlargement, and other thoracic abnormalities. The imaging findings were subsequently evaluated for their association with RA disease activity and inflammatory markers.

Data were entered into Microsoft Excel and analysed using IBM SPSS Statistics for Windows, Version 28.0 (IBM Corp., Armonk, NY, USA). Categorical variables were expressed as

frequencies and percentages, while continuous variables were presented as mean $\pm$ standard deviation (SD) for normally distributed data or median with interquartile range (IQR) for non-normally distributed data.

The chi-square test was used to examine associations between categorical variables, including HRCT abnormalities and categories of RA disease activity. Fisher's exact test was applied where expected cell frequencies were insufficient for the chi-square test.

Pearson's correlation coefficient was used to assess linear relationships between continuous variables, particularly RA disease activity scores (DAS28-ESR and DAS28-CRP), disease duration, and quantitative radiological parameters, where applicable. Spearman's rank correlation was considered for variables that did not satisfy the assumptions of Pearson's correlation.

Linear regression analysis was performed to examine the relationship between continuous measures of RA disease activity and relevant quantitative HRCT outcomes, where applicable. The dependent variable was the quantitative radiological outcome, while disease activity scores and other clinically relevant variables were considered independent variables. Regression coefficients, 95% confidence intervals, and p-values were reported as appropriate. All statistical tests were two-sided, and a p-value < 0.05 was considered statistically significant.

The study was approved by the Institute Ethics Committee (Human Studies), NEIGRIHMS, Shillong (reference number NEIGR/IEC/M11/P13/21). All participants provided written informed consent in English, Hindi, or Assamese. The study was conducted in accordance with the Declaration of Helsinki and the ethical guidelines of the Indian Council of Medical Research.

Result

A total of 63 patients with RA were included; 45 (71.4%) were women and 18 (28.6%) were men. The mean age was 45.3 (SD 13.4) years (range 18-79 years). Twenty-nine (46.0%) were newly diagnosed at the index assessment and 34 (54.0%) had a pre-existing diagnosis of RA; among previously diagnosed patients, recorded disease duration ranged from 1 to 10 years. Anti-CCP antibodies were positive in 44 (69.8%) patients. Hand radiographs showed deformity in 27 (42.9%) and foot radiographs in 9 (14.3%). Rheumatoid factor status and a formal anatomical/radiographic stage were not available in the master dataset and therefore could not be reported. Baseline characteristics are summarized in Table 1.

HRCT was normal in 27 (42.9%) patients and showed at least one abnormality in 36 (57.1%). The most frequent abnormalities were UIP-pattern ILD in 14 (22.2%) patients and ground-glass opacities in 12 (19.0%), followed by sub-centimetric pulmonary nodules in 4 (6.3%), bronchiolitis in 3 (4.8%), pulmonary arterial hypertension in 2 (3.2%), pulmonary tuberculosis in 2 (3.2%), and pneumonitis and bronchiectasis in 1 (1.6%) patient each. Cardiomegaly was recorded in 3 (4.8%) patients. Some patients had more than one abnormality; therefore, individual findings are not mutually exclusive (Table 2; Figure 1). Patients with abnormal HRCT had higher DAS28-ESR values than those with normal HRCT (mean 4.00 [SD 0.43] vs 2.63 [SD 0.39]; $p<0.001$) and higher ESR values (101.0 [SD 22.3] vs 36.4 [SD 17.5] mm/h; $p<0.001$). Disease duration was also longer in the abnormal-HRCT group (mean 3.56 [SD 3.26] vs 0.59 [SD 1.39] years; $p<0.001$). CRP was positive in 35/36 (97.2%) patients with abnormal HRCT compared with 2/27 (7.4%) with normal HRCT (Fisher's exact $p<0.001$). Anti-CCP positivity was more frequent in the abnormal-HRCT group (30/36, 83.3%) than in the normal-HRCT group (14/27, 51.9%; $p=0.012$). Age ($p=0.203$) and sex ($p=0.576$) were not significantly associated with HRCT abnormality. In univariable logistic regression, longer disease duration was associated with abnormal HRCT (OR 1.79 per year; 95% CI 1.25-2.57; $p=0.001$), as were higher DAS28-ESR (OR 70.52 per 1-unit increase; 95% CI 11.18-444.60; $p<0.001$) and higher ESR (OR 1.09 per 1-mm/h increase; 95% CI 1.05-1.13; $p<0.001$).

Discussion

In this prospective cross-sectional study of 63 adults with RA, 36 (57.1%) had at least one abnormality on HRCT. UIP-pattern ILD was the most frequent specific finding (22.2%), followed by ground-glass opacities (19.0%). Other abnormalities included pulmonary nodules, bronchiolitis, pulmonary arterial hypertension, pneumonitis and bronchiectasis. These findings demonstrate the heterogeneous thoracic involvement that may accompany RA and are broadly consistent with previous studies reporting ILD as an important pulmonary manifestation of the disease [12-15].

Abnormal HRCT findings were associated with higher DAS28-ESR, higher ESR, CRP positivity, anti-CCP positivity and longer disease duration, whereas age and sex were not significantly associated with HRCT abnormality in this cohort. The association with inflammatory activity is consistent with previous reports examining clinical and laboratory correlates of RA-associated pulmonary involvement [16-19]. However, the magnitude of the

associations in the present dataset was unusually large, with substantial separation of inflammatory markers between patients with normal and abnormal HRCT. These estimates should therefore be interpreted cautiously, particularly given the small sample size and cross-sectional design. The findings demonstrate association rather than prediction and cannot establish whether active RA preceded or caused the pulmonary abnormalities. Ground-glass opacity was retained as a descriptive HRCT finding rather than classified as NSIP because the available dataset did not contain the full radiological features required for retrospective pattern assignment.

Limitation:

This study has several limitations. It was conducted at a single centre and included a relatively small sample, which limits generalisability and the precision of effect estimates. The cross-sectional design prevents assessment of temporal relationships, progression of pulmonary abnormalities or causal inference. Sparse cells and marked separation of disease-activity and inflammatory variables between the normal and abnormal HRCT groups limited reliable multivariable modelling.

Conclusions

In this single-centre cross-sectional study from Northeast India, HRCT abnormalities were present in more than half of adults with RA, with UIP-pattern ILD and ground-glass opacities being the most frequent findings. Abnormal HRCT was associated with greater disease activity, higher inflammatory markers and longer disease duration. These results support careful respiratory evaluation in patients with RA, particularly in those with active disease or other clinical features suggesting pulmonary involvement. Larger prospective studies with standardized HRCT interpretation and pulmonary function assessment are required to determine temporal relationships and the clinical value of targeted HRCT screening.

References

1. Malaviya AN, Kapoor SK, Singh RR, et al. Prevalence of rheumatoid arthritis in the adult Indian population. *Rheumatol Int* 1993;13:131-4.
2. Venetsanopoulou AI, Alamanos Y, Voulgari PV, Drosos AA. Epidemiology and Risk Factors for Rheumatoid Arthritis Development. *Mediterr J Rheumatol* 2023;34:404-13.

3. Turesson C, O'Fallon WM, Crowson CS, et al. Occurrence of extraarticular disease manifestations is associated with excess mortality in a community based cohort of patients with rheumatoid arthritis. *J Rheumatol* 2002;29:62-7.
4. Youssef AA, Machaly SA, El-Dosoky ME, El-Maghraby NM. Respiratory symptoms in rheumatoid arthritis: relation to pulmonary abnormalities detected by high-resolution CT and pulmonary functional testing. *Rheumatol Int* 2012;32:1985-95.
5. Li L, Gao S, Fu Q, et al. A preliminary study of lung abnormalities on HRCT in patients of rheumatoid arthritis-associated interstitial lung disease with progressive fibrosis. *Clin Rheumatol* 2019;38:3169-78.
6. Yin Y, Liang D, Zhao L, et al. Anti-cyclic citrullinated peptide antibody is associated with interstitial lung disease in patients with rheumatoid arthritis. *PLoS One* 2014;9:e92449.
7. Rocha-Muñoz AD, Ponce-Guarneros M, et al. Anti-cyclic citrullinated peptide antibodies and severity of interstitial lung disease in women with rheumatoid arthritis. *J Immunol Res* 2015;2015:151626.
8. Kelly CA, Saravanan V, Nisar M, et al. Rheumatoid arthritis-related interstitial lung disease: associations, prognostic factors and physiological and radiological characteristics--a large multicentre UK study. *Rheumatology* 2014;53:1676-82.
9. Collins RL, Turner RA, Johnson AM, et al. Obstructive pulmonary disease in rheumatoid arthritis. *Arthritis Rheum* 1976;19:623-8.
10. Esposito AJ, Chu SG, Madan R, et al. Thoracic manifestations of rheumatoid arthritis. *Clin Chest Med* 2019;40:545-60.
11. Aletaha D, Neogi T, Silman AJ, et al. 2010 rheumatoid arthritis classification criteria: an American College of Rheumatology/European League Against Rheumatism collaborative initiative. *Ann Rheum Dis* 2010;69:1580-8. Erratum in: *Ann Rheum Dis* 2010;69:1892.
12. Zou YQ, Li YS, Ding XN, Ying ZH. The clinical significance of HRCT in evaluation of patients with rheumatoid arthritis-associated interstitial lung disease: a report from China. *Rheumatol Int* 2012;32:669-73.
13. Sabri YY, Taymour AT, Shaban MM, Kamel SF. The role of HRCT in evaluation of thoracic manifestations of rheumatoid arthritis. *Egypt J Chest Dis Tuberc* 2016;1:319-23.

14. Habib HM, Eisa AA, Arafat WR, Marie MA. Pulmonary involvement in early rheumatoid arthritis patients. *Clin Rheumatol* 2011;30:217-21.
15. Gabbay E, Tarala R, Will R, et al. Interstitial lung disease in recent onset rheumatoid arthritis. *Am J Respir Crit Care Med* 1997;156:528-35.
16. Banik S, Tapadar SR, Ray A, Chaudhuri AD. A study of pulmonary manifestations of Rheumatoid Arthritis. *J Clin Diagnostic Res* 2018;12:5-9.
17. Paulin F, Doyle TJ, Mercado JF, et al. Development of a risk indicator score for the identification of interstitial lung disease in patients with rheumatoid arthritis. *Reumatol Clin* 2021;17:207-211. [Article in English, Spanish].
18. Samy N, Salah H, Hammoda RM. Rheumatoid arthritis patients with interstitial lung disease: Clinical, radiological and laboratory characteristics. *Egypt Rheumatol* 2021;43:29-34.
19. Qin Y, Wang Y, Meng F, et al. Identification of biomarkers by machine learning classifiers to assist diagnose rheumatoid arthritis-associated interstitial lung disease. *Arthritis Res Ther* 2022;24:115.

Table 1. Baseline characteristics of patients with rheumatoid arthritis (n=63).

Characteristic	n (%) or mean (SD)
Women	45 (71.4%)
Men	18 (28.6%)
Age, years	45.3 (13.4)
Newly diagnosed RA	29 (46.0%)
Previously diagnosed RA	34 (54.0%)
Anti-CCP positive	44 (69.8%)
Hand radiograph deformity	27 (42.9%)
Foot radiograph deformity	9 (14.3%)
DAS28-ESR	3.41 (0.79)
CRP positive	37 (58.7%)

anti-CCP, anti-cyclic citrullinated peptide; CRP, C-reactive protein; DAS28-ESR, Disease Activity Score in 28 joints based on erythrocyte sedimentation rate; RA, rheumatoid arthritis; SD, standard deviation.

Table 2. HRCT thoracic findings in patients with rheumatoid arthritis (n=63).

Finding	n	% of cohort (n=63)
Normal HRCT	27	42.9
Any abnormal HRCT*	36	57.1
UIP-pattern ILD	14	22.2
Ground-glass opacities	12	19.0
Sub-centimetric pulmonary nodules	4	6.3
Bronchiolitis	3	4.8
Pulmonary arterial hypertension	2	3.2
Pulmonary tuberculosis	2	3.2
Pneumonitis	1	1.6
Bronchiectasis	1	1.6
Cardiomegaly	3	4.8

*Some patients had more than one abnormality; therefore, individual findings are not mutually exclusive. Abbreviations: HRCT, high-resolution computed tomography; ILD, interstitial lung disease; UIP, usual interstitial pneumonia.

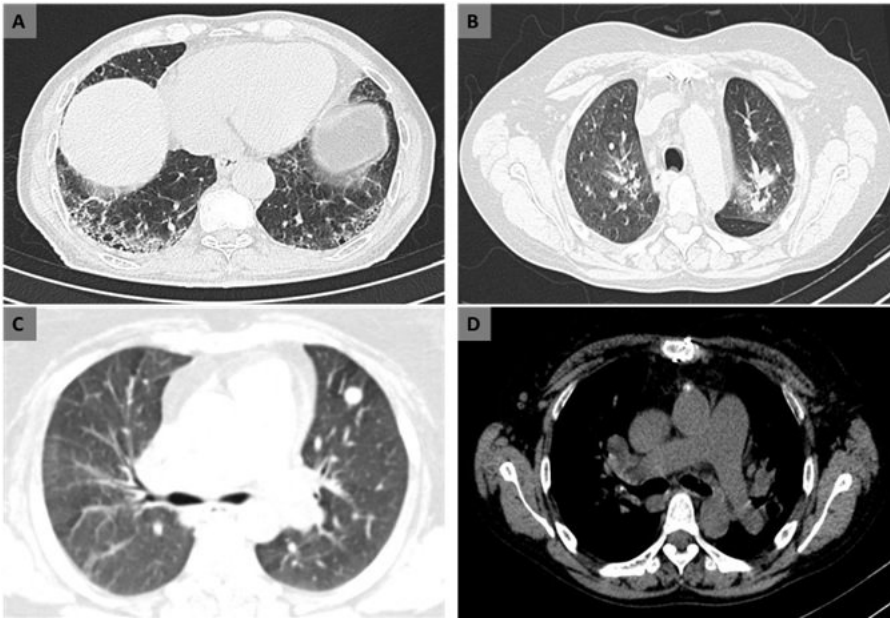


Figure 1. HRCT imaging of pulmonary changes in rheumatoid arthritis. A: Bi-basal reticulation with honeycombing and interlobular septal thickening, consistent with a UIP pattern. B: Patchy ground-glass opacification without other recorded features of ILD. C: Well-defined round intrapulmonary soft-tissue attenuation nodule in the anterior segment of the left upper lobe. D: Dilated main pulmonary artery with reversal of the aortopulmonary ratio in a patient with background ILD.