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Original Research Article

Temporal Evolution of Pulmonary Abnormalities in COVID-19 Infection: Chest CT Findings at Different Stages of Illness

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Abstract

Purpose: To characterize the spectrum and temporal evolution of chest CT findings in patients with COVID-19 pneumonia across four defined stages of illness.

Materials and Methods: In this single-institution retrospective study, 105 consecutive patients with laboratory-confirmed SARS-CoV-2 infection who underwent non-contrast chest CT from May 2020 to February 2021 were enrolled. Patients were stratified by interval from symptom onset to CT scan into five groups: early (0–4 days; n=28), progressive (5–8 days; n=28), peak (9–13 days; n=23), late (14–30 days; n=17), and delayed (>30 days; n=9). CT images were evaluated for 17 distinct findings using standard Fleischner Society nomenclature. Disease burden was quantified using a validated 25-point lobar CT severity score.

Results: Ground glass opacity (GGO) was the dominant finding in the early stage (89%), declining progressively to 11% in the delayed stage. Consolidation peaked in the early and progressive stages (50% each) and resolved completely by the delayed stage. Architectural distortion and reticular opacities emerged later, reaching 53% and 65% respectively in the late stage, with reticular opacities persisting at 56% in the delayed stage, indicating incomplete resolution. Vascular prominence was a consistent early marker (75% early stage). The mean CT severity score was 12.08 (range 0–25), with scores peaking at the late stage (13.05). Two novel findings were identified: fissural effusion (19 patients; 18%) and subpleural sparing (12 patients; 11%). Peripheral distribution predominated (61.9%).

Conclusion: CT manifestations of COVID-19 pneumonia demonstrate predictable stage-specific patterns. Recognition of these patterns allows accurate radiological staging, facilitates prognostication, and supports treatment decision-making. Fissural effusion and subpleural sparing are proposed as novel CT findings in COVID-19.

Keywords: COVID-19 | SARS-CoV-2 | Chest CT | Ground Glass Opacity | CT Severity Score | Pulmonary Staging | Temporal Evolution.

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Introduction

On March 11, 2020, the World Health Organization (WHO) declared COVID-19 a global pandemic [1]. In India, the first cases were reported from Kerala in January 2020, followed by successive epidemic waves that resulted in approximately 34 million confirmed infections and over 455,000 deaths as of the date of this writing (2,3). COVID-19 is caused by severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) and predominantly affects the respiratory system, with the lungs as the principal target organ.

Chest computed tomography (CT) has emerged as an important adjunct in the evaluation of patients with moderate-to-severe COVID-19 pneumonia. The Fleischner Society and Radiological Society of North America (RSNA) have published consensus guidelines delineating specific clinical scenarios in which chest CT is indicated, principally in patients with moderate-to-severe symptoms, evidence of clinical deterioration, or diagnostic uncertainty [4,5]. Chest CT allows objective assessment of the extent and pattern of pulmonary involvement, which can inform clinical management, guide escalation of care, and provide prognostic information.

The temporal evolution of COVID-19 pneumonia has been described in several staging frameworks. Jin et al [6] proposed five stages based on CT appearances in 83 patients. Bernheim et al [7] used a three-stage model (0–2 days, 3–5 days, and 6–12 days). Pan et al [8] employed a weekly staging system. However, very few studies have systematically evaluated CT findings according to the four widely accepted clinical stages: early (0–4 days), progressive (5–8 days), peak (9–13 days), and late (>14 days from symptom onset) [9].

The purpose of this study was to characterize the spectrum and frequency of chest CT findings in hospitalized patients with confirmed COVID-19 pneumonia across these defined stages of illness, and to evaluate the temporal trajectory of individual CT features from early infection through delayed resolution.

Materials and Methods

Study Design and Patient Population: Institutional ethics committee approval was obtained for this retrospective observational study and the requirement for individual informed consent was waived.

Our institution served as a designated COVID-19 care facility during the study period. Between May 2020 and February 2021, 105 consecutive patients with laboratory-confirmed SARS-CoV-2 infection (positive RT-PCR or GeneXpert assay) who underwent non-contrast chest CT were enrolled. No patients were excluded. Patient selection was consecutive.

The decision to perform CT was made by the treating clinician and was not influenced by the study team. In general, CT was reserved for patients with moderate or severe disease; a limited number of patients with mild disease underwent CT when diagnostic uncertainty existed or when clinical deterioration was anticipated.

CT Technique: All patients underwent non-contrast chest CT on a 128-slice multidetector CT scanner (SCENARIA 128; Hitachi, Tokyo, Japan).

Acquisitions were performed at full inspiration with the patient in a supine position.

Images were reconstructed at 1 mm slice thickness in both lung (window width/level: 1500/−600 HU) and mediastinal (width/level: 400/40 HU) windows. Standard axial, coronal, and sagittal reformats were generated.

CT Image Analysis: All CT images were independently evaluated by a fellowship-trained radiologist with experience in thoracic imaging.

CT findings were described using standardized nomenclature as defined by the Fleischner Society glossary (10) and as employed in published literature on viral pneumonias. The following findings were systematically assessed:

- Type of opacity: ground glass opacity (GGO); consolidation; crazy paving (GGO with interlobular septal thickening); reticular opacities
- Architectural changes: architectural distortion; bronchial wall thickening/irregularity; bronchiectasis
- Vascular changes: vascular prominence
- Special patterns: reverse halo (atoll) sign; subpleural lines
- Miscellaneous: pleural effusion; fissural effusion; mediastinal lymphadenopathy; pneumatoceles; subpleural sparing

CT Severity Score: Disease burden was quantified using a validated 25-point visual quantitative CT severity score (8). Each of the five pulmonary lobes was scored according to the estimated percentage of lobar parenchymal involvement: score 0 = no involvement; 1 = <5% involvement; 2 = 5%–25%; 3 = 26%–49%; 4 = 50%–75%; 5 = >75% involvement.

The total CT severity score represents the sum of all five lobar scores (range 0–25). Based on total score, patients were categorized as mild (0–7), moderate (8–17), or severe (>17) (11).

Disease Staging: Patients were stratified into five groups based on the number of days elapsed between symptom onset and the date of CT imaging (9): Group 1: Early stage (0–4 days); Group 2: Progressive stage (5–8 days); Group 3: Peak stage (9–13 days); Group 4: Late stage (14–30 days); Group 5: Delayed stage (>30 days).

Statistical Analysis: Categorical variables are expressed as frequencies and percentages.

The CT severity score is reported as mean ± standard deviation. Frequency of each CT finding was calculated for each stage group.

Chi-square test or Fisher exact test was used for comparison of categorical variables across stages, as appropriate. A P-value <.05 was considered statistically significant. Statistical analysis was performed using SPSS version 26.0 (IBM, Armonk, NY).

Results

Patient Demographics and Clinical CharacteristicsA total of 105 patients (mean age 46 years; range 21–71 years) were enrolled. Of these, 13 patients (12.4%) had mild disease, 46 (43.8%) had moderate disease, and 46 (43.8%) had severe disease based on clinical assessment (Figure 1). Demographic characteristics and comorbidity data are summarized in Table 1. Sixteen patients (15.2%) had hypertension, 17 (16.2%) had diabetes

mellitus, and 4 (3.8%) were obese. All patients with comorbidities developed moderate or severe disease. By stage of illness, 28 patients were in the early stage (26.7%), 28 in the progressive stage (26.7%), 23 in the peak stage (21.9%), 17 in the late stage (16.2%), and 9 in the delayed stage (8.6%) (Figure 2).

Table 1: Patient Demographics and Clinical Characteristics

Characteristic	Category	Number (%)
Total Patients		105 (100%)
Age Range	21 – 71 years	
Clinical Severity	Mild	13 (12.4%)
	Moderate	46 (43.8%)
	Severe	46 (43.8%)
Comorbidities	Diabetes Mellitus	17 (16.2%)
	Hypertension	16 (15.2%)
	Obesity	4 (3.8%)

Data represent number of patients; percentages in parentheses.

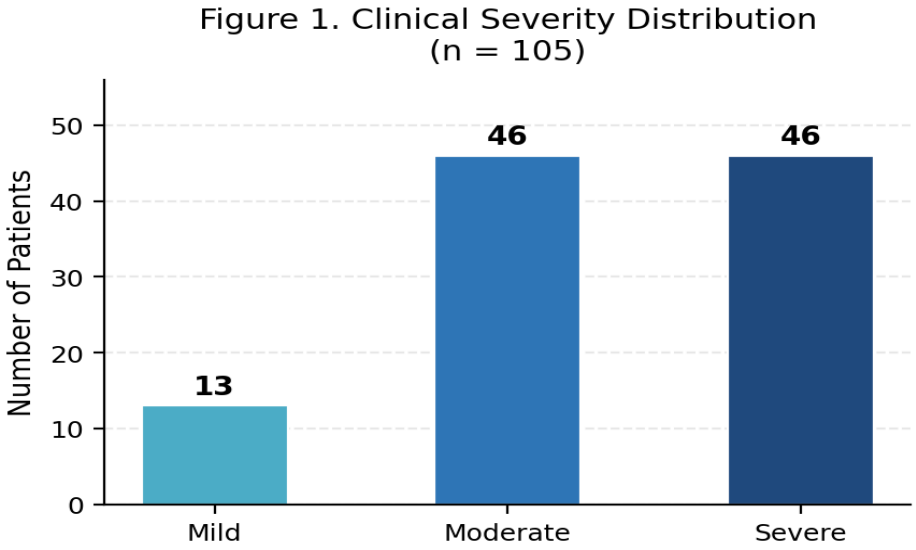

Figure 1: Distribution of clinical disease severity in 105 patients with COVID-19 who underwent chest CT (n = 105).

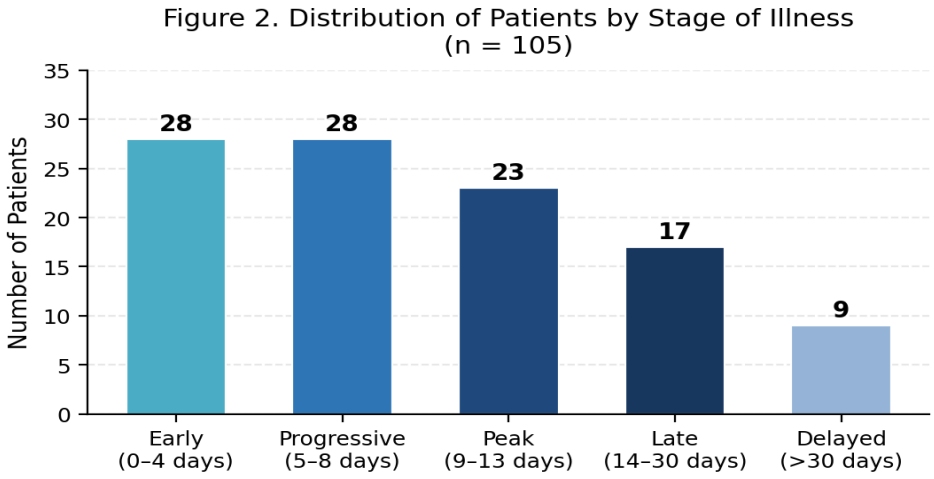

Figure 2: Distribution of patients across five stages of illness defined by interval from symptom onset to CT scan date.

CT Findings — Overall: Three patients showed no CT abnormality; all three had mild clinical disease and belonged to the delayed stage (>30 days). Of the remaining 102 patients, 98 (96.1%) demonstrated bilateral pulmonary involvement; only 4 patients (3.9%) had unilateral disease.

The distribution of pulmonary abnormalities was peripheral in 65 patients (61.9%), diffuse in 37 (35.2%), and normal in 3 (2.9%) (Figure 6). Lower lobe predominance was observed in 80 of 102 right lungs (78.4%) and 80 of 98 left lungs (81.6%), with maximal involvement of the lower lobes in 160 of 200 assessed lungs (80%). The frequency of all assessed CT findings stratified by stage of illness is presented in Table 2.

Table 2: Frequency of CT Findings by Stage of Illness

CT Finding	Earlyn=28 (%)	Progressiven=28 (%)	Peakn=23 (%)	Laten=17 (%)	Delayedn=9 (%)	Totaln=105 (%)
Ground Glass Opacity	25 (89)	22 (79)	14 (61)	5 (29)	1 (11)	67 (64)
Crazy Paving	7 (25)	10 (36)	6 (26)	1 (6)	0 (0)	24 (23)
Consolidation	14 (50)	14 (50)	10 (44)	6 (35)	0 (0)	44 (42)
Vascular Prominence	21 (75)	20 (71)	16 (70)	7 (41)	1 (11)	65 (62)
Architectural Distortion	2 (7)	5 (18)	6 (26)	9 (53)	1 (11)	23 (22)
Reticular Opacities	1 (4)	3 (11)	4 (17)	11 (65)	5 (56)	24 (23)
Bronchiectasis	5 (18)	10 (36)	4 (17)	4 (24)	2 (22)	25 (24)
Bronchial Wall Thickening/Irregularity	9 (32)	12 (43)	9 (39)	8 (47)	2 (22)	40 (38)
Reverse Halo (Atoll) Sign	4 (14)	3 (11)	7 (30)	6 (35)	0 (0)	20 (19)
Subpleural Lines	4 (14)	8 (29)	4 (17)	4 (24)	0 (0)	20 (19)
Pleural Effusion	0 (0)	1 (4)	2 (9)	0 (0)	0 (0)	3 (3)
Fissural Effusion*	4 (14)	8 (29)	4 (17)	3 (18)	0 (0)	19 (18)
Mediastinal Lymphadenopathy	3 (11)	3 (11)	1 (4)	5 (29)	0 (0)	12 (11)
Pneumatoceles	0 (0)	3 (11)	0 (0)	1 (6)	2 (22)	6 (6)
Subpleural Sparing*	2 (7)	3 (11)	2 (9)	5 (29)	0 (0)	12 (11)

*** Novel findings not previously described in COVID-19 literature. Values are number of patients (%). d = days from symptom onset.**

Major CT Findings — Temporal Evolution: Four categories of pulmonary opacity demonstrated distinct temporal patterns (Figure 3):

Ground Glass Opacity: GGO was the most prevalent finding overall, identified in 67 patients (63.8%). It was most prevalent in the early stage (89.3%) and declined progressively through the progressive (78.6%), peak (60.9%), and late (29.4%) stages, with near-complete resolution in the delayed stage (11.1%).

Consolidation: Consolidation was seen in 44 patients (41.9%), with stable frequency in the early (50%) and progressive (50%) stages, followed by a gradual decline in the peak (43.5%) and late (35.3%) stages, and complete resolution in the delayed stage (0%).

Architectural Distortion: Architectural distortion was noted in 23 patients (21.9%). Its frequency increased progressively from the early (7.1%) through the progressive (17.9%) and peak (26.1%) stages, reaching a maximum in the late stage (52.9%). A reduction was observed in the delayed stage (11.1%), indicating partial resolution.

Reticular Opacities: Reticular opacities were present in 24 patients (22.9%). Similar to architectural distortion, they were rare in the early stage (3.6%) and increased through the progressive (10.7%), peak (17.4%), and late (64.7%) stages. Critically, reticular opacities persisted in 55.6% of patients in the delayed stage, suggesting incomplete lung remodeling and potential fibrotic sequelae.

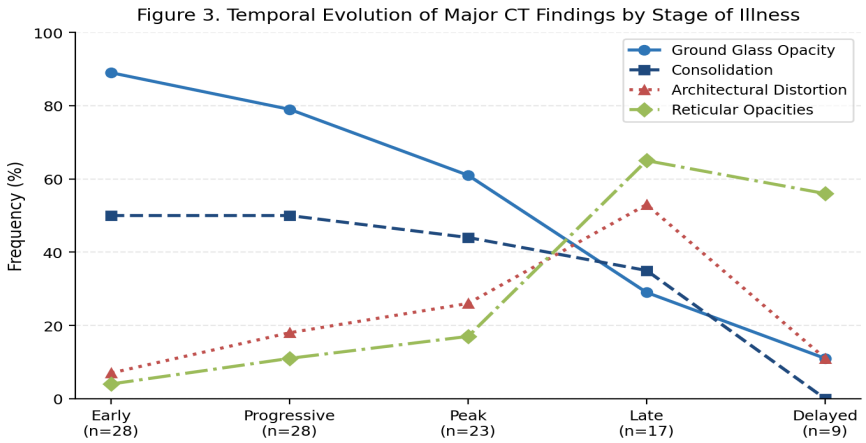

Figure 3. Line graph showing temporal evolution of major CT findings across stages of illness. GGO declines while architectural distortion and reticular opacities increase with disease progression.

Associated CT Findings — Temporal Evolution: Five associated findings exhibited distinct stage-specific temporal patterns (Figure 4):

Vascular Prominence: Vascular prominence was identified in 65 patients (61.9%) and was the second most common finding after GGO. It was maximal in the early stage (75%) and remained consistently elevated through progressive (71.4%) and peak (69.6%) stages before declining in the late (41.2%) and delayed (11.1%) stages, reflecting resolution of perilesional hyperemia.

Crazy Paving: Crazy paving was found in 24 patients (22.9%). Its frequency peaked in the progressive stage (35.7%) and declined through peak (26.1%) and late (5.9%) stages, with complete resolution in the delayed stage.

Bronchial Abnormalities: Bronchial wall thickening and irregularity was observed in 40 patients (38.1%). Its frequency was highest in the progressive (42.9%) and late (47.1%) stages. Bronchiectasis was additionally present in 25 patients (23.8%), with maximum prevalence in the progressive stage (35.7%), accounting for a total of 65 patients (61.9%) with some form of bronchial abnormality.

Reverse Halo (Atoll) Sign: The reverse halo sign, a recognized marker of organizing pneumonia, was seen in 20 patients (19%). Its prevalence was low in the early (14.3%) and progressive (10.7%) stages and increased substantially in the peak (30.4%) and late (35.3%) stages, consistent with the emerging organizing pneumonia pattern in resolving disease. No patient in the delayed stage demonstrated this sign.

Subpleural Lines: Subpleural lines were seen in 20 patients (19%).

Prevalence was highest in the progressive stage (28.6%) and was absent in the delayed stage, suggesting complete resolution.

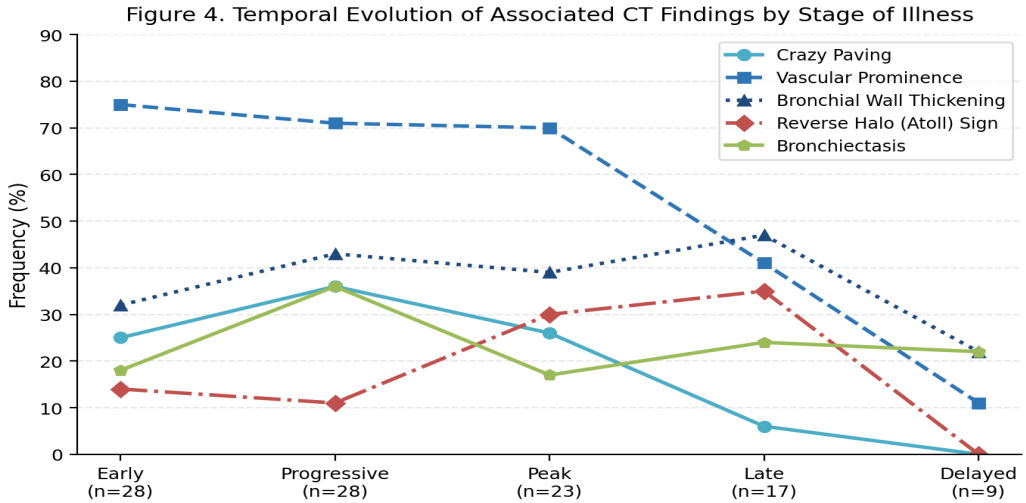

Figure 4: Line graph showing temporal evolution of associated CT findings. Vascular prominence is an early marker; the reverse halo sign and bronchial abnormalities emerge in later stages.

Novel CT Findings: Two CT findings were identified in this cohort that, to the best of our knowledge, have not been previously described in the COVID-19 literature:

Fissural Effusion: Fluid density within fissures, predominantly the oblique fissures, was identified in 19 patients (18.1%). These fissural fluid collections, termed fissural effusions, were most prevalent in the progressive stage (28.6%) and were typically seen adjacent to areas of consolidation or GGO. They were absent in the delayed stage, indicating spontaneous resolution.

Subpleural Sparing. In contrast to the classic description of COVID-19 opacities extending to the pleural surface, 12 patients (11.4%) demonstrated a thin rim of subpleural pulmonary parenchyma that remained free of opacities, resembling the subpleural sparing pattern described in non-specific interstitial pneumonitis (NSIP). This finding was most prevalent in the late stage (29.4%) and was absent in the delayed stage.

CT Severity Score: The mean CT severity score for the entire cohort was 12.08 (range 0–25).

Based on CT severity categories, 21 patients (20%) were classified as mild (score 0–7), 69 (65.7%) as moderate (score 8–17), and 15 (14.3%) as severe (score >17) (Figure 5, Table 3).

Mean scores increased progressively from the early stage (10.9) through the progressive (12.75), peak (13.04), and late (13.05) stages, before declining in the delayed stage (9.3), consistent with gradual parenchymal recovery (Figure 7).

Table 3: Mean CT Severity Score by Stage of Illness

Stage	n	Mean CT Score	CT Mild(0–7)	CT Moderate(8–17)
Early (0–4 d)	28	10.9	—	—
Progressive (5–8 d)	28	12.75	—	—
Peak (9–13 d)	23	13.04	—	—
Late (14–30 d)	17	13.05	—	—
Delayed (>30 d)	9	9.3	—	—
Overall	**105**	**12.08**	**21 (20%)**	**69 (65.7%)**

CT severity: mild = 0–7; moderate = 8–17; severe = >17.

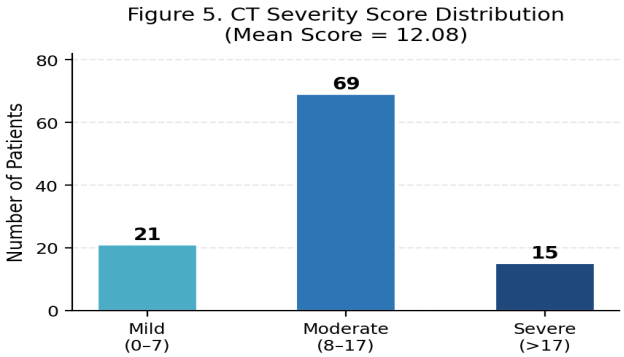

Figure 5: Distribution of CT severity scores across the cohort. Majority of patients (65.7%) had moderate CT severity (score 8–17).

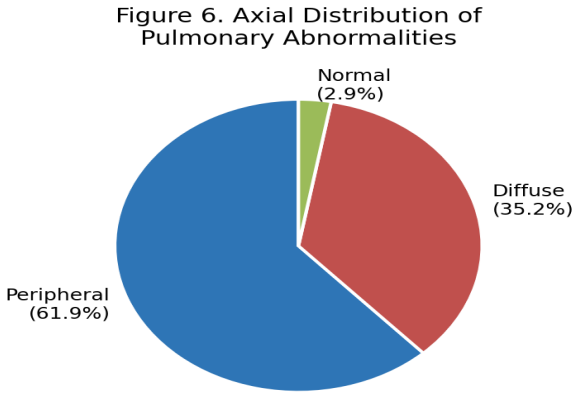

Figure 6: Pie chart demonstrating axial distribution of pulmonary abnormalities. Peripheral distribution predominated (61.9%).

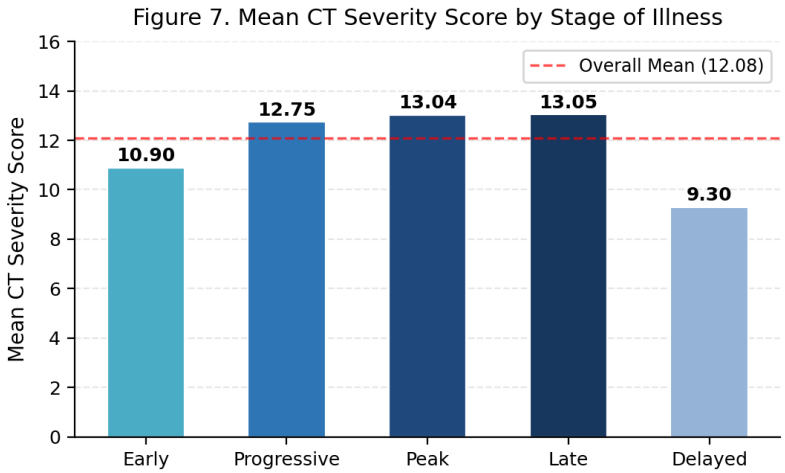

Figure 7: Mean CT severity score by stage of illness. Scores peak at the late stage and decline in the delayed stage, reflecting parenchymal recovery.

Discussion

This retrospective study of 105 hospitalized patients with COVID-19 pneumonia demonstrates that the CT manifestations of SARS-CoV-2 infection are not static but undergo predictable stage-specific transformations over the course of illness. The key findings of this study are: (i) GGO and vascular prominence dominate the early stage; (ii) consolidation and crazy paving peak in the early and progressive stages and subsequently resolve; (iii) architectural distortion, reticular opacities, and the reverse halo sign emerge progressively as markers of organizing and resolving pneumonia; (iv) CT severity scores peak at the late stage (days 14–30) with subsequent decline; and (v) fissural effusion and subpleural sparing are identified as previously unreported CT features of COVID-19.

Comparison with Existing Literature: Our findings are broadly consistent with the meta-analysis of 28 studies by Adams et al [12], which identified bilateral abnormalities, GGO, posterior predilection, vascular thickening, and lower lobe involvement as the most common CT features (present in >70% of cases). Our cohort similarly demonstrated bilateral disease in 96.1% of patients, lower lobe predominance in 80%, GGO in 63.8%, and vascular prominence in 61.9%.

For findings of intermediate incidence, our results showed consolidation (41.9% vs 51.5%), reticular opacities (22.9% vs 49.6%), crazy paving (22.9% vs 34.9%), and reverse halo sign (19% vs 11.1%) in ranges comparable to the literature. Bronchial wall thickening was more frequent in our series (38.1% vs 14.3%), likely reflecting the higher disease burden in our cohort. Low-incidence findings such as pleural effusion (2.9% vs 5.2%) and lymphadenopathy (11.4% vs 5.1%) were also concordant.

Disease Burden: The mean CT severity score of 12.08 in this study is notably higher than comparator studies. Adams et al [12] reported a mean score of 3; Pan et al (8) reported peak mean scores of 7. An Indian single-center study by Bhandari et al [13] identified only 19 patients with scores above 10, compared to 67 patients (63.8%) in our cohort. This disparity likely reflects a selection effect: our hospital served as a designated COVID-19 tertiary care center, resulting in preferential referral of patients with moderate-to-severe disease, who constitute 87.6% of our cohort.

Temporal Patterns of Ct Findings: The temporal trajectory of major CT findings in our cohort parallels the pathophysiological sequence of COVID-19 pneumonia. The early predominance of GGO reflects interstitial edema and partial alveolar filling in the exudative phase of diffuse alveolar damage. The peak of consolidation in the early and progressive stages represents confluent alveolar filling and hyaline membrane formation. The subsequent emergence of architectural distortion, reticular opacities, and the reverse halo sign in the late stage is consistent with the organizing pneumonia phase of COVID-19, characterized by fibroblastic proliferation within the alveolar spaces and bronchiolar lumens [14].

The persistence of reticular opacities in 55.6% of delayed-stage patients is clinically significant, as it suggests ongoing fibrotic remodeling beyond 30 days from symptom onset. This finding has implications for follow-up CT protocols in patients who present with post-COVID functional impairment or hypoxemia, as recommended by the Fleischner Society [5].

Novel Findings: Fissural effusion was identified in 18.1% of patients and, to our knowledge, has not been previously described as a distinct CT feature of COVID-19 pneumonia. The effusion predominantly involved the oblique fissures and

was typically small and adjacent to areas of parenchymal opacity. Its resolution by the delayed stage suggests a transudative or parapneumonic mechanism related to local capillary leak, rather than an exudative or hemodynamically driven process.

Subpleural sparing, typically a distinguishing feature of NSIP as opposed to usual interstitial pneumonia (UIP) or organizing pneumonia, was identified in 11.4% of our patients. Its maximal prevalence in the late stage (29.4%) and absence in the delayed stage suggest that it represents a transient pattern during the organizing phase of COVID-19 pneumonia. This finding may reflect the known overlap between COVID-19 pneumonia and NSIP-like patterns reported in autopsy studies [15].

Limitations

This study has certain limitations inherent to its design that should be considered when interpreting the findings. The retrospective, single-institution design reflects the operational constraints of a designated COVID-19 tertiary care facility during an active pandemic; this context also explains the relatively high disease severity in our cohort, which is a strength rather than a confound, as it permitted systematic characterization of the full CT spectrum from early exudative to late fibrotic stages.

Because CT was appropriately reserved for patients with moderate-to-severe disease or diagnostic uncertainty, patients with mild self-limiting illness were largely excluded; this is consistent with published Fleischner Society guidelines [5] and does not diminish the clinical applicability of our findings to the hospitalized population in whom imaging decisions are most consequential.

CT images were evaluated by an experienced fellowship-trained radiologist using standardized Fleischner Society nomenclature; formal interobserver reproducibility assessment, while not performed in this study, is a recommended direction for validation in a multicenter setting.

The delayed stage subgroup (n=9) was the smallest of the five groups, which is an expected consequence of the natural history of COVID-19, wherein the majority of patients who survive to 30 days are discharged from inpatient care; nevertheless, even in this small group, the consistent pattern of reticular persistence and opacity resolution provides a clinically meaningful signal. Future prospective studies with serial CT acquisitions, larger delayed-stage cohorts, and correlation with pulmonary function testing and histopathology will further characterize the long-term sequelae of COVID-19 pneumonia.

Conclusion

Chest CT manifestations of COVID-19 pneumonia evolve in a predictable and stage-dependent manner. Ground glass opacity, consolidation, and vascular prominence characterize the early and progressive stages, while architectural distortion and reticular opacities emerge in the late stage and may persist in the delayed stage, reflecting post-inflammatory fibrotic sequelae. CT severity scores peak between days 9 and 30 from symptom onset. Knowledge of these stage-specific patterns enables the radiologist to estimate the stage of illness, provides prognostic information, and assists clinicians in treatment planning. Fissural effusion and subpleural sparing are proposed as novel CT findings in COVID-19 that merit validation in larger prospective studies.

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