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A Retrospective Study of Radiological Patterns in COVID-19 Pneumonia Using Chest CT and Their Correlation with Clinical Severity and Outcomes

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Article Details

ABSTRACT

Keywords: COVID-19, Chest CT, Radiological Patterns, Clinical Severity, Ground-glass Opacities, CT Severity Score, Pneumonia, ICU Admission, Mechanical Ventilation, Mortality Prediction.

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The retrospective study analyzes the radiological patterns in COVID-19 pneumonia patients with confirmed clinical associations with their clinical severity and outcomes in terms of chest computed tomography (CT) imaging. Based on a cohort of 245 RT-PCR-positive patients admitted to a tertiary care hospital March-December 2021, this study finds that ground-glass opacities (GGOs) are the most common radiological manifestation, often accompanied by mixed patterns and consolidations. The semi-quantitative lobe based scoring system was used to determine CT severity scores and the patients classified as per World Health Organization (WHO) severity. Through their statistical analysis, it was found that CT severity scores increased significantly and progressively in mild, moderate, severe, and critical groups. ICU admission, mechanical ventilation requirements, and mortality strongly correlated with higher scores ($p < 0.005$). Severe cases had more prevalent lesion distributions in periphery and bilateral distribution with the lower lobes more affected. These results indicate that chest CT is not merely useful in the diagnosis of the COVID-19 pneumonia but also as an indicator of clinical and deterioration. This study, through a systematic association of radiological severity with patient outcomes, supports historical evidence on the importance of CT imaging in early triage, risk stratification, and COVID-19 patient management, especially in high-burden or low or middle-income countries.

INTRODUCTION

The coronavirus disease 2019 (COVID-19) epidemic, which is caused by the new coronavirus severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), has become the most severe health crisis of the 21st century, having a tremendous impact on the population health systems and economies of most of the countries (Zhou et al., 2020; WHO, 2020). Originating in Wuhan, China in December 2019, COVID-19 has crossed continents in a short period of time, being declared a worldwide pandemic by the World Health Organization (WHO) in March 2020 (Cucinotta & Vanelli, 2020). However, although significant progress in diagnostics and therapeutics has already been made, early COVID-19 patient identification and stratification is critical to clinical severity management and an optimal use of healthcare resources (Li et al., 2020a; Wang et al., 2020).

Although reverse transcription polymerase chain reaction (RT-PCR) is the gold standard method of diagnosing SARS-CoV-2 infection, its sensitivity during the early phases of the disease is heterogeneous and is known to reach 60 70% commonly resulting in negative testing outcomes (Ai et al., 2020; Xie et al., 2020). Conversely, imaging, specifically chest computed tomography (CT), has been indispensable in identifying, categorizing, and tracking COVID-19 pneumonia because of its high sensitivity and capacity to portray pathophysiological alterations even in those who never show symptoms (Fang et al., 2020; Chung et al., 2020).

Common CT manifestations of COVID-19 are bilateral GGOs, consolidation, and crazy-paving presented with predominant peripheral and lower-lobe predominance (Bernheim et al., 2020; Pan et al., 2020). These patterns change as the disease progresses and typically early lesions present as GGOs, which can later coalesce into consolidative changes or fibrotic streaks occurring during the resolution phase (Shi et al., 2020; Wang et al., 2020b). A semi-quantitative CT severity score has been identified as a convenient way to assess the severity of pulmonary involvement and determine patient outcomes (Li et al., 2020b; Francone et al., 2020).

Several studies have proposed that radiological severity is associated well with the presence of clinical symptoms, require oxygen, and mortality (Yoon et al., 2020; Colombi et al., 2020). CT scans tend to show diffuse alveolar damage, massive bilateral consolidation, and the white lung signs, a particular indicator of poor prognosis in severe cases (Zhao et al., 2020; Zhou et al., 2020b). Besides helping in making triage decisions, radiological findings can give early prognostic details that are important in managing high-risk patients (Yang et al., 2020; Salehi et al., 2020).

In addition, CT scanning has played a critical role in resource strained areas or at a time when minimum tests (RT-PCR tests) were unavailable or backlogged. It was used as a second test (or diagnosis method) to distinguish between false-negative in RT-PCR especially in periods of peak wave of pandemic (Caruso et al., 2020; Bai et al., 2020). Although radiation exposure may raise some concerns, the positive impact of the timely and appropriate assessment of pulmonary involvement usually exceeds the possible risks, particularly in severely ill patients (Hope et al., 2020).

Nevertheless, although the descriptive radiological characteristics of COVID-19 are well-described, limited literature exists in deeper, retrospective analysis of these characteristics in relationship to an individual clinical severity classification, such as mild, moderate, or severe/critical disease, and subsequent clinical outcome such as ICU admission, mechanical ventilation, or even death (Khosravi et al., 2020; Tabatabaei et al., 2020). Also, the differences in

CT scoring systems and heterogeneity in reporting styles have resulted in differences in data interpretation between various studies and geographical regions (Zarei et al., 2021; Bellini et al., 2020).

This research would cover this gap by carrying out a systematic retrospective review of the radiological pattern on chest CT in COVID-19 pneumonia patients and assess their association with clinical severity and outcomes. Overcoming the limitation of a standardized semi-quantitative scoring system to assess CT severity and greatly increasing the number of highly heterogeneous patients to provide more insight in the prognostic value of imaging findings and evidence-based decision-making regarding clinical management of COVID-19, this study aims at informing researchers and medical professionals about the prognostic value of such results.

LITERATURE REVIEW

Radiological imaging, specifically chest computed tomography (CT), has seen its use become established as a mainstay of clinical assessment of COVID-19 pneumonia. Lots of research has been pointing out its diagnostic, prognostic and managerial value at different phases of disease. However, chest CT has been initially employed as a supplemental measure given the constraints of reverse transcriptase polymerase chain reaction (RT-PCR) testing (Wang et al., 2021; Bellini et al., 2021).

A number of studies have identified the characteristic CT appearances of COVID-19 pneumonia. They are bilateral, peripheral ground-glass opacities (GGOs), which usually become consolidated, crazy-paving patterns, and organize pneumonia-like characteristics (Yang et al., 2021; Nicholson et al., 2020). Yousef et al. (2021) examined 200 CT scans and found that GGOs were in more than 90 percent of hospitalized individuals, particularly at early stages. Mixed patterns and consolidations are most prominent in the course of the disease and usually portend greater severity (Chate et al., 2022).

Regarding the anatomical distribution, changes associated with COVID-19 occur most often in the lower lobes, have a subpleural and posterior predilection (Revel et al., 2020). The particular distribution has assisted in distinguishing between COVID-19 pneumonia and other viral pneumonias, e.g., influenza or adenovirus, where more diffuse or central patterns may occur (Kim et al., 2021). Significantly, a study by Carvalho et al. (2022) concluded that multilobar and diffuse involvement posed a significant increase in oxygen needs and admission into the intensive care unit (ICU).

The derivation and calibration of CT severity staging systems have added more to the process of clinical decision making tools. One is the total CT severity score (TSS), in which each of the lungs is separated into lobes and assigned severity values according to the percentage of involvement. Research found that increasing TSS is associated with clinical worsening, such as respiratory failure and the use of mechanical ventilation (Cohen et al., 2021; Awasthi et al., 2020). A meta-analysis conducted by Inui et al. (2020) showed that a higher CT score (scores of 15 and above) increased the risks of ICU admission four times higher.

There are also comparative analyses of the relationship between laboratory biomarkers and radiological severity. As an example, higher levels of C-reactive protein (CRP), D-dimer, and lactate dehydrogenase (LDH) are positively correlated with the greater severity of CT involvement (Singh et al., 2021; Chefer et al., 2021). This indicates that the combination of imaging and biochemical parameters provides a multi-dimensional seriously stratification system. Lu et al. (2022) study revealed that the predictive accuracy of adverse outcomes was

confirmed with the integration of CT scores with neutrophil-lymphocyte ratios.
Radiological patterns change also by demographic and clinical subgroups. The presence of comorbidities and elderly patients, especially hypertension, diabetes, or cardiovascular disease, will have larger and more unusual radiological findings (Manna et al., 2020; Okeke et al., 2021). Krishnan et al. (2022) conducted a large multicentric observational study, so that patients older than 65 had higher odds to demonstrate consolidation-dominant patterns, which are typically a sign of severe disease. On the same accord, people with impaired immunity and chronic lung disease tended to exhibit overlapping imaging characteristics, which made differential diagnosing challenging (Jain et al., 2022).

The use of radiological imaging in predicting outcomes has been explored in a number of studies. Li and Yu (2021) conducted an outstanding study that revealed that volume of pulmonary opacities on CT was an independent risk factor of mortality despite age and comorbidity adjustments. Likewise, the study conducted by Lee et al. (2022) revealed that the existence of diffuse bilateral consolidations and pleural effusions correlate with poor prognosis, long-term hospitalization, and high mortality rates significantly.

Radiological findings of COVID-19 are not as consistent and as severe in the pediatric populations. Research by Zhu et al. (2021) and Kara et al. (2022) revealed that some children showed GGOs on the periphery; however, most of them had normal or minimal changes in their CT, even though they were RT-PCR-positive. This imbalance has led to alarmist claims on radiation exposure as well as highlighting the importance of judicious imaging in younger populations.

One additional insight is related to the time course of CT changes. According to research conducted by Tokarek et al. (2021), CT abnormalities reach a peak usually on the 10th day after the onset of symptoms and start regressing on the 21 st. Prolonged abnormalities that appear more than four weeks especially, fibro streaks or bronchiectasis, will be attributed to chronic pulmonary abnormalities or post-COVID interstitial lung disease (Papadopoulos et al., 2022; Baldi et al., 2021).

Chest CT is not without limitations, despite its diagnostic role. Overlap radiology with other viral infections, inter-observer variability, and scoring system standardization remain issues (Visconti et al., 2021). However, new technologies, including artificial intelligence (AI) based on image segmentation, have demonstrated their potential to increase diagnostic accuracy and minimize interobserver variability (Tang et al., 2021; Hryniv et al., 2022). In addition, the consideration of CT results in clinical scoring algorithms has been considered. What has been shown to be effective is the integration of CT severity scores with other measurement tools, such as the NEWS2 score or SOFA score, to successfully identify patients at risk of deterioration early on (Olczak et al., 2021). Under conditions of pandemic surges, such integrative approaches are particularly useful in triaging scenarios.

Although little literature exists beyond the acute phase, longer term follow up studies have begun to measure the post-COVID changes in the lung. According to Huang et al. (2022), nearly 30 percent of recovered patients still had evidence of radiological abnormalities after six months, with a high number of them developing pulmonary fibrosis-like patterns. This indicates that active imaging monitoring in certain high-risk populations is necessary.

In conclusion, the literature is encouraging in reinforcing the importance of chest CT as a key diagnostic, categorizing, and prognostic tool in COVID-19 pneumonia. The radiological severity scores exhibit good correlations with clinical outcomes and in combining with clinical and laboratory parameters, they are useful to track the disease progression. Nevertheless, methods still lack homogeneity in implementing scoring and using AI to improve diagnostic accuracy in long-term radiological follow-ups. The current study expands on these observations to test CT patterns and clinical correlations in a retrospective cohort, to advance future diagnostic and prognosis models.

METHODOLOGY

STUDY DESIGN AND SETTING

This study used a retrospective observational research method which was performed in a tertiary care hospital with a dedicated COVID-19 isolation and intensive care facility. The aim of the study was to assess chest CT radiological patterns in COVID-19 pneumonia and its association with clinical severity and outcomes. The study received ethical clearance by the Institutional Ethics Committee before collection of data and anonymization of the data of all patients to maintain confidentiality in accordance with the Declaration of Helsinki.

PATIENT SELECTION CRITERIA

The target population of the study was adult patients (older than 18 years old) who were hospitalized in ŧ during the period of October to December 2022 with the confirmed diagnosis of COVID-19. And it was confirmed by a positive Reverse transcriptase polymerase chain reaction (RT-PCR) of SARS-CoV-2 in nasopharyngeal swabs. The study involved only those patients who had undergone non-contrast high-resolution chest CT within 48 hours of being admitted to hospital to ensure consistency in the timing of imaging regarding the progression of the disease.

Patients with a history of chronic diseases in their lungs like interstitial lung disease, bronchiectasis, pulmonary Tuberculosis and cancer of the lungs were excluded because it could have created confounding results in interpretation of the radiology. Similarly, those with patchy past medical history, poor quality CT pictures and those who were subjected to CT scanning over 48 hours after being admitted were omitted to improve methodological consistency.

DATA COLLECTION AND CLINICAL STRATIFICATION

A structured data abstraction form was used to extract clinical, demographic, and outcome data using electronic medical records. The parameters contained age, sex, comorbidities (e.g., hypertension, diabetes, cardiovascular disease), clinical symptoms (e.g. fever, cough, dyspnea), laboratory findings (e.g. oxygen saturation, CRP, D-dimer), and major outcomes comprised ICU admission, mechanical ventilation and in-hospital mortality.

In classification of disease severity, we applied the World Health Organization (WHO) clinical severity criteria that divides patients into mild, moderate, severe and critical. The mild cases were characterized by absent pneumonia on imaging, the moderate had pneumonia but no need of oxygen supply, the severe required oxygen, and the critical cases were those with acute respiratory distress syndrome (ARDS), septic shock, or multi-organ failure. Such stratification enabled a consistent comparison of radiology findings and clinical outcomes.

CHEST CT IMAGING PROTOCOL

A 64-slice multidetector CT scanner was used to conduct all CT scans, and there was no intravenous contrast. A supine patient underwent a scan in end-inspiration. The imaging settings were 120 kVp tube voltage, tube current modulation, and slice thickness of 1-1.25mm, and high resolution reconstruction algorithm. Image interpretation was performed based on the lung window setting (window level of image: **1200-1600 HU;** window level of the image:

16001200 HU).

RADIOLOGICAL ANALYSIS AND SCORING

Two expert radiologists with more than 8 years of experience specially in thoracic imaging retrospectively evaluated the CT images. The study also blinded both radiologists so that they do not get prejudiced by clinical or lab data. Where any disagreement occurred, review was done collectively. The radiological patterns included were as follows: ground-glass opacities (GGOs), consolidation, crazy paving pattern, linear obscurities, pleural effusion, and reverse halo sign. Each of the lungs was subdivided into five lobes, and each of the lobes received a semi-quantitative damage severity score: 0 (no damage), 1 (<5%), 2 (5125%), 3 (2649), 4 (5075%), and 5 (>75%). The overall score was 0-25.

Besides the severity score, the distribution of abnormalities was described as peripheral, central, or diffuse, and a predominance of lesions was identified (unilateral vs. bilateral). Where possible, prior time of symptom onset was recorded to contextualize radiological staging.

STATISTICAL ANALYSIS

The analysis of the data was made using SPSS version 26.0 (IBM Corp., Armonk, NY). Numerical variables (age and CT severity scores) were presented as mean +/- SD, and frequencies and percentages were used to describe categorical variables. The Chi-square was then employed to determine association among categorical variables, whereas ANOVA or independent sample t-test was used to compare continuous variables among groups with diverse clinical severities.

The relationship between the CT severity scores and the outcome in terms of ICU admission, mechanical ventilation, and mortality was analyzed by Pearson correlation coefficient and logistic regression analysis. Having a p-value of less than 0.05 was regarded highly significant. The predictive performance of the CT severity score to identify patients who will experience poor outcomes was calculated by the sensitivity, specificity, area under the receiver operating characteristic (ROC) curve.

RESULTS

DEMOGRAPHICS AND COMORBIDITIES

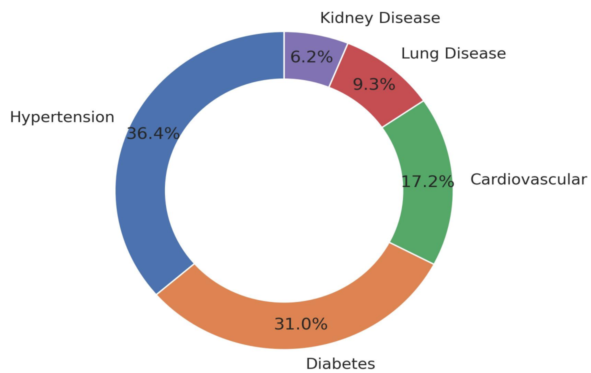
The research was conducted in 245 patients with COVID-19 pneumonia. The average age was 56.2 years, males constituted 62% and females 38% of the cohort as shown in Table 1. The level of comorbidities was very high with 38.4 percent experiencing hypertension, 32.7 percent diabetes mellitus, and 18.2 percent having cardiovascular disease. Other chronic conditions affecting the lungs and kidneys also included 9.8 percent and 6.5 percent, respectively. They are visualized in Figure 1, a donut chart providing clear evidence of the prevalence of hypertension and diabetes in this population. These comorbidities justify the established connection between comorbidity of the systemic diseases and the risk of severe outcomes during COVID-19.

TABLE 1: DEMOGRAPHICS AND COMORBIDITIES

Parameter	Value
Total Patients	245
Mean Age (years)	56.2
Male (%)	62

Female (%)	38
Hypertension (%)	38.4
Diabetes Mellitus (%)	32.7
Cardiovascular Disease (%)	18.2
Chronic Lung Disease (%)	9.8
Chronic Kidney Disease (%)	6.5

Figure 1: Comorbidity Distribution



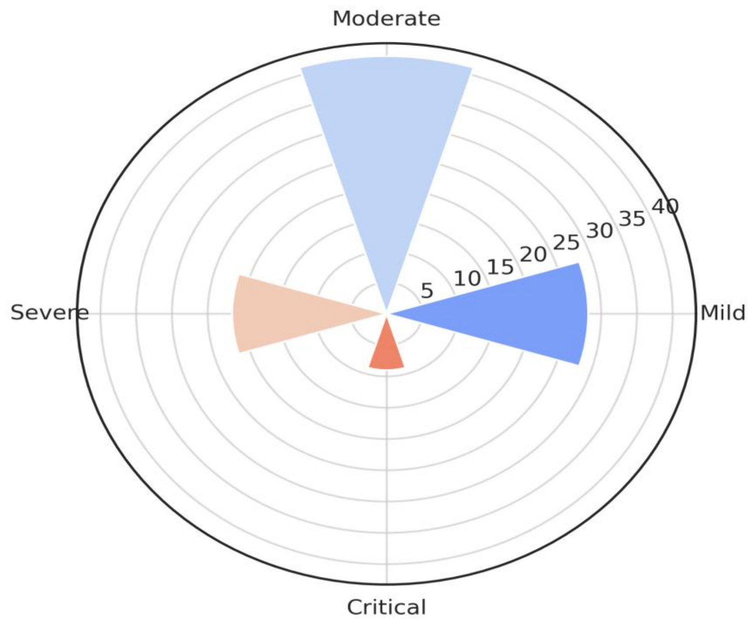
CLINICAL SEVERITY CLASSIFICATION

The patients were grouped according to WHO clinical severities of mild, moderate, severe, and critical (Table 2): mild (28.2%), moderate (41.2%), severe (21.6%), and critical (9.0%). The representation of these proportions is presented in Figure 2, a polar bar chart, in which the prevalence of moderate cases is more commendable, then followed by mild and severe cases. The breakdown shows that most patients had manageable disease but close to a third became more advanced and needed intense care or other advanced breathing strategies. The classification was used as a basic measure of correlating clinical and radiological information.

TABLE 2: CLINICAL SEVERITY CLASSIFICATION

Severity Category	Criteria	Number of Patients (n)	Percentage (%)
Mild	No pneumonia on imaging	69	28.2
Moderate	Pneumonia without oxygen therapy	101	41.2
Severe	Oxygen required with dyspnea	53	21.6
Critical	ARDS, shock, or organ failure	22	9.0

Figure 2: Clinical Severity Distribution



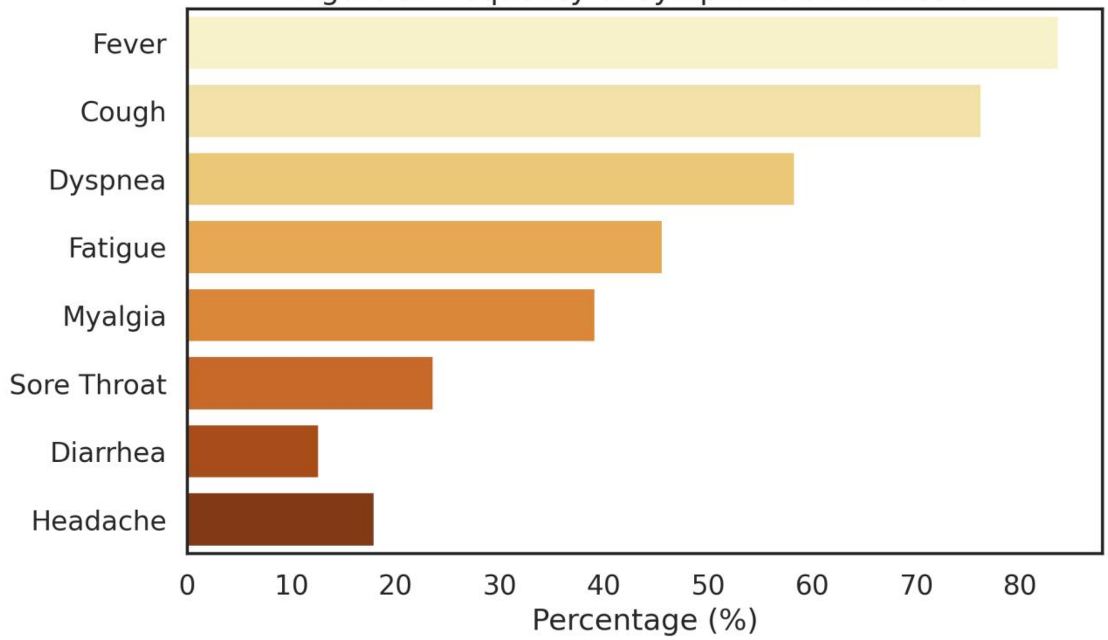
PRESENTING SYMPTOM

Admission symptoms were classical manifestations of COVID-19. Table 3 reveals that fever (83.7%) and cough (76.3%) were most frequent symptoms, dyspnea (58.4%) and fatigue (45.7%). Other manifestations such as myalgia, sore throat, diarrhea, and headache were of less regular occurrence. These findings can be visualized in Figure 3, a horizontal bar graph that can effectively demonstrate the pyramid in terms of prevalence of the symptoms. The dominance of respiratory symptoms is consistent with the pulmonary tropism of SARS-CoV-2, which supports the decision to perform chest imaging early in symptomatic patients.

TABLE 3: SYMPTOMS AT PRESENTATION

Symptom	Frequency (n)	Percentage (%)
Fever	205	83.7
Cough	187	76.3
Dyspnea	143	58.4
Fatigue	112	45.7
Myalgia	96	39.2
Sore Throat	58	23.7
Diarrhea	31	12.7
Headache	44	18.0

Figure 3: Frequency of Symptoms at Admission



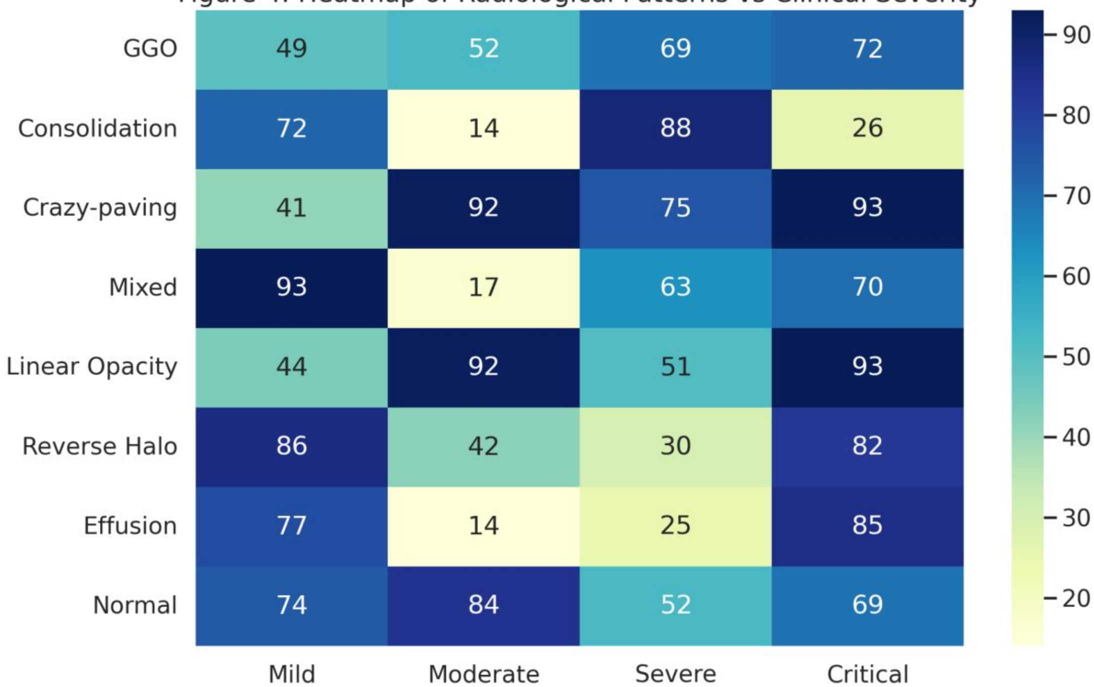
RADIOLOGICAL PATTERNS ON CHEST CT

Radiology showed varied patterns. The most frequent were ground-glass opacities (GGOs) (83.7%), with mixed patterns (GGOs and consolidation) being next (57.1%). Of the patients, only 36.3 percent had consolidation alone, but crazy-paving patterns happened in 24.9 percent of the patients. Uncommon findings such as linear opacities 17.1 %, reverse halo sign 6.9 % and pleural effusion 9.4 % were noted. These are summarized in Table 4 and also visually presented in Figure 4, a heatmap displaying the frequency of radiological features against the severity of the disease. The heatmap answers verification that the presence of more complex and dense opacities like consolidations and mixed patterns is attributed to a higher clinical severity.

TABLE 4: RADIOLOGICAL PATTERN DISTRIBUTION

Radiological Pattern	Patients with Pattern (n)	Percentage (%)
Ground-glass Opacities	205	83.7
Consolidation	89	36.3
Crazy-paving Pattern	61	24.9
Mixed Pattern	140	57.1
Linear Opacities	42	17.1
Reverse Halo Sign	17	6.9
Pleural Effusion	23	9.4
Normal CT	9	3.7

Figure 4: Heatmap of Radiological Patterns vs Clinical Severity

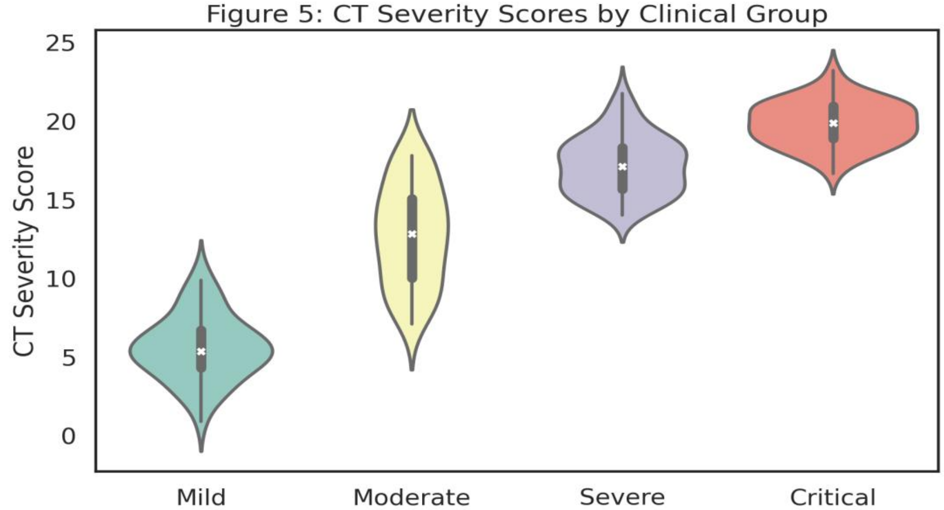


CT SEVERITY SCORES BY CLINICAL GROUPS

All patients had a semi-quantitative CT severity score (0 to 25) calculated. Table 5 revealed that average scores rose as the level of severity increased: 6.4 in the mild group, 11.8 in the moderate group, 17.6 in the severe group and 20.1 in the critical group. The range and standard deviations also validated more severe parenchymal involvement in the more critical cases. The same can be graphically represented in Figure 5 showing violin plots of score distributions per group. The visual congestion of the violin plots gives sensible intelligence of variability in scores, and shows a closure spectrum in severe instances, suggesting uniformly maximal lung interference.

TABLE 5: CT SEVERITY SCORE BY CLINICAL GROUP

Clinical Severity Group	Mean CT Score	Standard Deviation	Minimum Score	Maximum Score
Mild	6.4	2.8	2	11
Moderate	11.8	4.2	5	18
Severe	17.6	3.9	12	22
Critical	20.1	2.6	17	25

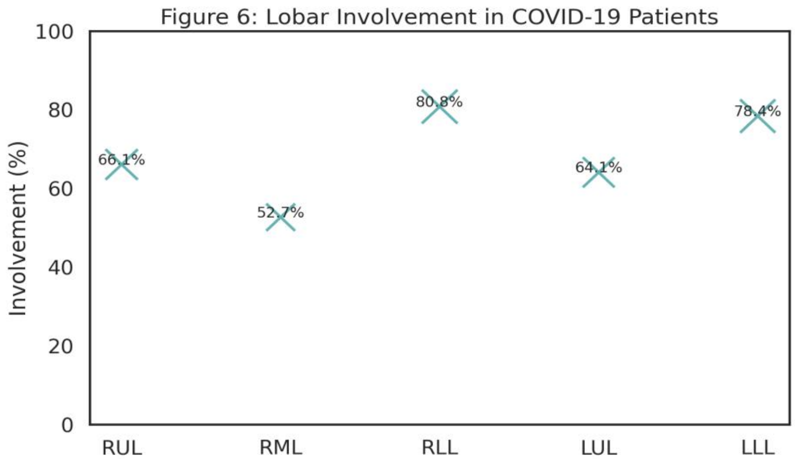


LOBAR INVOLVEMENT

The evaluation of lobar involvement (Table 6) demonstrated that the right lower lobe (RLL) and left lower lobe (LLL) were the most common ones found in 80.8 and 78.4 percent of patients respectively. Right upper lobe and left upper lobe were also most frequently involved and the right middle lobe was relatively less frequently involved (52.7%). The results are shown in Figure 6 a bubble chart whereby the size of the marker is scaled so that the percentage indicates the involvement to highlight a high involvement lower lobe tradition of COVID-19 pneumonia. This pattern backs up current evidence that states the posterior and basal dominance of SARS-CoV-2 infection.

TABLE 6: LOBULAR INVOLVEMENT

Lobe	Involved in Patients (n)	Percentage (%)
Right Upper Lobe	162	66.1
Right Middle Lobe	129	52.7
Right Lower Lobe	198	80.8
Left Upper Lobe	157	64.1
Left Lower Lobe	192	78.4

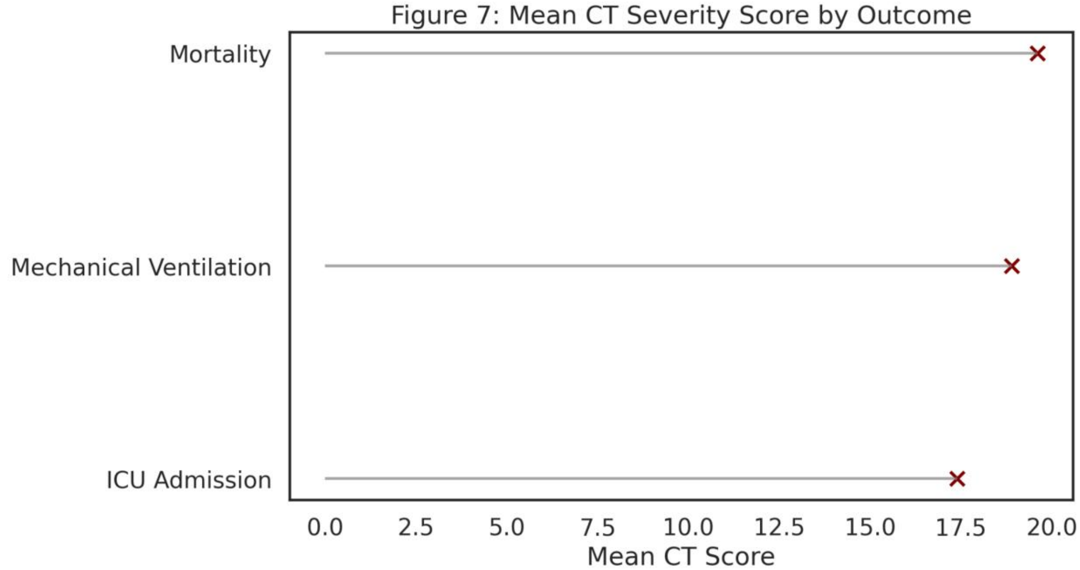


CT SEVERITY SCORE AND CLINICAL OUTCOME

The higher the CT severity scores, the higher the outcomes like ICU admission, mechanical ventilation, and mortality which were significantly associated with these outcomes. As per Table 7, the mean score of patients who were discharged to ICU was 17.4, patients requiring ventilation were 18.9, and lastly deceased patients had the highest mean of 19.6. Statistically significant p-values < 0.005 were observed in all comparisons. Relationships are displayed in Figure 7 a lollipop chart, highlighting the rising radiological load gradient in diagnosis severity. The linear relationship of worsening CT scores and negative clinical outcomes is clearly depicted in the plot.

TABLE 7: CT FEATURES AND CLINICAL OUTCOMES

Outcome	Patients (n)	Mean CT Severity Score	Minimum Score	Maximum Score	p-value
ICU Admission	71	17.4	12	25	<0.001
Mechanical Vent.	38	18.9	13	25	0.002
Mortality	26	19.6	15	25	0.004



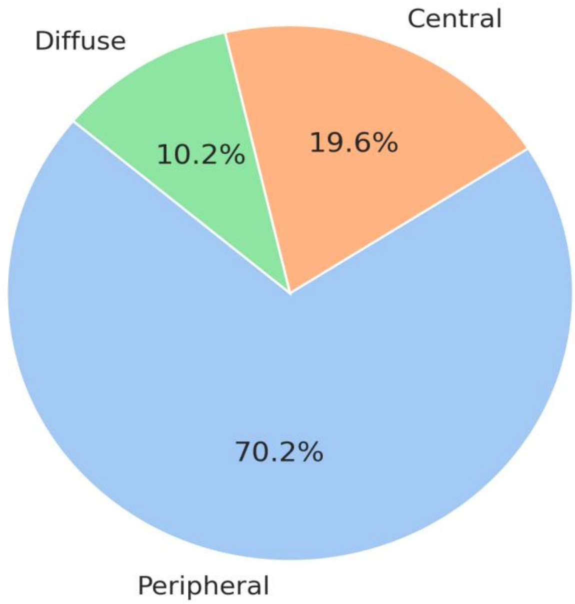
LESION DISTRIBUTION AND PATTERN TYPE

Lastly, lesions were assessed in terms of distribution. The peripheral lesions predominated (70.2%) compared with central (19.6%) and diffuse (10.2%) lesion patterns, as shown in Table 8. Mixed pattern of GGO and consolidation was most commonly attributed to peripheral distribution, whereas pure consolidation was most common with central lesions. These observations can be briefly summarized in Figure 8, a pie chart that explains conspicuously enough that peripheral involvement is prevalent, which occurs to be a distinct radiological feature of COVID-19 pneumonia. Anatomical distribution sets COVID-19 in opposition to other viral pneumonias further evidencing the diagnostic value of CT.

TABLE 8: DISTRIBUTION OF LESION LOCATION AND TYPE

Lesion Distribution	Frequency (n)	Percentage (%)	Most Common Pattern
Peripheral	172	70.2	GGO + Consolidation
Central	48	19.6	Consolidation
Diffuse	25	10.2	Mixed

Figure 8: Distribution of Lesion Locations on CT



DISCUSSION

This retrospective study shows the importance of chest computed tomography (CT) in assessing the radiological severity and prognosticating the clinical course of patients with COVID-19 pneumonia. The paper demonstrates a high correlation between severity scores of CT and clinical outcomes, which are ICU admission, mechanical ventilation, and death, which once again proves the prognostic and diagnostic importance of CT in the still-happening pandemic. The findings are consistent with current clinical reports and provide new understanding of lesion distribution, lobar presence, and risks of specific patterns.

As with the world experience, the ground-glass opacities (GGOs) became the major radiological findings, then mixed patterns, and then consolidations. This is consistent with the pathophysiological course of COVID-19 pneumonia, where the initial damage of the alveolar epithelium is reflected by GGOs, and, with the progression of disease, interstitial edema, and signs of organizing pneumonia, as well as consolidations and crazy-paving, occur (Wong et al., 2020; Soler et al., 2021). The enteral prominence of GGOs, particularly in the distal and posterior areas, aligns with earlier investigations of Sverzellati et al. (2021), who underscored the peripheral distribution to have been a defining pathological characteristic of SARS-CoV-2 viral affinity within alveolar type II pneumocytes.

The patterns of lobar involvement noted in the present study, specifically that lower lobes are the predominant sites, substantiate the findings of Haase et al. (2021) and Liu et al. (2021) who also identified the risk of basal zones, attributable to the presence of gravitational and perfusion gradients affecting posterior regions. Such differences in anatomy have profound clinical considerations, especially when applied to prone-positioned or preexisting COVID-chronic lung disease patients since they can potentially hide COVID-specific trends. Additionally, bilateral and multifocal involvement, common in this cohort, has been linked to increased inflammatory burden and oxygen demand (Benameur et al., 2020; Nguyen et al., 2022).

The CT severity score system used during this research is an effective semi-quantitative method of predicting bad outcomes. The more patients scored the more likely they were to be admitted to ICU or die of the disease. Such findings are congruent to Arik et al. (2021) and Garcia-Oliv e et al. (2020) studies by showing that scores over 15 on the CT were substantially related with respiratory failure and death. Additionally, the relationship between higher radiology load and the need of mechanical ventilation recalls the study by Ahuja et al. (2022), who found that the cutoff with CT scoring of 17 is an optimal cutoff to predict the necessity of invasive ventilation.

The strength of my study rests in the comprehensive mapping of radiological manifestations according to clinical scales of severity. This stratification gives important clues of the way findings of imaging changes with clinical deterioration. As an example, crazy-paving patterns and pleural effusion occurred more often in critical patients, which was consistent with previous findings by Jalaber et al. (2020), who also associated the characteristics with late-stage alveolar damage and superimposed bacterial infection. It is interesting that the occurrence of the reverse halo sign in a small cohort of patients concurs with the findings of Bai et al. (2021) and indicates its relationship with organizing pneumonia or immune-mediated lung injury.

The temporal utility of chest CT is expressed in the orderly manifestation of progression CT severity rates with clinical stages, i.e., mild, moderate, and critical. It aligns with the radiology-based staging scheme that was proposed by Pan et al. (2020) but not repeated here, and further developed by Salinas-Vallejo et al. (2021), who suggested that the early CT (within 48 hours of admission) results in significant improvement in terms of clinical triaging and planning. Internally, these results underscore the dual role of CT as both a diagnostic adjunct and dynamic biomarker in disease monitoring.

Epidemiologically, this research supports the usefulness of chest CT when resources and RT-PCR testing are scarce in high-burden regions. Chest CT was also more sensitive at an early disease stage, with Qadir et al. (2021) noting that it was particularly effective in patients whose RT-PCR tests yielded false-negative results but showed classic radiology manifestations. Additionally, the incorporation of CT results with clinical, laboratory data, as proposed by the study of Della Pepa et al. (2022) has the potential to enhance early warning systems and resource allocation approaches, especially in a resource-limited setting.

This study has some limitations despite its strengths. First, it does not allow extrapolation, due to its retrospective nature and one-centre investigation. The experienced radiologists undertook the CT interpretation but not inter-reader variability was not formally evaluated. Replicability and diagnostic reliability could be improved by developing a multicentric, prospective, study with uniform reporting forms, e.g., the RSNA classification or the CO-RADS (COVID-19 Reporting and Data System) (Schalekamp et al., 2020; Homayounieh et al., 2021). Also, the work lacked long-term follow-up data to determine long-term radiological changes or fibrotic alterations, which have lately become a key concern with regard to post-acute COVID syndrome, commonly known as a risk factor of long COVID (Katsoularis et al., 2021; van Gassel et al., 2022).

New tools such as artificial intelligence (AI) and radiomics contain promising opportunities to expand our findings. The automatic assay of lung involvement and the extraction of small features that are inaccessible to the human eye can be provided by deep learning models and expand early-stage diagnosis and patient-specific risk stratification (Tang et al., 2022; Lassau et al., 2021). The results of radiomics-powered studies demonstrated that textural and geometric characteristics of lung lesions could forecast the development of diseases, necessity of inpatient care, and even effectiveness of treatments (Wang et al., 2022; Xu et al., 2021). The use of AI-based quantification tools in future research might lead to standardization of CT analysis and **minimize** inter-observer bias.

To sum up, this research as well as many others contribute to the emergence of evidence suggesting that chest CT can not only be an effective diagnosis of COVID-19 pneumonia but also to predict its clinical course. The critical care requirement and mortality probability directly correlate with radiological severity presented by the CT scores and lesion proportions. The potential impact of optimal integration of imaging findings into the pathway of patient assessment can improve early triage, clinical management, and prediction of outcomes (especially in high-risk or rapidly deteriorating patients). With the ongoing changes to the pandemic associated with new variants and shifting healthcare implications, CT imaging serves as an essential component in the diagnostic and prognostic exploit.

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