

Quantitative Assessment of Lung and Infiltration Volumes on Chest CT for Predicting Clinical Severity and Mortality in Viral Pneumonia: Insights from COVID-19 Experience

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Abstract

Aim: This study aimed to evaluate the relationship between lung volume, infiltration volume, and percentage of involvement with laboratory findings, hospitalization status, and mortality in patients with pneumonia.

Materials and Methods: This retrospective and observational study was conducted on 125 patients who presented to the emergency department between January and June 2021 and had pulmonary infiltration detected on chest computed tomography. The patients' lung volume, infiltration volume, and percentage of involvement were assessed along with laboratory parameters, hospitalization level, and mortality status.

Results: Among the 125 patients included, 56.8% were male and 43.2% were female, with a mean age of 49.8 ± 14.4 years. Severity categories were as follows: mild in 85 (68.0%), moderate in 23 (18.4%), and severe in 17 (13.6%) patients. The mean total lung volume was 3034.4 ± 1271.9 mL overall, 3398.7 ± 1346.7 mL in the mild group, and 2192.9 ± 466.8 mL in the severe group ($p < 0.001$). The mean infiltration volume was 271.4 ± 309.3 mL overall, 97.2 ± 77.9 mL in the mild group, 456.7 ± 162.9 mL in the moderate group, and 891.9 ± 231.1 mL in the severe group ($p < 0.001$). Mortality rates were 1.2% in the mild group, 30.4% in the moderate group, and 70.6% in the severe group, showing a direct association between mortality and the severity of involvement ($p < 0.001$). Age, severity of involvement, C-reactive protein (CRP), and troponin levels were positively correlated with mortality.

Conclusion: In pneumonia cases, reduced lung volume, increased infiltration volume, and a higher percentage of lung involvement are predictive of mortality. Additionally, elevated CRP and troponin levels show a significant correlation with both the percentage of involvement and mortality.

Keywords: Emergency department, lung volume, pneumonia, involvement volume, mortality, COVID-19

Introduction

The chest imaging features associated with this lethal disease are crucial for achieving accurate and early diagnosis of coronavirus disease 2019 (COVID-19) (1). However, accurately predicting the impact of a disease on a patient's life, which includes both the likelihood of mortality and the severity of the illness, can be difficult. This can result in a variety of outcomes, including the absence of symptoms and severe and potentially fatal consequences. The diagnostic approach is based on a combination of factors, including a patient's history of exposure,

clinical features, reverse transcription polymerase chain reaction (RT-PCR) testing, chest X-ray (CXR), and computed tomography (CT) of the thorax (2).

Microbiological testing, specifically real-time polymerase chain reaction (RT-PCR) or sequencing methodologies, is the gold standard for COVID-19 verification. Samples from the respiratory tract are used to conduct these procedures (3). CXR can be employed as the initial imaging method in COVID-19 pneumonia because it is simpler to clean the device, allows for bedside application, and contains lower radiation doses. Nevertheless,



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its sensitivity is lower than that of CT because low densities are challenging to detect and may be considered normal in the early stages (4). The chest CT is employed as a diagnostic instrument for COVID-19 patients to evaluate the severity of the disease, identify diagnostic challenges, and select the most suitable treatment approach. COVID-19 pneumonia is frequently characterized by bilateral multifocal peripheral ground-glass opacities, as evidenced by a chest CT scan (5). In comparison to RT-PCR, chest CT imaging may provide a more reliable, convenient, and rapid method for the diagnosis and evaluation of COVID-19 (6).

The detailed examination of tomographic imaging, which has made a significant contribution to diagnosis and treatment, has been necessary over time. Hospitals are able to prioritize medical efforts, particularly when human resources are scarce, by classifying the severity of COVID-19 in at-risk patients. Numerous studies have developed severity score systems to evaluate the extent of COVID-19 pulmonary involvement (7-10). Although these scores enhanced the assessment of COVID-19 severity, they were not without their limitations. They require time due to their complexity. Evaluation is difficult, due to the extensive scoring in specific scores that range from 20 to 40 regions. Secondly, the right lung is larger than the left lung in overall size, not in terms of chambers or segments. Dedicated software and a trained operator are necessary even for quantitative methodologies that quantify pneumonic lesion volume (11,12).

This study aimed to illustrate the influence of this involvement percentage (IP) on clinical and mortality outcomes in light of the previous findings. This was achieved by calculating the ratio of the involvement volume to the total volume of the patient's lung in a more consistent manner, irrespective of the segment, lobe, or side.

Materials and Methods

The study was conducted in accordance with the ethical principles outlined in the Declaration of Helsinki and with the consent of the Institutional Ethics Committee (protocol code: 129, date: 15.03.2021) prior to its commencement.

Study Design and Data

This retrospective and observational study was conducted in the emergency department of a tertiary training and research hospital between January 1 and June 30, 2021. During this period, a total of 2911 consecutive adult patients (≥ 18 years) who underwent both RT-PCR testing for SARS-CoV-2 and chest CT at their initial emergency department presentation were screened for eligibility.

According to the World Health Organization definition, only patients with a positive RT-PCR result were considered confirmed COVID-19 cases. Therefore, RT-PCR-negative patients were excluded prior to eligibility assessment. Subsequently, a series of exclusion criteria were applied to ensure data consistency and homogeneity of the study population.

Hospitalization level (general ward vs. intensive care unit) and mortality outcomes were extracted from the institutional electronic medical record system and verified with patient follow-up documentation. Quantitative CT parameters—including lung volume (LV), infiltration volume (IV), and $[IP = (IV/LV) \times 100]$ —were recorded for each patient. For interpretability, LV was categorized as 1000-2000, 2000-3000, 3000-4000, and >4000 mL, and IP was used to classify involvement severity (IS) as mild (0-15%), moderate (15-30%), and severe ($>45\%$).

Inclusion and Exclusion Criteria

Patients aged 18 years or older with a positive RT-PCR test result for SARS-CoV-2 and evidence of parenchymal infiltration on chest CT—manifesting as ground-glass opacity and/or consolidation—were included in the study. Only those with complete demographic, laboratory, imaging, and outcome data were eligible for analysis. Patients were excluded if they had a negative RT-PCR result for SARS CoV-2 ($n=1387$), no parenchymal infiltration on CT ($n=534$), or incomplete or poor-quality imaging and/or missing laboratory data, including cases with motion artifacts or inadequate CT coverage ($n=428$). Additionally, individuals with known chronic comorbidities such as chronic obstructive pulmonary disease, congestive heart failure, malignancy, or chronic kidney disease ($n=268$), as well as those under 18 years of age ($n=45$) or duplicate/repeat hospital admissions ($n=37$), were excluded from the analysis.

After applying all exclusion criteria, 1,212 RT-PCR-positive patients remained eligible for inclusion. From this refined cohort, 125 patients were consecutively included according to the predefined inclusion criteria until the target sample size was reached (Figure 1). This approach ensured that cases were selected consecutively and without arbitrary sampling, thereby representing a clinically and temporally unbiased subset of COVID-19 pneumonia patients during the study period.

Power Analysis

Prior to analysis, a sample size justification was performed using G* Power version 3.1. The primary endpoint was in-hospital mortality, with quantitative CT metrics (IV and IP) as the main predictors. A logistic regression framework was adopted, assuming:

Two-tailed $\alpha=0.05$

Statistical power $(1-\beta)=0.80$

Expected effect size [odds ratio (OR) ≈ 1.8 per SD change in IP]

Anticipated mortality rate=15-20%, consistent with prior emergency department data

Based on these assumptions, the minimum requisite sample size was calculated to be between 110 and 130 individuals, which corresponds to our final cohort of 125 patients. A post hoc power analysis utilizing the observed area under the ROC curve [area under the curve (AUC) =0.92, where IV predicted mortality] confirmed a power exceeding 0.90, hence validating the statistical sensitivity for the study's primary purpose. The study population and sample size were considered methodologically sound and aligned with established norms for retrospective observational research.

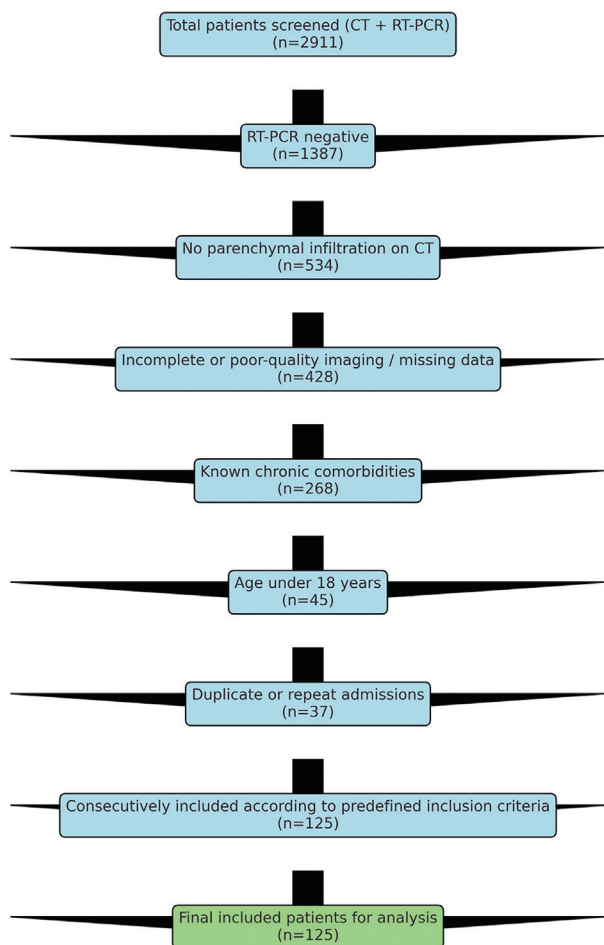


Figure 1. Patient selection flow diagram

CT: Computed tomography, RT-PCR: Reverse transcription polymerase chain reaction

Laboratory Analysis

Laboratory data were obtained from the institutional electronic medical record system, including white blood cell (WBC) count, creatinine (CRE), alanine aminotransferase, aspartate aminotransferase (AST), C-reactive protein (CRP), and troponin (TRP) values for each case. Complete blood count analyses were performed using the Sysmex DI-60 Hematology Analyzer (Sysmex Corp., Kobe, Japan), and biochemical parameters were measured with the Beckman Coulter AU-680 Automated Chemistry Analyzer (Beckman Coulter, Inc., Fullerton, CA, USA). All hematologic and biochemical results were processed and reported within approximately 45-60 minutes after sample collection.

CT Imaging and Volume Calculation

All chest CT exams were conducted using a Siemens SOMATOM Edge 128-slice multidetector CT scanner (Siemens Healthcare GmbH, Erlangen, Germany). Scans were conducted in the supine position during a single inspiratory breath-hold. The imaging settings included collimation of 128×0.6 mm, a rotation duration of 1.0 s, a pitch of 0.8, a tube voltage of 120 kVp, and automatic tube current modulation. Image reconstruction was executed with a 5 mm slice thickness and a 3 mm interval, utilizing a high-resolution reconstruction kernel (B70f). The CTDIvol measured 4.3 mGy, and the DLP was 175 mGy·cm.

All volumetric analyses were performed using Siemens Syngo software. Employing the VB30 workstation, utilizing the “lung analysis” and “MM reading” modules for semi-automated three-dimensional segmentation. The lung parenchyma algorithm automatically segmented each lung according to voxel density distribution. Subsequent to automatic segmentation, the radiologist meticulously adjusted the contours to exclude significant arteries, bronchi, and pleural effusions as required.

The IV was measured using a voxel-based density thresholding method, wherein all lung voxels within the attenuation range of -750 to -300 Hounsfield units (HUs) were classified as exhibiting inflammatory involvement (ground-glass opacity or consolidation). The software automatically calculated for each patient:

LV: The aggregate volume of aerated lung parenchyma (in mL).

IV: The total volume of voxels designated as infiltration within the specified HU range (in mL).

IP is determined using the formula, $IP = (IV/LV) \times 100$, which indicates the fraction of lung parenchyma impacted by inflammation.

All measures were conducted by two radiologists who have 10 years of expertise in thoracic imaging and who were unaware

of the clinical results. To guarantee intra-observer reliability, each segmentation and volume extraction was conducted twice, one week apart, and the mean data were utilized for statistical analysis. Inter-observer variability was not evaluated, as the complete dataset was examined by a single reader adhering to the defined workflow methods.

After volumetric analysis, the LV, IV and [IP = (IV/LV) × 100] were automatically calculated and recorded for each patient. To facilitate clinical interpretation, LV values were categorized into four subgroups (1000-2000 mL, 2000-3000 mL, 3000-4000 mL, and >4000 mL). Based on the IP values, the IS was classified as mild (0-15%), moderate (15-30%), and severe (>45%). Hospitalization and mortality data were obtained from the institutional electronic medical records and patient follow-up forms.

Statistical Analysis

All statistical analyses were performed using IBM SPSS Statistics version 26.0 (IBM Corp., Armonk, NY, USA). Continuous variables were presented as mean ± standard deviation (SD) or median (interquartile range) according to their distribution, while categorical variables were expressed as counts and percentages. Group comparisons were made using the Student's t-test or Mann-Whitney U test for continuous variables and the χ^2 test for categorical variables. To identify factors associated with disease severity and mortality, univariate logistic regression analyses were first performed. Variables with $p < 0.05$ in the univariate analysis were subsequently entered into a multivariate logistic regression model to control for potential confounding effects. The variables tested included age, TRP, WBC count WBC, CRP, LV, IV, and IP. Results were expressed as ORs) with 95% confidence intervals

(CIs). Model performance was further assessed using ROC curve analysis, and the AUC values, were calculated to evaluate the predictive accuracy of quantitative CT parameters for mortality. A two-tailed p -value < 0.05 was considered statistically significant.

Results

The mean age of the 125 patients [71 (56.8%) male, 54 (43.2%) female] included in the study was 49.78 ± 14.40 years and there were 85 (68.0%) mild, 23 (18.4%) moderate, 17 (13.6%) severe cases in the IS groups. It was observed that IS increased with increasing age ($p < 0.001$). The increase in CRP and TRP levels also showed a significant relationship with IS ($p < 0.001$). While LV was determined to be 3034.37 ± 1271.86 ml in all cases, it was 3398.71 ± 1346.68 ml in the mild group and 2192.87 ± 466.78 mL in the severe group ($p < 0.001$). In the IV evaluation, the mean IV value of the cases was 271.42 ± 309.34 ml. In the mild group, it was 97.17 ± 77.93 mL; in the moderate group, 456.73 ± 162.91 mL; and in the severe group, 891.99 ± 231.09 mL ($p < 0.001$). IP values were 3.44 ± 3.31 , 19.71 ± 3.71 , and 40.80 ± 6.59 in the groups, respectively ($p < 0.001$) (Table 1).

When variables were evaluated according to mortality status, the mean age in the mortality group was 62.30 ± 12.29 years ($p < 0.001$). High CRP and TRP levels were also significantly associated with mortality ($p < 0.001$). In the mortality group, LV was 2441.22 ± 1057.59 ml ($p < 0.017$). IV and IP were 743.99 ± 331.16 mL and 33.01 ± 12.61 % in the mortality group and 181.41 ± 207 (21) mL and 7.42 ± 9.59 % in the survival group. Both were significantly higher in the mortality group ($p < 0.001$) (Table 2).

Table 1. Age, laboratory and involvement data according to the severity of involvement

	All patients n (%): 125 (100)	Involvement severity			p value*
		Mild n (%): 85(68.0)	Moderate n (%): 23 (18.4)	Severe n (%): 17 (13.6)	
	Mean ± SD	Mean ± SD	Mean ± SD	Mean ± SD	
Age (year)	49.78±14.40	45.34±11.92	59.83±16.03	58.35±13.43	<0.001
WBC (10 ³ /UL)	7.26±3.75	6.47±2.65	7.64±3.20	10.66±6.51	0.027
CRE (mg/dL)	0.89±0.58	0.90±0.66	0.92±0.38	0.87±0.37	0.429
ALT (IU/L)	33.60±27.99	35.27±28.31	38.56±33.15	18.59±7.95	0.035
AST (IU/L)	43.93±32.31	44.14±26.91	56.52±51.19	25.82±10.61	0.014
CRP (mg/dL)	67.12±68.13	44.72±52.01	104.64±46.79	128.35±100.47	<0.001
TRP (ng/L)	20.33±95.86	4.83±3.68	8.38±8.26	114.03±245.45	<0.001
LV (mL)	3034.37±1271.86	3398.71±1346.68	2309.86±652.50	2192.87±466.78	<0.001
IV (mL)	271.42±309.34	97.17±77.93	456.73±162.91	891.99±231.09	<0.001
IP (%)	11.52±13.79	3.44±3.31	19.71±3.71	40.80±6.59	<0.001

*: Kruskal Wallis test, SD: Standart deviation, WBC: White blood cell, CRE: Creatinine, ALT: Alanine aminotransferase, AST: Aspartat aminotransferase, CRP: C-reactive protein, TRP: Troponin LV: Lung volume IV: Involvement volume IP: Involvement percentage

When the variables were evaluated for IS, no significance was found between gender and IS ($p=0.180$). In the severe group, 11 (64.7%) patients of 17 patients had LV between 2000-3000 mL, and 6 (35.3%) had LV between 1000-2000 mL. In the severe group, there was no patient with LV over 3000 mL. In the moderate group, there was no patient who had LV<4000 ($p<0.001$). In the mild group, there was no patient followed up in intensive care. Thirteen (56.5%) in the moderate group and 12 (70.6%) in

the severe group were followed up in intensive care ($p<0.001$). Mortality was observed in 1 (1.2%) mild, 7 (30.4%) moderate, and 12 (70.6%) severe group cases, and increased with the severity of involvement ($p<0.001$) (Table 3).

Age, IS, CRP, and TRP revealed a strong positive correlation with mortality. While a strong negative correlation was determined between LV and mortality, a weak negative correlation was observed between AST and mortality (Table 4).

Table 2. Age, laboratory and involvement data according to mortality status

Mortality			
	No n (%): 105 (84.0)	Yes n (%): 20 (16.0)	p value*
	Mean \pm SD	Mean \pm SD	
Age (year)	47.39 \pm 13.56	62.30 \pm 12.29	<0.001
WBC (10^3 /UL)	6.65 \pm 2.60	10.45 \pm 6.49	0.053
CRE (mg/dL)	0.91 \pm 0.62	0.85 \pm 0.34	0.798
ALT (IU/L)	36.21 \pm 29.68	19.95 \pm 7.58	0.053
AST (IU/L)	47.15 \pm 34.09	27.00 \pm 9.69	0.005
CRP (mg/dL)	56.06 \pm 56.08	125.18 \pm 94.11	<0.001
TRP (ng/L)	5.08 \pm 3.59	100.43 \pm 227.74	<0.001
LV (mL)	3147.35 \pm 1282.11	2441.22 \pm 1057.59	0.017
IV (mL)	181.41 \pm 207.21	743.99 \pm 331.16	<0.001
IP (%)	7.42 \pm 9.59	33.01 \pm 12.61	<0.001

*: Mann-Whitney U tes test, SD: Standart deviation, WBC: White blood cell, CRE: Creatinine, ALT: Alanine aminotransferase, AST: Aspartat aminotransferase, CRP: C-reactive protein, TRP: Troponin LV: Lung volume IV: Involvement volume IP: Involvement percentage

Table 3. Evaluation of the involvement severity in gender, lung volume, hospitalization and mortality groups

		Involvement severity				p value*	
		Mild	Moderate	Severe	All patients		
		n (%)	n (%)	n (%)	n (%)		
Gender	Male	50 (58.8)	15 (65.2)	6 (35.3)	71 (56.8)	0.180	
	Female	35 (41.2)	8 (34.8)	11 (64.7)	54 (43.2)		
lung volume	1000-2000	10 (11.8)	7 (30.4)	6 (35.3)	23 (18.4)	<0.001	
	2000-3000	32 (37.6)	13 (56.5)	11 (64.7)	56 (44.8)		
	3000-4000	18 (21.2)	3 (13.0)	0 (0)	21 (16.8)		
	4000<	25 (29.4)	0 (0)	0 (0)	25 (20.0)		
	Inpatient service	85 (100)	10 (43.5)	5 (29.4)	100 (80.0)		<0.001
	Intensive care	0 (0)	13 (56.5)	12 (70.6)	25 (20.0)		
mortality	No	84 (98.8)	16 (69.6)	5 (29.4)	105 (84.0)	<0.001	
	Yes	1 (1.2)	7 (30.4)	12 (70.6)	20 (16.0)		
Total		85 (100)	23 (100)	17 (100)	125 (100)		

*: Chi-square test

In the univariate logistic regression analysis, several clinical and radiological parameters—including age, TRP, CRP, IV, and IP—were found to be significantly associated with both disease severity and mortality ($p < 0.05$ for each). When these variables were further evaluated in the multivariate logistic regression model, age, TRP, and IP remained independent predictors of mortality ($p < 0.05$), whereas other factors lost statistical significance after adjustment for potential confounders. Among quantitative CT parameters, IP demonstrated the strongest independent association with mortality, indicating that a higher

percentage of parenchymal involvement was linked to worse clinical outcomes (Table 5).

According to ROC curve analysis, the optimal cut-off values for affected volume and LV to predict mortality were identified with a threshold of 45%, yielding 97.1% sensitivity and 95.0% specificity for affected volume (AUC: 0.920; 95% CI: 0.847-0.992, $p < 0.001$) and 81.9% sensitivity and 78.1% specificity for LV (AUC: 0.331; 95% CI: 0.213-0.450, $p = 0.017$). (Figure 2). An IP cut off of 45% on initial chest CT predicted mortality with high accuracy (AUC: 0.92, $p < 0.001$). Clinically, patients exceeding this threshold were substantially more likely to require ICU admission, suggesting that this level of pulmonary involvement may represent a critical threshold for early escalation of care.

Discussion

Pneumonia cases are frequently presented to the emergency department and are an important cause of morbidity and mortality. In pneumonia cases, the clinical course and prognosis can be affected by many factors, such as the patient's age, additional diseases, and the agent of pneumonia. Although there may be no infiltration on CT in pneumonia, we thought that the area of pulmonary involvement in cases with infiltration may also affect the clinical course. This study was motivated by the hypothesis of both LV and IV affecting the clinical outcome of cases of an atypical viral pneumonia, such as COVID-19. While evaluating these, we also had the opportunity to assess the relationship between some laboratory parameters and infiltration and clinical outcome.

	Mortality	
	r	p value*
Age	0.373	0.001
Gender	0.016	0.861
LV	-.210	0.019
IS	0.637	<0.001
WBC (10 ³ /UL)	0.174	0.053
CRE (mg/dL)	0.023	0.799
ALT (IU/L)	-0.174	0.052
AST (IU/L)	-0.255	0.004
CRP (mg/dL)	0.340	<0.001
TRP (ng/L)	0.362	<0.001

*Spearman's rho correlation, IS: Involvement severity, LV: Lung volume, WBC: White blood cell, CRE: Creatinine, ALT: Alanine aminotransferase, AST: Aspartat aminotransferase, CRP: C-reactive protein, TRP: Troponin

		Univariate			Multivariate		
		OR	95% CI	p value	OR	95% CI	p value
Involvement severity	Age	0.445	0.020-0.870	0.040	0.551	0.017-0.912	0.012
	TRP	1.404	1.280-1.528	<0.001	1.392	1.261-1.613	0.016
	WBC	0.938	0.667-1.199	<0.001			
	CRP	1.113	0.954-1.271	<0.001			
	LV	2.141	1.834-2.448	<0.001			
	IV	0.876	0.806-0.946	<0.001			
	IP	0.878	0.829-0.927	<0.001	0.893	0.852-1.011	<0.001
Mortality	Age	1.079	1.038-1.121	<0.001	1.080	1.004-1.161	0.039
	TRP	1.216	1.103-1.340	<0.001	1.180	1.030-1.353	0.017
	WBC	1.249	1.102-1.415	<0.001			
	CRP	1.013	1.006-1.021	0.001			
	LV	0.999	0.999-1.000	0.030			
	IV	1.006	1.004-1.008	<0.001			
	IP	1.147	1.090-1.206	<0.001	1.331	1.046-1.695	0.020

OR: Odds ratio, CI: Confidence interval, WBC: White blood cell, TRP: Troponin, CRP: C-reactive protein, LV: Lung volume IV: Involvement volume IP: Involvement percentage

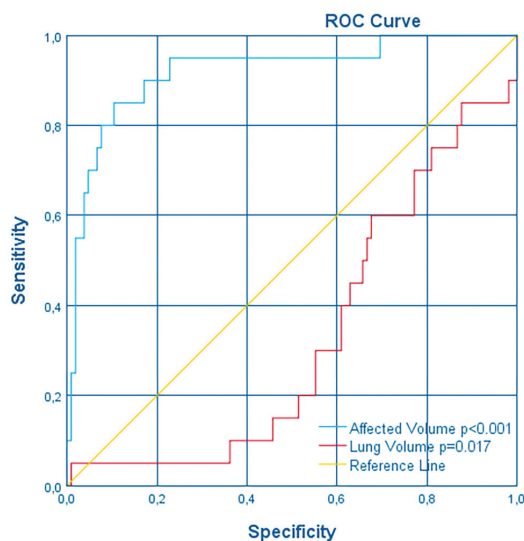


Figure 2. ROC curves showing the diagnostic performance of infiltration volume and involvement percentage for predicting mortality

Ground glass opacities are the predominant CT finding in cases of COVID-19 pneumonia. Research has documented their characteristic profiles: bilateral, peripheral, multilobar, and posterior localization (13). Ground glass opacities may be observed either independently or in conjunction with consolidation, thickening of the interlobular septum, and dilatation of blood vessels (14). Consolidations often have multifocal, segmental patchy patterns primarily observed in the lower lobe and peripheral areas, and may also include air bronchograms (15). It has been documented that they are more commonly seen in individuals of advanced age, in patients who have seen disease progression, or in the later stages of the illness (15). The experiments conducted by Pan et al. (10) revealed that consolidation is infrequent during the initial phases, but it undergoes expansion and diffusion in subsequent stages.

If we look at the main factors of age and gender, Ozdemir et al. (16) have shown in compatible studies that clinical severity increases significantly with increasing age. Regarding gender, Jin et al. (17) reported that male patients showed a worse prognosis in their study on gender factors. Similarly, in our study, we observed that both the volume involved and mortality increased significantly with increasing age. However, in our study, there was no association between gender and mortality. Unlike other studies, we did not include cases with additional diseases in our study. With this result, we can state that gender has no relationship with prognosis, even if we exclude additional diseases.

Inflammatory markers have been shown to be associated with disease severity and prognosis in COVID-19 (18,19). It is known

that blood CRP and WBC elevation are associated with oxygen demand and disease severity (18,19). Many studies in the literature have reported different results regarding blood cell counts associated with the immune response. In one study, increased CRP and CRE were found to be associated with a high mortality rate. A strong relationship between increased CRP and acute lung injury in COVID-19 cases was previously shown in a study (20). Another analysis showed that CRP was higher in the group with higher severity (21). In the study by Majure et al. (22) including 6247 COVID-19 patients, TRP was a predictor of death, and significantly increased mortality rates were observed in the group of patients with high TRP levels compared to patients with normal TRP levels. Du et al. (23) studies have shown that advanced age (≥ 65), pre-existing concurrent cardiovascular or cerebrovascular diseases, and especially high cTnI levels of 0.05 ng/mL and above are important biomarkers for mortality in COVID-19 pneumonia patients. In our study, the relationship between some laboratory parameters and the increase in IV and mortality was evaluated. The increase in WBC, CRP, and TRP values was related to both IV and mortality, similar to findings of other studies. However, we found that CRE values were not related to these variables. This may be because we did not include chronic renal failure patients in our study, which evaluated spontaneous CRE values in cases without additional diseases.

A study by Saeed et al. (24) revealed a significant correlation between CT score and both lymphopenia and elevated levels of serum CRP, D-dimer, and ferritin. Furthermore, Zhang et al. (25) observed a positive correlation between chest CT score and CRP, erythrocyte sedimentation rate, WBC count, procalcitonin, and impaired coagulation function, and a negative correlation with lymphocyte count.

The typical findings in COVID-19 pneumonia and the changes in findings over time in the course of the disease, as well as rare and atypical findings, have been described in many studies (26). However, it should not be forgotten that similar findings can be seen in many diseases such as viral pneumonia, especially influenza, organized pneumonia, or drug toxicity. Typical CT findings and changes in findings over time have been described in the diagnosis and triage of COVID-19 pneumonia. With thoracic CT, areas with increased density, number of segments of pneumonia, and the extent to which each segment is involved can be scored using various software or visually, and the rate of lung involvement and severity of inflammation can be predicted (27). Determining severity can help predict which patients need hospitalization and mechanical ventilation. It has been reported that not only the area covered by lesions but also some findings is effective in predicting severity.

Li et al. (28) reported that a decline in the total lung capacity suggested a poor prognosis. The study conducted by Lanza et al. (29) revealed that patients with COVID-19 who required intubation had reduced total LV. Carvalho et al. (30) showed that the degradation of lung capacity directly correlated with the escalation of disease severity. In contrast to the majority of research, Ippolito et al. (31) did not demonstrate a correlation between the reduction in LV and a negative prognosis. Varying technical specifications may exist in the three-dimensional applications and devices employed in these investigations carried out at different centers. In addition, Uzun et al. (32) reported in their study that mortality increased with decreasing LV values in both sexes. In our study, consistent with previous research, both the severity and percentage of pulmonary involvement and the mortality rate were higher in patients with lower total LV. This finding can be physiologically explained by the fact that a reduction in vital capacity increases the work of breathing, leading to impaired ventilation efficiency and a higher proportional involvement of the remaining functional lung tissue.

The primary observation of COVID-19 pneumonia on thorax CT was the extensive involvement of peripheral and particularly posterior regions, as well as consolidation areas. Our findings were consistent with those documented in existing literature (33,34). Timely and precise medical evaluation of patients and proper treatment of their illnesses before they deteriorate are crucial (35). Several chest CT scoring systems were created to establish a uniform criterion for evaluating the extent of radiological lung involvement (36,37). Analysis of chest CT severity grading systems was conducted to assess interobserver agreement, revealing a high level of agreement. Nevertheless, other research is necessary to validate the findings due to the limited number of severe and critically ill patients included in both reviews. Although we created groups classifying severity as mild, moderate, and severe in the study, we think that calculating the involvement volume as a numerical percentage directly makes the results more realistic. Most studies have been conducted on the CT severity score (38), and although they show similar results to our study, our specific numerical IP calculation makes the result more valuable. As reported by Li et al. (9), the current chest CT score demonstrated a sensitivity of 80% and specificity of 82.8%, with a threshold value of 7. A semi-quantitative CT-SS devised by Pan et al. (10) was used by Francone et al. (33) to determine that a CT score of ≥ 18 was linked to a higher risk of mortality.

As mentioned above, previous studies have investigated the relationship between the extent of pulmonary involvement on CT and both clinical severity and mortality. In the present study, we similarly demonstrated that reduced total LV, a

higher percentage of pulmonary involvement, and the overall severity of infiltration were all directly associated with increased mortality. Unlike several earlier studies that categorized disease severity using semi-quantitative CT scores, our analysis directly calculated the IP, which provided a more objective and reproducible indicator of disease burden. As the percentage of lung involvement increased, both mortality rates and ICU admissions rose proportionally. Consistent with this radiologic progression, inflammatory biomarkers such as CRP, WBC, and TRP levels also showed a significant positive correlation with the degree of parenchymal involvement.

The strongest discrimination for mortality prediction was achieved with an IP cutoff value of approximately 45% evidenced by the ROC curve analysis, which gave an AUC of 0.92. In the clinical setting, this threshold may function as an early radiological marker to identify patients who are at risk of accelerated deterioration. Patients who presented with a parenchymal involvement of $\geq 45\%$ on their initial chest CT were more likely to require admission to the intensive care unit and had a significantly higher mortality rate. This observation implies that the quantitative CT assessment of lung involvement may facilitate early risk stratification and triage decisions in the emergency department. Previous imaging-based investigations have disclosed comparable results. For example, Colombi et al. (39) found that patients with more than 40-50% lung involvement on admission CT had significantly higher rates of ICU admission and mortality than those with moderate disease. Other studies have verified that quantitative CT metrics are significantly correlated with the severity of hypoxemia, inflammatory markers, and short-term outcomes in viral pneumonias, such as COVID-19 (33,40). Consequently, a clinically meaningful and reproducible cut-off of approximately 45% for IP may be used to identify patients at high risk, offering both radiologic and prognostic insight during the initial evaluation. Integrating quantitative CT assessment into emergency department workflows may help physicians identify high-risk patients earlier, guide timely escalation of care, and improve the allocation of critical care resources during surges of viral pneumonia cases.

Study Limitations

This research contains several limitations that necessitate acknowledgment. Initially, the research was conducted in a single-center, retrospective design, which may inherently restrict the generalizability of the findings and introduce selection bias. Nevertheless, a representative sample was guaranteed by the consecutive inclusion of all eligible patients in accordance with predefined criteria, thereby mitigating potential bias. Secondly, the internal validity of the results was improved by the implementation of stringent inclusion and exclusion

criteria, which in turn resulted in a more homogeneous study population, despite the fact that the sample size (n=125) was modest in comparison to the total number of screened cases. Third, only the initial chest CT scans that were obtained at the time of presentation were analyzed. As a result, the temporal evolution of lung involvement could not be assessed, and alterations in CT findings during the clinical course remain unexplored. Further longitudinal investigations that incorporate serial CT examinations are necessary to resolve this limitation. Fourth, to mitigate confounding effects, patients with substantial chronic comorbidities were excluded. Although this method restricts the external generalizability of the results to broader COVID-19 populations, it facilitated a more precise evaluation of the isolated impact of acute viral pneumonia on outcomes. Ultimately, two seasoned radiologists, each with over a decade of experience in thoracic imaging, conducted quantitative CT analyses independently. Despite the absence of formal quantification of inter-observer agreement, both readers adhered to standardized segmentation protocols and cross-validated a subset of cases to guarantee consistency. This dual-reader design significantly reduces subjective bias and improves the reliability of volumetric measurements. The present study provides a unique, quantitative, and reproducible perspective on the relationship between patient outcomes and CT-derived lung involvement, despite these limitations. The results may be a valuable reference for future multicenter prospective investigations that involve a more diverse and extensive patient population.

Conclusion

This study revealed that both quantitative increases in infiltration, and decreases in total LV on chest CT are strongly associated with adverse outcomes in viral pneumonia. A greater volume of infiltration and percentage of involvement were significantly associated with disease severity, intensive care unit hospitalization, and mortality, whereas a reduced total LV indicated advanced parenchymal damage and compromised breathing capacity. As pulmonary involvement intensified, markers of inflammation (CRP, WBC) and heart damage (TRP) increased correspondingly, highlighting a strong correlation between radiologic burden and systemic response. Among all quantitative CT characteristics, IP exhibited the most reliable predictive capability, serving as an independent indicator of worse prognosis. The findings indicate that quantitative CT assessment, encompassing both infiltration and volume analysis, might offer objective early risk classification and may inform clinical decision-making and resource allocation in emergency care.

Ethics

Ethics Committee Approval: The study was conducted in accordance with the ethical principles outlined in the Declaration of Helsinki and with the consent of the Institutional Ethics Committee (protocol code: 129, date: 15.03.2021) prior to its commencement.

Informed Consent: This is a retrospective study.

Footnotes

Author Contributions

Surgical and Medical Practices: B.D., Concept: B.D., Design: B.D., E.F., Data Collection or Processing: B.D., E.F., A.C., S.G., Analysis or Interpretation: B.D., E.F., A.C., S.G., Literature Search: B.D., E.F., A.C., S.G., Writing: B.D., E.F.

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