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Research Article

Evaluation of COVID-19 Findings on Thoracic CT: Is There any Correlation with Age and Comorbidity?

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Abstract

Aim: To share insights gained from low-dose thoracic computed tomography (CT) findings of patients diagnosed with COVID-19. Additionally, we aimed to evaluate the correlation between the observed CT findings, CT severity index, patient age, and the presence of comorbid conditions.

Material and Method: One hundred patients having a COVID-19 diagnosis were included in the study's sample. We meticulously reviewed the thoracic CT image characteristics, the lung severity index, and various clinical data related to the patients. The relationships between these factors were then analyzed to draw meaningful conclusions.

Results: The study included 100 patients, consisting of 67 men and 33 women. Among these patients, 30 had at least one underlying comorbid condition, with hypertension being the most prevalent. CT scans were positive in 65 patients. Within this group, 60 patients (93.3%) exhibited ground-glass opacities (GGO), 27 patients (41.5%) showed signs of consolidation, 22 patients (33.8%) had both GGO and consolidation, and 8 patients (12.3%) displayed the crazy paving pattern. The total lung severity score (TLSS) ranged from 0 to 19, with mean score of 3.11±3.71. Each lung lobe was systematically evaluated for the extent of involvement. We found a statistically significant relationship indicating that increasing age correlated with higher grades of lung involvement. Furthermore, significant association was noted between presence of comorbidities and the lung involvement grades. Our analysis revealed a moderate positive correlation between CT lung involvement grade and patient age, alongside a weaker positive correlation between the lung involvement grade and comorbid conditions.

Conclusion: CT imaging has proven to be important tool in managing patients suspected of or confirmed to have COVID-19. Notably, the CT lung severity grade was significantly elevated in patients over 65 years and those with comorbidities. These findings underscore the critical role that CT plays in evaluating and managing the severity of COVID-19 pneumonia.

Keywords: COVID-19, comorbidity, computed tomography, computed tomography lung severity grade

INTRODUCTION

Severe Acute Respiratory Syndrome SARS-CoV-2, also known as the coronavirus, is an RNA virus that is encapsulated and attacks the respiratory system. It causes viral pneumonia known as Coronavirus Disease 2019 (COVID-19) (1,2).

The outbreak of COVID-19 first emerged in December 2019 in Wuhan, China, and rapidly escalated into a global pandemic, affecting millions of individuals worldwide. Characterized by its high transmissibility, SARS-CoV-2 can lead to severe respiratory illnesses, particularly pneumonia. Patients with COVID-19 typically present with a range of clinical symptoms, the most prevalent of which include fever, persistent cough, shortness of breath, and overall weakness (3).

For diagnosing COVID-19 pneumonia, real-time polymerase chain reaction (RT-PCR) tests play a pivotal role as the primary diagnostic method. However, it is important to note that these tests can sometimes yield false-negative results or may not detect the virus in its early stages of

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infection. This limitation can lead to delays in diagnosis and subsequent treatment (4,5). Consequently, imaging studies, particularly chest Computed Tomography (CT) scans, have become essential in the clinical evaluation of patients suspected of having COVID-19 pneumonia (5). Typical findings observed on chest CT in COVID-19 patients often include bilateral peripheral multifocal ground-glass opacities, subsegmental patchy consolidations, and a distinctive crazy paving pattern. These radiological features are frequently located in the lower lobes and posterior segments of the lungs (6,7).

The presence of underlying health conditions, referred to as comorbidities, can significantly worsen the clinical course of COVID-19 pneumonia, especially among older adults (8). Moreover, individuals with pre-existing comorbidities are at an increased risk of developing severe complications from the virus, which can lead to poor health outcomes (9).

In light of these factors, the objective of our study is to share our clinical experiences regarding the findings from low-dose thoracic CT scans in patients during the COVID-19 pandemic. We also aim to investigate the correlation between the severity of CT imaging findings and variables such as the patients' age and the presence of comorbid conditions. By doing so, we hope to contribute valuable insights into the clinical management of COVID-19 pneumonia.

MATERIAL AND METHOD

Patients Selection

The Helsinki Declaration's ethical criteria were followed in the conduct of this retrospective investigation, which was approved by our Institutional Clinical Research Ethics Committee (Decision no: 2020/273). We undertook a comprehensive review of patients who were admitted to the emergency department with suspected cases of COVID-19 between March 2020 and June 2020. Each of these patients underwent chest CT upon admission and was diagnosed with COVID-19 through RT-PCR testing of naso-oropharyngeal swabs.

For inclusion in our study, patients were required to have a confirmed COVID-19 diagnosis based on RT-PCR results obtained at the time of their admission. Additionally, the chest CT images had to be captured within the first 24 hours following the PCR test. Major exclusion criteria were: patients under 18 years of age, patients with unconfirmed PCR diagnosis, and patients with artifactual CT images that would interfere with appropriate evaluation. Initially, 108 patients were identified as meeting the inclusion criteria. However, after applying the exclusion criteria, 8 patients were removed from the study: one was found to be under 18 years of age, and seven others exhibited motion artifacts in their CT images, which rendered those images unsuitable for analysis. Consequently, a total of 100 patients were ultimately included in our investigation.

Clinical parameters—including age, gender, and the presence of comorbidities—were meticulously collected from the hospital information system.

Computed Tomography Imaging and Analysis of Images

All non-contrast chest CT images were acquired using a 16-section multidetector CT scanner (Toshiba Alexion, Tokyo, Japan). The imaging parameters were set as follows: kilovoltage peak (kVp) at 120, a rotation time of 0.75 seconds, a matrix size of 256x256, a slice thickness of 2 mm, and a low-dose algorithm to minimize radiation exposure. The existing low-dose CT protocol employed standard settings (AIDR3D, Canon Medical Systems, Otawara, Japan) to ensure consistent imaging quality while adhering to safety guidelines. The mean volume computed tomography dose index (CTDIvol) recorded was 3.3 mGy, with a range from 2.2 to 4.9 mGy, indicating a generally low radiation exposure for patients.

All CT images were carefully assessed using lung and mediastinum window settings to optimize the visibility of relevant structures. Two radiologists, each possessing 10 and 11 years of experience, respectively, independently evaluated the images without knowledge of the clinical data. They subsequently reached a consensus on their findings. The analysis of CT image features was organized into four primary categories: localization, infiltration pattern, additional features, and degree of lung involvement.

In the localization assessment, factors such as laterality, the specific lobes affected, and parenchymal distribution (whether central, peripheral, or diffuse) were thoroughly examined. The evaluation of infiltration patterns focused on identifying various characteristics, including ground-glass opacities (GGO), consolidations, GGO accompanied by consolidation, nodular lesions, crazy paving patterns, linear-reticular patterns, reverse halo sign, and vascular enlargement, as depicted in Figure 1. Additional CT features assessed included mediastinal lymphadenopathy (LAP), pleural effusion, thickening of the bronchial walls, bronchiectasis, halo sign, pericardial effusion, and the presence of an air bubble sign, illustrated in Figure 2.

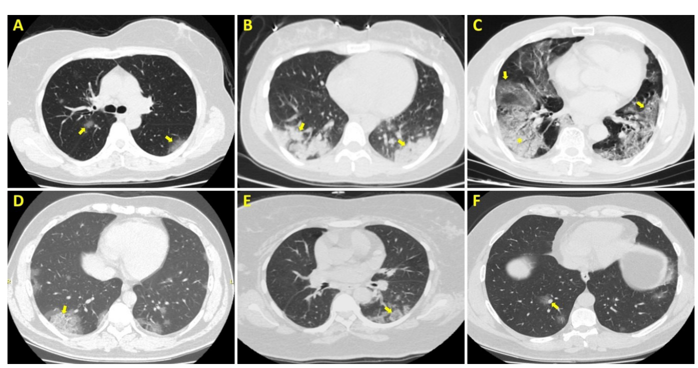

Figure 1. Parenchymal infiltration patterns of COVID-19 in lungs; **A.** ground glass opacity, **B.** consolidation, **C.** ground glass opacity (arrow) with consolidation (asterisk), **D.** crazy-paving pattern, **E.** reverse halo sign, **F.** vascular enlargement

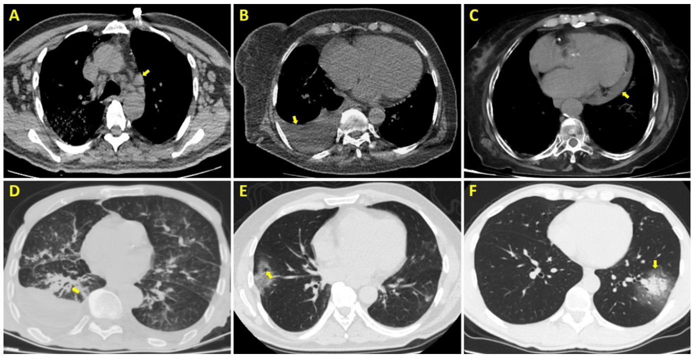

Figure 2. Other CT findings of COVID-19 on thoracic CT; **A.** mediastinal lymphadenopathy, **B.** pleural effusion, **C.** pericardial effusion, **D.** bronchial wall thickening, **E.** air bubble sign, **F.** halo sign

Lung severity scoring was performed according to established guidelines documented in the literature (5). Each lung lobe was evaluated for the extent of involvement and categorized into five categories. The overall lung involvement score, which ranges from 0 points to 20 points, was calculated by adding the degree of participation for each lobe. Patients were categorized based on their CT lung severity score as follows: a score of 0 classified as grade 0, scores between 1-5 as grade 1, scores of 6-10 as grade 2, scores of 11-15 as grade 3, and scores of 16-20 as grade 4. This systematic approach provided a comprehensive evaluation of lung involvement in patients diagnosed with COVID-19.

Statistical Analysis

The statistical software Statistical Package for the Social Sciences 18.0 (SPSS, IBM, Chicago, USA) was used to conduct the statistical analysis for this investigation. For the presentation of data, all quantitative variables were expressed as means accompanied by standard deviations, along with their respective ranges. Meanwhile, categorical variables were summarized as counts and percentages, offering a comprehensive overview of data distribution. This approach facilitated a clearer understanding of the characteristics and relationships within the dataset.

A test of normality was performed to assess whether the quantitative variables adhered to a normal distribution, which is essential for determining the appropriate statistical tests to apply. We used the Fisher Freeman Halton test, an appropriate technique for evaluating categorical data, to assess the association between the grade of CT lung involvement and variables including age and the existence of comorbidities. Furthermore, correlation analyses were conducted to explore the relationships between CT lung involvement grades and age, as well as CT lung involvement grades and comorbidities. The Spearman nonparametric correlation coefficient was utilized for this purpose, providing insights into the strength and direction of these associations without the assumption of normality. If p value is less than 0.05, it's accepted as statistically significant.

RESULTS

Patient Population and Clinical Data

Sixty-seven (67%) of the participants were male and 33 (33%) were female. The average age of participants was 44.21±17.09 (range 18-89). Among the patients, 70 (70%) had no accompanying comorbidities, while 30 (30%) had at least one, which included conditions such as hypertension (HT), diabetes Mellitus (DM), chronic obstructive pulmonary disease (COPD), cardiovascular disease, cerebrovascular disease, malignancy, asthma, and rheumatoid arthritis (RA). The most prevalent comorbidity was HT at 24%, followed by DM at 11% and cardiovascular disease at 8%. The frequencies of other comorbidities were as follows: COPD at 4%, cerebrovascular disease at 4%, malignancy at 2%, asthma at 4%, and RA at 2% (Table 1).

Table 1. The patient's clinical features

Parameter	Patients (n=100)
Sex	
Men	67
Women	33
Age	
Mean	44.21
Range	18-89
Standart deviation	17.09
Comorbidity	
Positive	70
Negative	30
Distribution of comorbidities	
Hypertension	24
Diabetes mellitus type 2	11
Chronic obstrucitve pulmonary disease	4
Cardiovascular disease	8
Cerebrovascular disease	4
Malignity	2
Asthma	4
Romatoid arthritis	2

Chest CT Findings

RT-PCR test results were positive for all patients (n=100). Upon evaluating the CT findings of these 100 patients based on the specified criteria, 35 patients were classified as grade 0, indicating that although their PCR tests were positive, their CT scans showed no findings (Table 2). Among the 65 patients with positive CT findings, 60 (93.3%) exhibited ground-glass opacities (GGO), 27 (41.5%) had consolidations, 22 (33.8%) presented both GGO and consolidation, and 8 (12.3%) displayed a crazy paving pattern. Examining the lateralization of lung involvement in these patients, 9 (13.8%) had involvement limited to the right lung, 8 (12.3%) to the left lung, and 48 (73.8%) had involvement in both lungs. When assessing the distribution of lung lobe involvement, the results were as follows: right upper lobe involvement in 43 patients (66.1%), right middle lobe in 34 patients (52.3%), right lower lobe in 54 patients (83%), left upper lobe in 42 patients (64.6%), and left lower lobe in 51 patients (78.4%). The total lung severity score was 3.11±3.71 (Table 3).

Table 2. Evaluating of relationship between age and lung severity grade in patients					
Chest CT lung severity grade	Age (year)			Fisher Freeman Halton test	
	Lower than 65	65 and above	Total	p	r
Grade 0	34	1	35	0.001*	0.429
Grade 1	38	1	39		
Grade 2	10	6	16		
Grade 3	4	2	6		
Grade 4	1	3	4		
Total	87	13	100		

*p value <0.05

Table 3. Findings on chest CT scans	
	Number of patients (n=65)
CT findings	
GGO	60 (93.3%)
Consolidation	27 (41.5%)
GGO and consolidation	22 (33.8%)
Crazy paving pattern	8 (12.3%)
Lateralisation of paranchymal findings	
Right	9 (13.8%)
Left	8 (12.3%)
Bilateral	48 (73.8%)
Frequency	
RUL	43 (66.1%)
RML	34 (52.3%)
RLL	54 (83.0%)
LUL	42 (64.6%)
LLL	51 (78.4%)
TLSS	
Mean	3.11
Range	0-19
Standart deviation	3.71

CT: computed tomography, GGO: ground glass opacity, RLL: right lower lobe, RML: right middle lobe, RUL: right upper lobe, LLL: left lower lobe, LUL: left upper lobe, TLSS: total lung severity score

When analyzing the characteristic features of the opacities seen in thoracic CT scans, nodular morphology was noted in 28 patients (43%), linear opacities in 38 patients (58.4%), a crazy paving pattern in 8 patients (12.3%), a reverse halo sign in 1 patient (1.5%), and a halo sign in 5 patients (7.6%). In terms of axial distribution of opacities within the lung parenchyma, 40 patients (61.5%) exhibited a peripheral distribution, while 25 patients (38.4%) showed a diffuse distribution. There were no patients with exclusively central distribution in our study. Regarding additional CT findings, we identified pericardial effusion in 1 patient (1.5%), pleural effusion in 8 patients (12.3%), mediastinal lymphadenopathy in 7 patients (10.7%), bronchiectasis in 9 patients (13.8%), bronchial wall thickening in 1 patient (1.5%), and air bubble findings in 2 patients (3%). Five patients had pre-existing lung parenchymal diseases; three had emphysema and two had fibrosis (Table 4).

When looking at the relationship between age and CT lung involvement grades in our study population, we found a significant relationship, showing that older age is associated with more severe grades of involvement ($p<0.001$) (Table 4). There was also a moderate positive correlation between age and the CT lung involvement grades ($p<0.001$, $r=0.429$).

Table 4. The imaging features on CT scan	
Features	Number of patients (n=65)
Characteristics of opacities	
Rounded opacities	28 (43.0%)
Linear opacities	38 (58.4%)
Crazy paving pattern	8 (12.3%)
Reverse halo	1 (1.5%)
Halo sign	5 (7.6%)
Axial distribution of opacity	
Peripheral	40 (61.5%)
Central	0 (0%)
Diffuse (peripheral+central)	25 (38.4%)
Other findings	
Pericardial effusion	1 (1.5%)
Pleural effusion	8 (12.3%)
Mediastinal LAP	7 (10.7%)
Airways	
Bronchiectasia	9 (13.8%)
Bronchial wall thickening	1 (1.5%)
Air bubble sign	2 (3.0%)
Underlying paranchymal lung disease	
Emphysema	3 (4.6%)
Fibrosis	2 (3.0%)

CT: computed tomography

As the CT lung involvement grade increased, the rate of accompanying comorbidity also increased in the study population, showing a statistically significant relationship between comorbidity and lung involvement grades (p<0.001) (Table 5). There was a weak positive correlation between comorbidity and CT lung involvement grades (p<0.001, r=0.348).

Table 5. Evaluating of relationship between comorbidity and lung severity grade in patients

Chest CT lung severity grade	Comorbidity		
	Present	Absent	Total
Grade 0	7	28	35
Grade 1	7	32	39
Grade 2	7	9	16
Grade 3	5	1	6
Grade 4	4	0	4
Total	30	70	100

Fisher Freeman Halton test was used and p value was obtained as <0.001

DISCUSSION

This study demonstrated the relationship between the CT severity index and factors such as age, gender, and comorbidities in COVID-19 pneumonia.

This study showed that 67% of the patients were male. This was similar to the literature; the number of males was higher than females. In our study, the mean age was determined as 44.21 and the mean age of our study group was younger, according to the literature. Studies in literature have shown that male prevalence of COVID-19 in Chinese population is between 55% and 60%, with an average age of 47 to 59 years (10,11). In a study conducted in Europe, the male rate was reported as 52% and the average age was 57 (12). A meta-analysis examining 59 researches and total of 36,470 patients reported that male gender was at greater risk of infection and had higher rates of disease severity and mortality after infection (13).

Studies in the literature have reported that patients with comorbidities are at greater risk and more susceptible to COVID-19 infection (14). There are many studies reporting that HT, coronary artery disease, DM, COPD, malignancy, cerebrovascular disease and chronic kidney disease are more common in groups with higher COVID-19 infection severity (15-17). Guan et al. (2020) reported that 25% of COVID-19 patients had a comorbidity, and the most common comorbidities were HT (16.9%), DM (8.2%), and cardiovascular disease (3.7%) (18). Also in our research, consistent with literature, 30% of the patients had at least one comorbidity. Similarly, the three most common comorbidities were HT (24%), DM (11%), and cardiovascular disease (8%), respectively.

Our study found that the most common thoracic CT finding was GGO, accounting for 93.3%, consistent with the existing literature. The second and third most common findings were consolidation (41.5%) and GGO accompanied by consolidation (33.8%), respectively. When we look at distribution of findings in parenchyma in our study; similar to the literature, bilateral involvement (73.8%) was most frequent in lateralization, and peripheral distribution (61.5%) was the most frequent in axial distribution. The study by Pan et al (2020), development of findings in COVID-19 infection over time was summarized (4). While peripherally located ground glass opacities due to alveolar damage are observed initially, consolidation occurs later with an increase of damage in alveoli and coalescence of the GGO. Secondary to involvement of the pulmonary interstitium, thickening of the interlobular septa occurs and causing formation of a crazy paving pattern. After approximately the first week, consolidation becomes the predominant parenchymal finding. In the second week and later, GGO and crazy paving pattern can be seen again in these areas due to the regression in consolidations. As a result of many studies in literature, GGO with peripheral, lower lobe, and posterior involvement have been reported as typical imaging findings of COVID-19 pneumonia (5,19,20). In the consensus on reporting COVID-19-related thoracic CT findings published by RSNA, bilateraly, peripheraly, and multifocal GGO (with or without consolidation), crazy paving pattern, and reverse halo sign in later stages of the disease were stated as typical findings (21). In a meta-analysis comprising 109 studies and 2,908 patients, the most frequently observed parenchymal findings of COVID-19 on thoracic CT were reported as ground-glass opacities (68%), ground-glass opacities accompanied by consolidation (48%), and consolidation alone (18%) (22). When the findings were evaluated in terms of lobar distribution in our study, the right lung lower lobe was the most frequently affected lobe with 83%, left lung lower lobe was in second place with 78.4% and right lung upper lobe was in third place with 66.1%. Similar to our study, Caruso et al. (2020) reported the most frequently affected lobes in COVID-19 as right lung lower lobe, left lung lower lobe, and right lung upper lobe, respectively (12).

Numerous studies indicate that older age is a risk factor for COVID-19, increasing susceptibility to infection (23-25). A meta-analysis involving a large patient population found that individuals aged 70 and older had a higher risk of contracting COVID-19, experienced more severe disease, and required intensive care more frequently compared to younger age groups (13). In our study, the proportion of patients aged 65 and older was significantly higher among those with high-grade CT lung involvement, consistent with existing literature (p<0.001). This trend is associated with the prevalence of comorbidities often found in older patients and changes in immune system responses due to aging (26,27). It is believed that elevated proinflammatory cytokines resulting from age-related immune response alterations may significantly influence the progression of the disease (28).

In our investigation, we found a strong positive correlation between the CT lung involvement grade and the existence of comorbidities. Literature contains studies indicating that the presence of accompanying comorbidities exacerbates the severity of COVID-19 infection and increases the need for intensive care (11,15). A meta-analysis involving 1558 patients found that COVID-19 was more severe in individuals with comorbidities such as COPD, DM, HT, cardiovascular disease, and cerebrovascular disease. Additionally, this meta-analysis reported that having COPD as a comorbidity raised the risk of severe COVID-19 infection by 5.9 times compared to those without it (29). Similarly, Bhandari (2020) reported in their study that the presence of comorbidities significantly increased the severity of lung involvement observed in CT scans (30).

This study has some limitations that should be acknowledged. Firstly, as it was conducted at a single center, the findings may not be fully generalizable to other populations or healthcare settings. Additionally, due to the retrospective design, data collection was dependent on pre-existing records, which may lead to information bias. Furthermore, our sample size was limited, and some comorbidities or demographic subgroups may not have been sufficiently represented, which could impact the robustness of the statistical analyses.

CONCLUSION

The severity of lung involvement on CT is notably greater in patients aged 65 and older, as well as in those with comorbidities. A moderate positive correlation is present between the CT lung involvement grade and age, whereas a weak positive correlation is noted between the CT lung involvement grade and comorbidity.

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Ethical approval: *The Helsinki Declaration's ethical criteria were followed in the conduct of this retrospective investigation, which was approved by our Institutional Clinical Research Ethics Committee (Decision no: 2020/273).*

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