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Congruence of radiological scoring systems used in COVID-19 pneumonia and effect of comorbid diseases on radiological features

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Ethics Committee Approval
The study was approved by the Ethics Committee of Binali Yildirim University (decree no: 27/10/2022-/04/6).
All procedures in this study involving human participants were performed in accordance with the 1964 Helsinki Declaration and its later amendments.

Conflict of Interest
No conflict of interest was declared by the authors.

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Abstract

Background/Aim: Several scoring systems have been developed to standardize radiological findings in patients with COVID-19 pneumonia. The most commonly used scoring systems in the radiological examination of COVID-19 are those of the North American Radiology Association (RSNA), British Thoracic Society (BTS), and COVID-19 Reporting and Data System (CO-RADS). However, the compatibility between these radiological scoring systems has not been evaluated before. Therefore, this study evaluated the radiological features of COVID-19 pneumonia and congruence between radiological scoring systems and determined the effect of comorbidities and demographic characteristics on radiological features and thoracic computed tomography (TCT) findings in the context of COVID-19.
Methods: A retrospective cohort study was performed on patients attending our unit with a suspicion of COVID-19 who also had a positive real-time transcriptase-polymerase chain reaction (RT-PCR) test. All TCT images were subjected to the RSNA, BTS, and CO-RADS scoring systems. Demographic data such as age and gender, and comorbid conditions were recorded.
Results: TCT showed peripheral, posterior, and bilateral involvement in 97.7%, 97.7%, and 87.6% of the patients, respectively. The most common TCT finding was ground glass appearance, which was found in 95.5% of the patients. The Charlson Comorbidity Index (CCI) score was found to have an impact on RSNA and BTS criteria (P=0.011 and P=0.014), while age, gender, and the presence of comorbidities such as cardiovascular disease (CVD), diabetes mellitus (DM), and chronic pulmonary disease (CPD) did not have such an effect (P>0.05 for all). On the other hand, CCI scores and the presence of CPD had an association with CO-RADS, but there was no effect of age, gender, DM, and CVD (P=0.915 and P=0.730).
Conclusion: TCT plays an important role in early management, isolation, and follow-up of patients with COVID-19 pneumonia. The radiological scoring systems were found to exhibit good compatibility, but comorbid conditions could have an impact on the assessment. Therefore, we conclude that these radiological assessment criteria are useful in the management and monitoring of such patients.

Keywords: COVID-19, pneumonia, radiological appearance, scoring systems, comorbid diseases

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Introduction

Coronaviruses are important pathogens in both humans and animals. Toward the end of the year 2019, a clustering of pneumonia cases caused by a novel type of coronavirus was observed in the city of Wuhan in Hubei Province, China, which rapidly spread to other parts of the world. In February 2020, the disease was declared a pandemic and termed as coronavirus disease 2019 (COVID-19) [1]. Lungs represent the most important site of involvement in COVID-19 [2]. Therefore, radiological documentation of lung involvement is of the utmost importance.

Although real-time transcriptase-polymerase chain reaction (RT-PCR) is the gold standard diagnostic modality, radiological findings have also been commonly used for diagnosis due to inadequate access to PCR testing in some parts of the world, as well as false-negative results early in the course of the disease [3,4]. The reported sensitivity of chest X-rays is between 30% and 60% [5]. Therefore, it should be borne in mind that a normal chest X-ray does not rule out a diagnosis of COVID-19, and clinically suspicious cases should be assessed with thoracic computed tomography (TCT).

In a previous report, the observed sensitivities of TCT and RT-PCR in establishing a diagnosis of COVID-19 were 98% and 71%, respectively [6,7]. Thus, even in the absence of a positive RT-PCR result, the presence of positive TCT findings in patients with suspected COVID-19 pneumonia allows early diagnosis [6-8]. However, TCT should always be interpreted in light of clinical manifestations.

The North American Radiology Association (RSNA) criteria have been proposed as a means to reduce variability and achieve standardization in patient reporting, as well as to reach a terminological consensus while assessing a possible diagnosis of COVID-19 pneumonia [9]. A similar attempt to standardize TCT findings in COVID-19 pneumonia was made by the British Thoracic Society (BTS) [10]. The COVID-19 Reporting and Data System (CO-RADS) is another categorical assessment scheme to estimate the presence of COVID-19 in patients with moderate to severe symptoms and to document pulmonary involvement of COVID-19 [11]. COVID-19 pneumonia has also been classified clinically into four groups [12] to achieve clinical and radiological standardization among patients, which may facilitate the use of similar terminology for diagnosis and management of patients as well as the creation of algorithms for clinicians. In this study, our objective was to assess the congruence between RSNA, BTS, and CO-RADS scoring systems for radiological classification of pulmonary involvement in patients with COVID-19. Also, we aimed to determine factors that impact the scores. Another objective was to evaluate the frequency of the most common sites of pulmonary involvement (central, peripheral, posterior, anterior, or bilateral etc.), total area of pulmonary involvement (number of lobes), and frequent radiological features (e.g. ground glass appearance, air bronchogram, subpleural lines, halo, reverse-halo sign, air bubbles, vascular enlargement, bronchial widening etc.). We also determined the effect of age, gender, and comorbidities on radiological features of COVID-19.

Materials and methods

We retrospectively evaluated consecutive patients with COVID-19 and a positive RT-PCR result who had TCT findings consistent with COVID-19 pneumonia between May 1, 2021, and November 31, 2021. Data from digital hospital records were used to record demographic information and comorbid conditions (cardiovascular disease [CVD], diabetes mellitus [DM], chronic pulmonary disease [CPD], etc.). The CCI score was calculated for each patient. TCT images were obtained in a supine position without contrast media using a 256-slice CT device for all patients (Aquillon, Toshiba Medical Systems, Tokyo, Japan). TCT images were assessed by a team of experienced medical specialists consisting of one radiologist (18 years of expertise) and three pulmonologists (20, 20, and 10 years of expertise, respectively) at workstations (Syngo Via Console, Software v. 2.0; Siemens Medical Solutions, Erlangen, Germany).

Each image was evaluated with regard to lung parenchyma, bronchial pathology, pleural effusion, concurrent pericardial effusion, and mediastinal lymphadenopathy (LAP). Recorded lung parenchymal pathologies included the number of lobes involved, the presence of ground-glass appearance, air bubbles, subpleural bands, reticular densities, and fibrosis. Air bronchograms and bronchial wall injuries were assessed when evaluating bronchial pathologies.

RSNA, BTS, and CO-RADS scores were recorded. The RSNA chest CT classification system includes four categories: negative for pneumonia, atypical, indeterminate, and typical [9]. The BTS classifies COVID-19 radiology as classic COVID-19 (100% compatible), probable COVID-19 (71-99% compatible), uncertain (<70% compatible), and “COVID-19 excluded” (<70% compatible with another diagnosis) [10]. CO-RADS was developed by the Dutch Association for Radiology with grades ranging from 1 to 5 to suggest ascending disease probability according to the CT chest findings [11].

The exclusion criteria were the absence of a PCR test result, poor image quality, and a history of lung fibrosis or emphysema. The study procedures were carried out after ethical approval by the local ethics committee of Erzincan Binali Yıldırım University (decree no: 27/10/2022-/04/6). The study was performed according to the ethical standards specified in the 1964 Declaration of Helsinki and its later amendments.

Statistical analysis

Analysis of the data was done with IBM SPSS 19 (IBM Corp. Released 2010. Armonk, NY). Categorical variables were reported as n (%), and descriptive statistics for continuous variables were reported as the mean (standard deviation) or median (minimum-maximum) value according to the distribution type. A chi-squared test was used in the analysis of categorical variables. Whether continuous variables had a normal distribution was evaluated by the Kolmogorov-Smirnov test. The Mann-Whitney U test was used when comparing the numbers of lobes in groups in cases where assumptions were not provided, and a student's t test was used in the cases provided. In all statistical analyses, $P<0.05$ was considered significant.

Results

A total of 396 patients were included, of which 56.1% (n=222) were male and 43.9% (n=174) were female. The mean age of the patients was 56.18 (18-94). TCT showed peripheral, posterior, and bilateral involvement in 97.7% (n=387), 97.7% (n=387), and 87.6% (n=347) of the patients, respectively. The most common TCT finding was ground glass appearance in 95.5% of the patients (n=378; Table 1, Figure 1). The most common comorbid conditions included CVD in 34.3% (n=136), chronic pulmonary disease (CPD) in 24.2% (n=96), diabetes mellitus (DM) in 21.7% (n=86), allergic conditions in 14.4% (n=57), and cancer in 2.8% (n=11).

Figure 1: A: ground glass view in the middle lobe of the right lung and in the lower lobe superior segment and air bubbles in the lower lobe superior segment to the right lung. B: Peripheral halo with ground glass densities in the left lung lower lobe air bubble view. C: Paving stone view and several air bubbles in the lower lobe superior segment of the left lung D: Peripheral ground glass view.

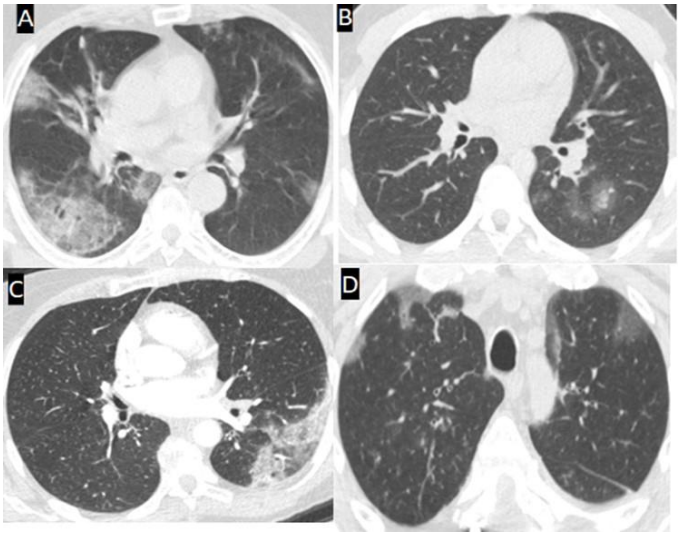


Table 1: Radiological findings of patients with COVID-19 pneumonia on thorax CT are observed

		n	%
Peripheral	No	9	2.3
	Yes	387	97.7
Posterior	No	9	2.3
	Yes	387	97.7
Bilateral	No	49	12.4
	Yes	347	87.6
Ground glass	No	18	4.5
	Yes	378	95.5
Consolidation	No	240	60.6
	Yes	156	39.4
Air bronchogram	No	383	96.7
	Yes	13	3.3
Vascular enlargement	No	284	71.7
	Yes	112	28.3
Bronchial dilatation	No	362	91.4
	Yes	34	8.6
Halo	No	391	98.7
	Yes	5	1.3
Reverse halo	No	393	99.2
	Yes	3	0.8
Nodule	No	390	98.5
	Yes	6	1.5
Air bubble	No	366	92.4
	Yes	30	7.6
Subpleural band	No	283	71.5
	Yes	113	28.5
Reticular density	No	344	86.9
	Yes	52	13.1
Pleural thickening	No	394	99.5
	Yes	2	0.5
Pleurisy	No	388	98.0
	Yes	8	2.0
Pericardial effusion	No	395	99.7
	Yes	1	0.3
Paving stone	No	345	87.1
	Yes	51	12.9

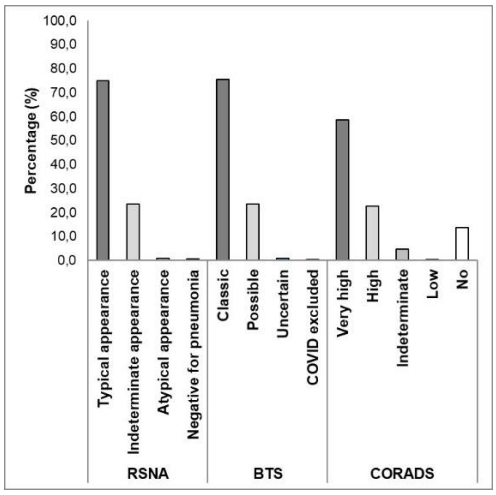
Table 2 shows the results of RSNA, BTS, and CO-RADS classification in COVID-19 patients. Score assessments based on RSNA and BTS criteria were found to be congruent Also, CO-RADS scores were in agreement with RSNA and BTS scores (Figure 2). Increasing patient age was associated with an increased number of bilateral involvement, consolidation, subpleural bands, reticular density, and disease stage at presentation, while no association was found between age and dominant site of involvement (i.e., posterior, peripheral, etc.) (P<0.001, P=0.026, P<0.001, P=0.001, P=0.002, P=0.069, and P=0.627, respectively). Also, age was not associated with an increased incidence of ground glass appearance, vascular enlargement, number of lobes involved (P=0.692, P=0.637, and P=0.167, respectively), RSNA, BTS, and CO-RADS scores (P=0.086, P=0.084, and P=0.059, respectively) (Figure 3).

Table 2: RSNA, BTS and CO-RADS scores of our patients diagnosed with COVID-19 pneumonia

		n	%
RSNA	Typical appearance	297	75.0
	Uncertain appearance	93	23,5
	Atypical appearance	4	1.0
	No pneumonia	2	0.5
BTS	Classical	299	75.5
	Possible	93	23.5
	Uncertain	3	0.8
	No COVID	1	0.3
CO-RADS	1	54	13.6
	2	1	0.3
	3	19	4.8
	4	90	22.7
	5	232	58.6

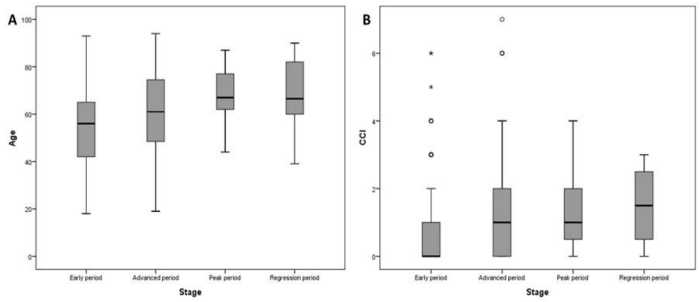
RSNA: North American Radiology Association, BTS: British Thoracic Imaging Society, CO-RADS: Coronavirus disease 2019 (COVID-19) Reporting and Data System

Figure 2: Compatibility of RSNA, BTS and CO-RADS indices in thorax CT classification of patients with COVID-19 Pneumonia



RSNA: North American Radiology Association BTS: British Thoracic Imaging Society CO-RADS: Coronavirus disease 2019 (COVID-19) Reporting and Data System

Figure 3: The effect of age (A) and CCI score (B) of patients with COVID-19 pneumonia on disease stage,



CCI: Charlson Comorbidity Index

Our findings showed that gender had no effect on bilateral, posterior, or peripheral involvement in patients with COVID-19 pneumonia (P=0.278, P=0.975, and P=0.184,

respectively). Also, gender had no effect on the occurrence of ground glass appearance, consolidation, vascular enlargement, subpleural bands, and reticular densities (P=0.054, P=0.0551, P=0.163, P=0.175 and P=0.519, respectively) or on the disease stage at presentation, number of lobes involved, and RSNA, BTS, and CO-RADS scores (P=0.234, P=0.530, P=0.764, P=0.625, and P=0.109, respectively). CCI scores were associated with bilateral involvement, reticular densities, advanced disease stage at presentation, and the indeterminate appearance category in RSNA, BTS, and CO-RADS (P=0.002, P=0.02, P=0.048, P=0.011, P=0.014, and P=0.046, respectively). On the other hand, there was no association between CCI scores and dominant posterior or peripheral involvement, ground glass appearance, consolidation, vascular enlargement, subpleural bands, and number of lobes involved (P=0.870, P=0.337, P=0.260, P=0.112, P=0.148, P=0.30, and P=0.096, respectively) (Figure 3).

COVID-19 pneumonia patients with CVD were more likely to have bilateral involvement, reticular densities, subpleural bands, and higher disease stage at presentation (P=0.012, P<0.001, P=0.017, and P=0.009, respectively). However, there were no associations between CVD and posterior or peripheral involvement, ground glass appearance, consolidation, and vascular enlargement (P=0.439, P=0.439, P=0.926, P=0.680, and P=0.777, respectively). Also, the presence of CVD had no effect on the number of lobes involved and on RSNA, BTS, and CO-RADS scores (P=0.253, P=0.609, P=0.622, and P=0.730, respectively) (Figure 4A). The presence of DM in patients with COVID-19 pneumonia was found to increase the likelihood of ground glass appearance, reticular density, vascular enlargement, and number of lobes involved (P=0.017, P=0.039, P=0.019, and P=0.043, respectively). However, it did not have an effect on the incidence of bilateral involvement as well as posterior and peripheral involvement (P=0.178, P=0.435, and P=0.110). Also, the presence of DM had no effect on the occurrence of consolidation, subpleural band, disease stage at presentation, and RSNA, BTS, and CO-RADS scores (P=0.639, P=0.141, P=0.113, P=0.057, P=0.491, and P=0.915, respectively) (Figure 4B). In patients with COVID-19 pneumonia, the presence of CPD was found to affect CO-RADS scores (P=0.015), while it had no effect on bilateral involvement, posterior or peripheral involvement, ground glass appearance, consolidation, vascular enlargement, subpleural bands, reticular density, disease stage at presentation, number of lobes involved, and RSNA and BTS scores (P>0.05 for all).

Discussion

COVID-19 pneumonia is a readily transmittable viral pneumonia of the lower airways caused by the novel coronavirus SARS-CoV-2. Numerous studies have been carried out to evaluate the TCT findings in COVID-19 patients, particularly with respect to the role of TCT in early diagnosis of pneumonia. Establishment of diagnostic radiological standards may facilitate the use of common diagnostic and therapeutic terminology and development of clinical algorithms. Our results show that scoring systems used for reporting TCT images are in good agreement, but comorbid conditions could have an impact on the scores obtained in these systems.

Many studies have established that ground glass densities represent the most common pathological imaging finding in COVID-19 and are thought to arise from pulmonary edema and hyaline membrane formation [13]. These areas are identified in 88% to 98% of the patients, they are frequently bilateral, and they mostly involve lower lobes and peripheral sites [14-17]. Similarly, all of our patients had ground glass appearance (mostly bilaterally and peripherally).

In patients with ground glass appearance, the most common accompanying sign is consolidation, which a post-mortem study has shown to be caused by cellular accumulation of fibro-myxoid exudate in the alveoli [18]. Several reports suggest that consolidation may be a predictor of disease progression [19]. Previous reports suggest that 5 to 36% of COVID-19 patients may have consolidation, which was the second most common radiological finding in our patients.

Vascular enlargement is thought to arise from capillary wall injury and was observed in 56.5% of the study population in a study involving 919 patients [20]. In our study, 28.3% of the patients had this finding. More common occurrence of vascular enlargement in patients with DM may be a sign of worse prognosis and increased likelihood of thrombotic complications.

In a previous study from China, patients who required intensive care unit (ICU) admission were older and had at least one comorbidity [21]. In a retrospective study, elderly patients with COVID-19 were more likely to be admitted to the ICU and had higher mortality than younger patients [22]. Aging causes anatomical alterations, muscular atrophy, reduced lung reserve, and reduced airway clearance in the lungs [22]. Such factors may explain the increased morbidity and mortality among elderly COVID-19 patients.

In our study, increasing age was associated with more advanced disease stage, increased consolidation, subpleural bands, reticular density, and bilateral involvement but not with vascular enlargement, ground-glass appearance, or the number of lobes. TCT reporting scores did not change with age. More advanced disease at presentation may be an indicator of more severe clinical features in the elderly, while increased incidence of subpleural bands and reticular densities may be predictors of fibrosis following COVID-19.

Women are less likely to be affected by bacterial and viral infections compared to men, presumably due to factors involving the innate and adaptive immune responses [23]. Accordingly, the risk of ICU admission among COVID-19 patients was found to be 1.55-times higher in males than in female patients [24]. In a study involving 1813 patients, patients admitted to the ICU were more likely to be male and elderly [24]. However, in our study, gender did not have an effect on the stage of the disease, the number of lobes involved, bilateral posterior involvement, peripheral involvement, pathological imaging findings, and TCT scoring systems.

In a previous study, certain comorbid conditions have been associated with elevated ACE-2 receptor expression [25]. In a review of 29,096 COVID-19 patients, 8.3%, 8.03%, 6.19%, and 4.83% of the patients were found to have comorbid DM, CVD, CPD, and HT, respectively [26]. In our study, the most common comorbidity was CVD. Also, COVID-19 patients with higher CCI scores were more likely to present with a more

advanced disease stage. CCI scores were found to affect RSNA, BTS, and CO-RADS and were associated with an increased likelihood of bilateral reticular involvement. Our results suggest that patients with higher CCI scores present with more advanced disease stage, despite having more widespread involvement.

DM is associated with elevated ACE-2 expression, impaired T cell function, and increased interleukin-6 (IL-6) [27,28]. DM patients may also have impairment in innate immunity, increased susceptibility to infections due to impaired phagocytic functions [29], and excessive pro-inflammatory cytokine release [30]. Similarly, another study found higher morbidity and mortality in diabetic COVID-19 patients [31]. In our study, 21.7% (n=86) of the patients had DM, which did not have an impact on disease stage at presentation or RSNA, BTS, and CO-RADS scores. On the other hand, DM was associated with an increased number of lobes involved, vascular expansion, ground glass appearance, and increased reticular density. Increased occurrence of lung involvement, vascular enlargement, and reticular density may present predictors of ICU admission and mortality in these subjects.

Asthmatic COVID-19 patients have an increased risk of asthma episodes, pneumonia, and ARDS [32]. Elevated ACE-2 expression may facilitate the entry of the virus into cells and may worsen the disease course [26]. In our study, the presence of CPD in COVID-19 patients was not associated with more advanced disease at admission, reticular density, subpleural band, bilateral involvement, posterior, peripheral dominance, increased ground glass appearance, increased consolidation, or increased lobe count. On the other hand, while CPD in these patients did not affect RSNA and BTS scores, it was found to affect CO-RADS scores.

Since most HT patients receive treatment with ACE inhibitors, ACE-2 receptors are upregulated, possibly increasing the susceptibility of these subjects to COVID-19 infection [33]. HT patients may also have impaired CD8 T cell function and cytokine dysregulation. Increased ACE-2 expiration in the cardiovascular may lead to fatal outcomes including myocarditis [26]. However, it was observed that having CVD did not affect posterior or peripheral involvement, the prevalence of ground glass appearance density, increased consolidation, increased vascular involvement, number of involved lobes, and RSNA, BTS, and CO-RADS scores. In our study, COVID-19 patients with CVD had more peaks and an increased number of hospital admissions. These observations suggest that COVID-19 patients with CVD may have a worse prognosis with increased risk of fibrosis following infection.

Our literature search did not reveal any studies comparing different radiological reporting systems in patients with COVID-19 pneumonia. Our findings showed good agreement between RSNA, BTS, and CO-RADS systems, suggesting that these TCT reporting systems may facilitate the standardization of radiological reporting of TCT imaging. In our study, CCI scores had an impact on RSNA and BTS scores, while age, gender, CVD, DM, and CPD had no such effect. CCI scores and the presence of CPD had an effect on CO-RADS scores, while age, gender, DM, and CVD did not affect them. Therefore, CCI scores and CPD should probably be taken into consideration when using radiological reporting systems for COVID-19.

Limitations

The limitations of our study include its retrospective nature and acquisition of study data from the hospital database.

Conclusion

In conclusion, TCT imaging plays an important role in the early diagnosis of COVID-19 patients. Radiological scoring systems for COVID-19 pneumonia exhibit a good level of agreement, which supports their usefulness in the diagnosis and treatment of these patients. Comorbid conditions in these patients may have an impact on these scoring systems when utilized for classification of the lung involvement. Further studies examining pathological correlations are warranted to determine the prognostic factors of this disease.

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