Severity Assessment in COVID-19 Pneumonia: Comparison of Semi-Quantitative and Quantitative CT Analyses

COVID-19 Pnömonisinde Hastalık Ciddiyetini Öngörme: Semi-Kantitatif ve Kantitatif BT Analizinin Karşılaştırılması

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ABSTRACT

Objective: To investigate the performance of semi-quantitative CT (SCT) and automated quantitative CT (QCT) analyses for differentiating mild disease from the severe disease in COVID-19 pneumonia.
Materials and Methods: Sixty-seven laboratory confirmed COVID-19 patients were enrolled. The patients were grouped into mild and severe disease regarding clinical features. CT images were evaluated by three observers independently. Three different SCT scoring methods and QCT analysis were performed. The two disease groups were compared in terms of SCT and QCT parameters. Intraclass correlation coefficient was used to investigate inter-rater reliability. The performance of SCT and QCT in the differentiation of mild disease and severe disease was evaluated using receiver operating characteristics (ROC) analysis.
Results: Inter-rater reliability was excellent for all SCT scores. SCT and QCT scores were significantly different between two disease groups ($p<0.05$). Five-point score showed the best performance regarding to area under curve (AUC) values. The cut-off value of >7 for 5-point score had 88.89% sensitivity and 82.76% specificity and cut-off value of >10.29% for QCT score (%) had 75.00% sensitivity and 98.04% specificity for differentiating the mild disease from severe disease.
Conclusion: QCT may play an important role in the management of COVID-19 pneumonia with its high specificity values.

Keywords: Clinical Classification; Computed tomography; COVID-19; Quantitative analysis; visual scoring

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ÖZET

Amaç: COVID-19 pnömonisinde hafif hastalığı şiddetli hastalıktan ayırt etmede semi-kantitatif BT (SBT) ve kantitatif-BT (KBT) analizlerinin performansını karşılaştırmak.
Yöntem: Çalışmaya 67 laboratuvar tarafından doğrulanmış COVID-19 hastası dahil edildi. Hastalar klinik özelliklerine göre hafif ve ağır hasta olarak gruplandırıldı. BT görüntüleri bağımsız olarak üç gözlemci tarafından değerlendirildi. Üç farklı SBT skorlama yöntemi ve KBT analizi uyulandı. İki hastalık grubu SBT ve KBT parametreleri açısından karşılaştırıldı. Gözlemciler arası güvenilirliği araştırmak için sınıf içi korelasyon katsayısı kullanıldı. Hafif hastalık ve ağır hastalık ayrımında SBT ve KBT'nin performansı, ROC analizi kullanılarak değerlendirildi.
Bulgular:Gözlemciler arası güvenilirlik, tüm SBT skorları için mükemmeldi. SBT ve KBT değerleri hafif ve ağır hastalık grupları arasında anlamlı olarak farklıydı ($p<0.05$). Eğri altındaki alan (EAA) göz önüne alındığında SBT skorlama yöntemleri arasında beşli skorlama en iyi performansı gösterdi. ROC analizinde beşli skorlama için en uyun kesim noktası 7 olarak belirlenmiş olup bu değere ait duyarlılık %88.89, özgüllük %82.76 olarak hesaplanmıştır. KBT değeri (%) için kesim noktası %10.29 olarak belirlendiğinde duyarlılık değeri %75.00, özgüllük değeri ise %98.04 olarak hesaplanmıştır.
Sonuç:KBT, yüksek özgüllük değerleri ile COVID-19 pnömonisinin yönetiminde önemli bir rol oynayabilir.

Anahtar Sözcükler: Bilgisayarlı tomografi; COVID-19; kantitatif analiz; semikantitatif analiz

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INTRODUCTION

Coronavirus disease 2019(COVID-19), which is caused by a new type of coronavirus (SARS-CoV-2), emerged in China in December 2019 and became a worldwide outbreak within months. As of November 10th, 2020, there were 50,676,072 confirmed cases and 1,261,075 COVID-19 related deaths (1). The respiratory system is the primary involvement site in COVID-19 patients. Although patients mostly present with mild symptoms, severe cases can progress to acute respiratory distress syndrome or even death. In a retrospective study of 44.672 COVID-19 patients, severe and critical cases accounted for 18.5% (2). It has been reported that the mortality rate reaches 43.3% in severe disease (3). As treatment protocol alters depending on the clinical severity, it's important to predict patients' outcome early in the disease course. The real-time reverse transcriptase-polymerase chain reaction (rRT-PCR) is considered the gold standard method for diagnosing COVID-19. Even though rRT-PCR is highly specific, lower sensitivity values of 60-70% were reported (4). On the other hand, chest computed tomography (CT) has a sensitivity of 98% (5). In this context, CT plays a pivotal role in the management of COVID-19 patients as it can provide a fast diagnosis and enables early isolation (6). Radiological findings are associated with the severity and vary in the disease course. It has been shown that visual (semiquantitative) evaluation of disease extent on chest CT is correlated with the clinical severity score of the patients (7,8). Measuring disease burden by visual quantification enablesassessment of disease severity and may predict prognosis.

During the pandemic, it has been a common practice for radiologists to quantify the extent of the disease by visual scoring. Various visual scoring methods based on either lobe, zones, or segments were applied in previous studies (8-13). As these semi-quantitative CT (SCT) scoring methods are subjective and time consuming, rapid and accurate severity score measurments are required. Quantitative CT (QCT) techniques, which have been increasingly implemented in imaging of various lung diseases, provide objective and reproducible data that aid lesion characterization and quantification (14). There are studies showing that quantitative CT may be useful in the management of COVID-19 patients (15). This study aimed to evaluate the performance of SCT and QCT methods in severity assessment of COVID-19 and compare mostly used CT visual scoring methods according to their correlation with clinical severity.

MATERIALS and METHODS

Study population and clinical classifications

Local ethics committee was approved this retrospective study and informed consent was waived. From March 01 to May 01, 2020, 67 laboratory confirmed COVID-19 patients who underwent chest CT scan were included. Available medical records of these patients were collected including symptoms. All patients were sorted into four groups according to disease severity based on the published standard protocols from the continously-updated National Health commission of the Peoples's Republic of China (16). Mild type: Mild clinical symptoms with no sign of pneumonia on imaging; moderate type: Fever and respiratory symptoms with pneumonia in imaging; severe type: respiratory distress (≥30 breaths/min), oxygen saturation ≤93% at rest; critical: Respiratory failure requiring mechanical ventilation, shock, other organ failure requiring intensive care. Since severe and critical cases were few in number, severe and critical cases were merged in the severe disease group, and mild and moderate cases were grouped in the mild disease group.

Informed consent

This retrospective study was approved by the institutional review board (IRB Approval number:338, Date: May 22 th, 2020), and the requirement of written informed consent was waived.

CT protocol

Patients underwent unenhanced chest CT. CT scans were acquired in volumetric mode, performed in the supine position during deep inspiration breath-hold, using a multi-detector CT system (Brightspeed 16, General Electronic Medical Systems, USA). The tube voltage and current were 120 kVp and 30-150 mAs. Slice thickness after reconstruction was 2 mm and reconstruction matrix of 512x512. Sharp reconstruction kernel used for lung parenchyma.

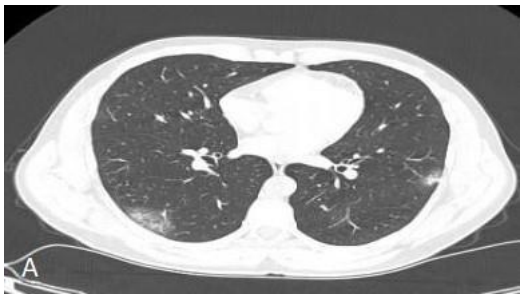
Chest CT Evaluation

All chest CT images were reviewed independently by a board certified radiologist with 7 years of experience, a radiology resident who completed thoracic imaging training and a senior thoracic radiologist with more than 20 years of experience without knowing the clinical data. All images were reviewed in both lung and mediastinal window settings. CT images of all 67 patients were evaluated for the following features: (1) presence of findings suggestive of pneumonia on chest CT. If any, findings were grouped as typical, indeterminate or atypical according to Expert Consensus Statement (17), (2) attenuation of lesions: ground-glass opacity, consolidation or mixed pattern, (3) distribution of lesions: peripheral or central, anterior or posterior,upper or lower lobe and mixed pattern, (4) number of affected lobes and involvement of lungs (unilateral single lobe, unilateral multiple lobe or bilateral multiple lobe), (5) presence of minor signs (crazy-paving, linear opacities, air bronchogram, halo sign, reverse halo sign, cavitation, tree-in-bud sign, pleural effusion, pericardial effusion, mediastinal lymphadenopathy (lymph node with a ≥10 mm in short-axis diameter), bronchial wall thickening, vascular enlargement). The characterization of lesions was made according to the nomenclature determined by the Fleischner Society (18).

Visual (semi-quantative) computed tomography analysis

CT images were scored independently and blindly by three observers. Three different semi-quantitative scoring methods were applied. All of them were previously described scoring methods in the literature (9,10,13). Evaluation criteria for scoring methods are as follows; 4-point score: Each of five lung lobes was evaluated for percentage of involvement and grouped as none(0%), minimal (1-25%), mild (26-50%), moderate (51-75%), or severe (76-100%) with corresponded score as 0, 1, 2, 3 or 4. The total severity score was calculated by summing the five lobe scores (range from 0 to 20) (9). 5-point score: Each of the five lung lobes was visually rated for percentage of the involvement as: 0, none; 1, <5% involvement; 2, 5-25% involvement; 3, 26-50% involvement; 4, 51-75% involvement; 5, >75% involvement. The total severity score was calculated by summing the five lobe scores (range from 0 to 25) (10). Multiplier score: The percentage of involvement was assessed for each of three zones: upper (above the carina), middle (below the carina and above the inferior pulmonary vein), and lower

Each of the six lung zones was visually scored for percentage of involvement as: 0, normal; 1, 1-25% involvement; 2, 26-50% involvement; 3, 51-75% involvement; 4, >75% involvement. The CT lesion was also graded according to attenuation as: 1, normal attenuation; 2, ground-glass attenuation; 3, consolidation. The four-point scale of involvement was then multiplied by the attenuation score for each lung zones. Major attenuation pattern was taken into account when consolidation and ground glass were combined within the lesion. The total severity score was calculated by summing the six zone scores (range from 0 to 72) (13). The scores provided by the senior radiologist were used for further analyses. Two examples of visual scoring are shown in Figure 1.



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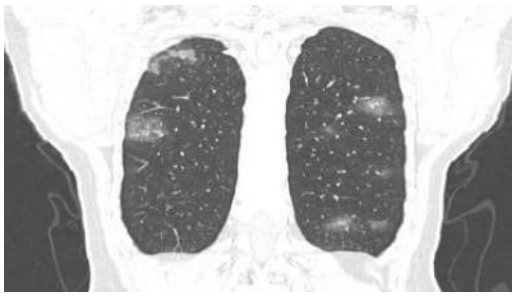

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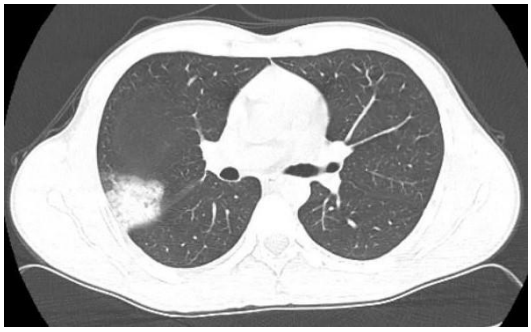

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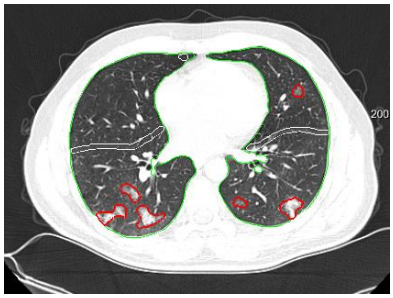
Figure 1. Examples of semi-quantitative analysis.
(A,B): 33-year-old male with COVID-19. Multifocal GGOs with consolidations in both lungs. The SCT scores were 4 for the 4-point score, 5 for 5-point score, and 18 for Multiplier score.
(C,D): 26-year-old male with COVID-19. Bifocal consolidations in the right lung. The SCT scores were 2 for the 4-point score, 2 for 5-point score, and 6 for Multiplier score. GGO= Ground-glass opacity, SCT= Semi-quantitative computed tomography.

Quantitative computed tomography image analysis

All reconstructed images were anonymized and transferred to the workstation for analysis using CT Pneumonia Analysis software (syngo.via VB10, Siemens Healthineers, Germany), an Artificial Intelligence-based software. The automated segmentation of lung parenchyma, was performed under a trained radiologists' supervision. Total lung volume (ml) and mean density of the lung (HU) were measured for the segmented lung. After the automated segmentation of abnormal opacity, manual corrections were made, if necessary. Opacity volume (ml), percentage of opacity (%), and mean density opacity (HU) were measured. The segmentation and three-dimensional reconstruction of lung lesions are shown in Figure 2.



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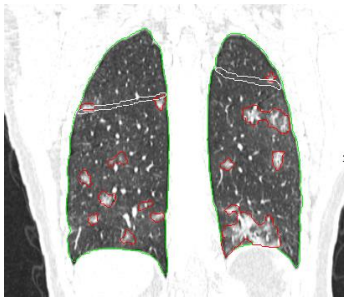

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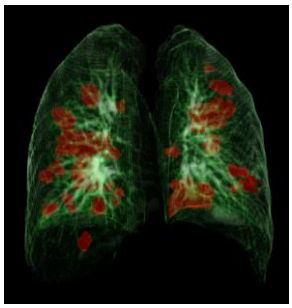

2C

Figure 2. Illustration of automatic segmentation of lesions by computer software.
(A, B, C): 33-year-old male with Covid-19. Bilateral multifocal GGOs. All lesions were segmented as shown on axial and coronal view (A, B, within line). C represent the three-dimensional reconstruction of lesions (C, nodular). GGO= Ground-glass opacity.

Statistical Analysis

Statistical analysis was performed using IBM SPSS Statistics Software (version 22; IBM, USA) and MedCalc for Windows (version16.0; MedCalc Software, Mariakerke,
Belgium). Descriptive statistics were done for demographic, clinical and CT imaging characteristics of patients. The continuous data were expressed as mean±standard deviation whereas categorical variables were presented as counts and percentages. As Shapiro Wilk test revealed non-normal distribution of data, Mann Whitney U test was used to evaluate the comparisons of the continuous variables. Chi-square test or Fisher's exact test was employed for categorical variables. The correlation between imaging parameters including semiquantitative visual score and QCT parameters and clinical severity were analyzed using Spearman's correlation test.
A r-value of 0-0.30 was considered as weak, 0.31-0.50 moderate, 0.51-0.70 good and 0.71-1.00 was considered excellent correlation. Intra-class correlation coefficient (ICC) was used to analyze the inter-rater reliability for semiquantitative visual score and classified as follows: no agreement 0-0.2; weak agreement 0.21-0.4; moderate agreement 0.41-0.60; good agreement 0.61-0.80; excellent agreement 0.81-1.0. The receiver operating characteristic (ROC) curves were plotted and areas under curves (AUC) were calculated for semi-quantitative visual scores and QCT parameters.

Youden's method was used to calculate the optimal cut- off points. The AUC's were compared with the method defined by Delong et al. (20). In all comparisons, p< 0.05 was accepted as significant.

RESULTS

Clinical Characteristics of patients

Sixtyseven patients with COVID-19 were enrolled. The mean age was 47.5 ±16.9 (range 18-81), and 39 (58.2%) of the patients were male. The most frequent comorbidity was hypertension (16/67, 23.9%). Fever (40.3%) was the most common presenting symptoms. According to the mentioned parameters for disease severity, 58 (86.6%) of the patients were in the mild disease group, and 9 (13.4%) were in the severe disease group. The demographic and clinical characteristics of patients are summarized in Table 1.

Table 1. Clinical Characteristics of 67 Patients with COVID-19 on Admission. The continous data were expressed as mean±standard deviation whereas categorical variables were presented as counts and percentages (in parentheses).

	All patients (n=67)
Gender	
Male	39 (58.2)
Female	28 (41.8)
Age (years mean ± SD)	47.57 ± 16.96
Chronic diseases	
Diabetes	7 (10.4)
Hypertension	16 (23.9)
COPD	2 (3)
Asthma	5 (7.5)
Chronic kidney disease	2 (3)
Coronary artery disease	3 (4.5)
Congestive heart failure	5 (7.5)
Malignancy	1 (1.5)
Smoking history	
None	44 (65.7)
Former/current	23 (34.3)
Symptom	
None	15 (22.4)
Fever	27 (40.3)
Dyspnea	23 (34.3)
Cough	24 (35.8)
Myalgia	15 (22.4)
Headache	7 (10.4)
Sore throat	8 (11.9)
Diarrhea	5 (7.5)
Sputum	6 (9)
Duration of symptoms (days)	4± 2.7
Clinical score	
Mild	30 (44.8)
Moderate	28 (41.8)
Severe	4 (6)
Critical	5 (7.5)

Chest CT findings

In 40/67 (59.7%) of cases had findings suggestive of pneumonia on CT. Among 40 cases with pneumonia, the mixed distribution pattern was most frequent in axial (55%), craniocaudal (80%), and anteroposterior (62.5%) direction. The most common CT findings were GGO with consolidation in 21/40 patients (52.5%).
The most frequent CT sign was vascular enlargement (87.5%). There was significant difference in number of involved lobes, bilateral lung involvement, distribution pattern, crazy-paving sign, bronchial wall thickening, vascular enlargement and linear opacities between the two severity groups (p<0.05). The chest CT findings of patients are summarized in Table 2.

Semiquantitative CT analysis

In SCT analysis, the inter-observer reliability of three observers was excellent for all visual scoring methods (ICC for 4-point score: 0.944 (95%CI; 0.918-0.963), ICC for 5-point score: 0.934 (95%CI; 0.903-0.957), ICC for multiplier score: 0.875 (95%CI; 0.820-0.917).

The SCT scores of three scoring methods were significantly different between the two clinical severity groups (p<0.001) (Table 3). There was moderate correlation between clinical severity score and 4-point score and multiplier score (p<0.001, r=0.493 and p<0.001, r=0.483 respectively). 5-point score and clinical severity score had good correlation (p<0.001, r=0.513). The area under curve (AUC) values of SCT scores for differentiating mild disease group from the severe disease group were as follows: 0.902 (95% CI 0.805-0,961) for 4-point score, 0.920 (95% CI 0.827-0.972) for 5-point score and 0.895 (95% CI 0.795-0.956) for multiplier score (Fig. 3). Considering the AUC values, 5-point score established the best performance in evaluating the severity of COVID-19 pneumonia. The cut-off value of >7 for 5-point score had 88.89% sensitivity and 82.76% specificity for differentiating the mild disease from severe disease. The cut-off value of >5 for 4-point score had 66.67% sensitivity and 87.93% specificity for differentiating the mild disease from severe disease. The cut-off value of >7 for Multiplier score had 88.89% sensitivity and 79.31% specificity for differentiating the mild disease from severe disease (Table 4).

Table 2. CT findings of 40 patients with COVID-19 pneumonia. Categorical variables were presented as counts and percentages (in parentheses).

CT Characteristics	Total (n=40)	Mild group (n=31)	Severe group(n=9)	p
CT pneumonia				
COVID-19 typical	35 (87.5)	26 (83.87)	9 (100)	
COVID-19 indeterminate	3 (7.5)	3 (9.67)	0	0.022
COVID-19 atypical	2 (5)	2 (6.45)	0	
Number of lobes involved				
1	5 (12.5)	5 (16.12)	0	
2	4 (10)	4 (12.90)	0	
3	3 (7.5)	3 (9.67)	0	0.009
4	6 (15)	4 (12.90)	2 (22.22)	
5	22 (55)	15 (48.38)	7 (77.77)	
One/Two sided				
Single lobe	5 (12.5)	5 (16.12)	0	
One side multiple lobes	1 (2.5)	1 (3.22)	0	0.009
Two sides multiple lobes	34 (85)	25 (80.64)	9 (100)	
Axial distribution pattern				
Peripheral	17 (42.5)	13 (41.93)	4 (44.44)	
Central	1 (2.5)	1 (3.22)	0	0.022
Mixed	22 (55)	17 (54.83)	5 (55.55)	
Craniocaudal distribution pattern				
Middle-lower	5 (12.5)	5 (16.12)	0	
Upper	3 (7.5)	3 (9.67)	0	0.016
Mixed	32 (80)	23 (74.19)	9 (100)	
Anteroposterior distribution pattern				
Posterior	13 (32.5)	12 (38.70)	1 (11.11)	
Anterior	2 (5)	2 (6.45)	0	0.003
Mixed	25 (62.5)	17 (54.83)	8 (88.88)	
Attenuation				
GGO	17 (42.5)	13 (41.93)	4 (44.44)	
Consolidation	2 (5)	2 (6.45)	0	0.024
Mixed	21(52.5)	16 (51.61)	5 (55.55)	
Minor CT signs				
Crazy-paving	20 (50)	12(38.70)	8 (88.88)	<0.001
Linear opacities	29 (72.5)	20 (64.51)	9 (100)	<0.001
Air bronchogram	14 (35)	10 (32.25)	4 (44.44)	0.084
Halo	23 (57.5)	17 (54.83)	6 (66.66)	0.054
Reverse halo	1 (2.5)	1 (3.22)	0	1.0
Cavitation	0	0	0	
Tree-in-bud	1 (2.5)	1 (3.22)	0	1.0
Vascular enargement	35 (87.5)	26 (83.87)	9 (100)	0.002

CT= Computed tomography, GGO= Ground-glass opacity.

Table 3. Comparison of mild and severe disease according to SCT scores and QCT parameters. The continous data were expressed as mean±standard deviation.

	Mild group (n=58)	Severe group (n=9)	Total population (n=67)	p
4-point score	2.31±2.71	7 ±2.2	2.94 ±3.09	<0.001
5-point score	3.14 ±3.98	11 ±3.3	4.19 ±4.73	<0.001
Multiplier score	4.50 ±6.03	15.1 ±7.2	5.93 ±7.14	<0.001
TLV (cm3)	5168.4 ±1278.7	4030.7 ±423.4	5085.6 ±1269.9	0.052
Volume of opacity (cm3)	59.6 ±136.4	622.5 ±438.4	100.5 ±222.9	0.005
QCT score (%)	1.5 ±4.2	15.2 ±10.2	2.5 ±5.9	0.005

TLV= Total lung volume, QCT= Quantitative computed tomography, HU= Hounsfield unit.

Table 4. Thresholds, sensitivities, specificities of SCT scores, and QCT parameters for distinguishing severe disease from the mild disease.

Parameter	AUC [95% CI]	Treshold value	Sensitivity (%)	Specificity (%)
4-point score	0.902[0.805-0.961]	>5	66.67	87.93
5-point score	0.920 [0.827-0.972]	>7	88.89	82.76
Multiplier score	0.895 [0.795-0.956]	>7	88.89	79.31
QCT score (%)	0.890 [0.776-0.758]	>10.29%	75.00	98.04
TLV (cm3)	0.794 [0.664-0.891]	≤ 4611	100	64.71

AUC= Area under curve, CI= Confidence interval, TLV= Total lung volume, QCT= Quantitative computed tomography, HU= Hounsfield unit.

Quantitative CT analysis

The mean QCT score was 2.5±5.9%, and there was a moderate correlation between QCT score and clinical severity score (p=0.004, *r*=0.380). The volume of opacity was significantly different between the two clinical severity groups (p=0.005) (Table 3). In ROC analysis, the AUC value of the QCT score was 0.890 (95% CI 0.776-0.758). The cut-off value of >10.29% had 75.00% sensitivity and 98.04% specificity for differentiating the mild disease from severe disease. The AUC value of total lung volume (TLV) was 0.794 (95% CI 0.664-0.891), and the TLV cut-off of ≤4611 ml had 100% sensitivity and 64.71% specificity (Figure 3, Table 4). There was no statistically significant difference between AUC values of QCT and SCT scores. QCT analysis was not possible in 11 patients (16.4%) because of motion artifacts.

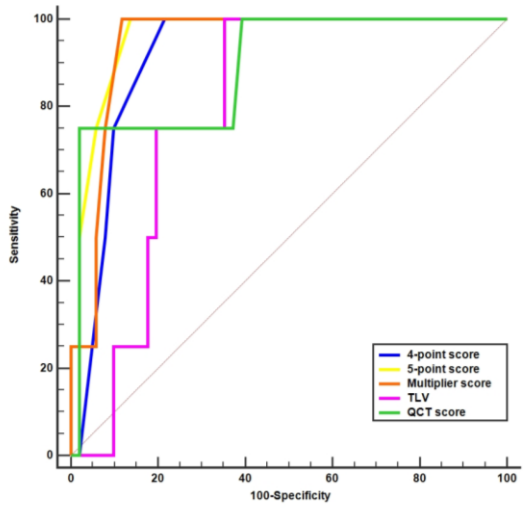

Figure 3. Receiver operating characteristic (ROC) curve analysis was obtained to differentiate the severe disease from mild disease in Covid-19 patients. The ROC analysis showed quantitative CT (QCT) score had an area under curve (AUC) of 0.890 (95% CI 0,776-0,758), total lung volume (TLV) had an area under curve (AUC) of 0.794 (95% CI 0.664-0.891), 4-point score had an area under curve (AUC) of 0.902 (95% CI 0.805-0.961), 5-point score had an area under curve (AUC) of 0.920 (95% CI 0.827-0.972) and multiplier score had an area under curve (AUC) of 0.895 (95% CI 0,795-0,956). CT= Computed tomography, HU= Hounsfield unit, CI= Confidence interval.

DISCUSSION

In the current study, we investigated the performance of QCT and three different SCT visual scoring methods to identify disease severity in COVID-19 patients. Our results revealed that three of all SCT scores and QCT parameters, including the percentage of opacity and volume of opacity, were successful in discriminating the mild disease from severe disease.

Regarding the AUC, 5-point score performed best in the prediction of severe disease among three different scoring systems (AUC, 0.920; 95% CI 0.827-0.972).

During the COVID-19 outbreak, it is vital to identify severe COVID-19 patients at the early stage of the disease. Previous studies have shown that visual assessment of disease extent based on several scoring methods was significantly correlated with disease severity. Yang et al. revealed that the SCT score cut-off value was 19.5 for identifying severe COVID-19 with 83.3% sensitivity and 94% specificity (21). In our study, the 5-point score cut-off value of 7 had 88.89% sensitivity and 82.76% specificity. However, as the visual scoring methods are subjective, the level of consistency among readers with different levels of experience need to be revealed. In the current study, CT images were re-evaluated by a radiology resident, a radiologist and a senior thoracic radiologist. In accordance to previous studies, the result showed that inter-rater reliability was excellent for all visual scoring methods for three observers with different experience levels. Furthermore, our results showed that all visual scores significantly correlated with QCT score (p<0.001) and there was no statistically significant difference between AUC values of QCT and SCT scores.

Various CT scoring methods were proposed in the literature to assess lung involvement in viral pneumonia, including severe acute respiratory syndrome (SARS), H7N9 pneumonia, and COVID-19 pneumonia (22). In COVID-19 studies, 4-point and 5-point score are most widely used scoring methods, and in these methods, scoring is only based on the extent of the lung opacities. Francone et al. revealed that the incidence of consolidation was significantly higher in severe and critical cases (23). In addition, Sun et al. suggested that consolidation/GGO ratio in total lesion is significantly higher in severe group (24). In order to consider the density of the lesion as well as the extent, scoring methods including attenuation pattern in scoring were applied. Yuan et al. used the scoring method that combined the four-point scale with attenuation score and revealed that a cut-off value of 24.5 had a sensitivity of 85.6% and specificity of 84.5% for the prediction of mortality (13). To our knowledge, this is the first study comparing the most widely used visual scoring methods according to their performance in discriminating severe disease and mild disease. Our results revealed that 5-point score performed best in distinguishing severe disease from mild disease in COVID-19 pneumonia.

In accordance with previous studies, in our study lung opacities mostly involved both lungs and multiple lobes with mixed peripheral and central distribution (24). The most frequent finding was mixed GGO and consolidation in our study (52.5%). In agreement with our findings, in a review article Carotti et al. demonstrated that the average percentage of mixed GGO and consolidation was 47% of the patients (26). The most frequent additional CT sign was vascular enlargement in our study (87.5%). Similarly Li et al. reported that vascular enlargement sign was found in 82.4% of the patients (27). The prevalence of crazy-paving sign was 50% in our population also consistent with literature (8). The reversed halo sign, an uncommon CT sign in COVID-19 patients, was found in only 2.5% of our population.

QCT, which has been widely used in diffuse lung diseases, provides accurate, objective, and quantitative data in a reproducible manner. It has been shown that QCT is an efficient tool to evaluate disease severity and monitor treatment effectiveness (14). Liu et al. demonstrated that CT quantification of lesions could predict disease severity and prognosis (15). Similarly, Lyu et al. reported that QCT parameters were significantly different between ordinary and severe cases.

Also in this study, the AUC value of mean lung density (MLD) was 0,96 (95% CI 0,82-0,98) and MLD cut-off value of ≤-816 HU had 91% sensitivity and 90% specificity (28).

In our study, the AUC value of QCT score was 0.890 (95% CI 0.776-0.758) and QCT score (%) cut-off value of >10.29% had 75.00% sensitivity and 98.04% specificity. Visual scoring method that showed the best performance according to AUC value was 5-point score and had 88.89% sensitivity and 82.76% specificity for cut-off value of >7. There was no statistically significant difference between AUC values of QCT and SCT scores. Although QCT score had relatively low sensitivity value, specificity was significantly higher than SCT scores. As the number of COVID-19 cases is still increasing globally, limited healthcare resources remain a concern. Higher specificity values of QCT may be considered as an advantage in this situation. Besides, QCT is widely used tool which provides fast and standardized data, and it has a low learning curve. On the other hand, this method still needs a radiologist's supervision for accurate segmentation and unable to perform analysis in the presence of severe artifacts. Sun et al. reported that in 15 patients of 126 patients (11.9%) had severe artifacts on CT and QCT analysis was not possible (24). This rate was 16.4% in our study.

Our study has several limitations. First, it was a single-center study, and the sample size was small, especially in the severe disease group. Larger sample size are required to corroborate our findings. Second, only CT scan at admission was analyzed in our study. Follow–up images were needed to understand pathophysiological changes of the disease. Finally, radiomics, as an advanced quantitative tool, may be applied to images of COVID-19 to predict prognosis.

CONCLUSION

In conclusion, our study revealed that QCT parameters, including QCT score and volume of opacity, could be used in severity assessment. QCT can play an important role in the management of patients with its remarkably high specificity, especially when health care resources were limited. Our results showed that among the SCT scoring methods, the 5-point score performed best in discriminating severe disease from the mild disease. Also, SCT scoring methods are reliable and consistent regardless of experience level. Based on the results of our study, we recommend the use of QCT assessment together with the five-point visual scoring system to differentiate the severe disease group with high sensitivity and specificity in COVID-19 pneumonia.

Conflict of interest

No conflict of interest was declared by the authors.

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