The role of CT-based body composition parameters in the course of COVID-19

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Acknowledgment/disclaimers/conflict of interest

All authors have seen and agree with the contents of the manuscript and there is no financial interest to report.

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Informed consent

The study was approved by the Ethics Committee of Izmir Tepecik Training and Research Hospital (No:2022/10-11). Individual consent for this retrospective analysis was waived.

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Abstract

Background/aim: A significant correlation is observed between the course of COVID-19 and body composition parameters including visceral fat quantification, muscle mass, and hepatic attenuation. The aim of the study is to investigate the correlation between the extent of lung involvement and various CT parameters, as well as laboratory findings in COVID-19 patients.

Materials and methods: A retrospective analysis was conducted on 72 adult patients with laboratory-confirmed SARS-CoV-2 infection who underwent two consecutive thorax CT scans at least 2 weeks apart. The patients were divided into two groups, progressive and non-progressive, based on the presence of two consecutive CT scans. Skeletal muscle area (SMA), subcutaneous fat area (SFA), visceral fat area (VFA), total fat area (TFA), liver-spleen density ratio (L/S), and laboratory findings were compared between the groups. The correlation between the extent of lung involvement and CT parameters, as well as laboratory findings were assessed.

Results: A total of 72 patients were included, with 34 (47.2%) being female and 38 (52.8%) male. Hemoglobin levels were significantly lower in the progressive group compared to the non-progressive group. C-Reactive Protein (CRP) values were higher in the progressive group during follow-up. The non-progressive group exhibited decreases in subcutaneous fat area, visceral fat area, and total fat area, while liver density increased. The progressive group showed a decrease in T12 paravertebral muscle area and muscle index.

Conclusion: In the comparison of laboratory and radiological data in the course of COVID-19, white blood cell (WBC) and neutrophil counts increase, T12 – skeletal muscle area (SMA), and skeletal muscle index (SMI) decrease in the lung progressive group. Hemoglobin and CRP levels at admission may indicate disease progression. Future studies are warranted to increase the reliability with larger series.

Key worlds: COVID-19, risk factors, body composition, prognosis, thorax

1. Introduction

The Severe Acute Respiratory Syndrome Coronavirus 2 (SARS-CoV-2) virus, which causes Coronavirus Disease 2019 (COVID-19), has rapidly spread around the globe since December 2019 [1]. This prompted the World Health Organization (WHO) to classify it as a global pandemic on March 11th, 2020*.

The Reverse Transcriptase-Polymerase Chain Reaction (RT-PCR) test is currently the most reliable and effective way to diagnose the factor [2].

Due to its widespread availability and its role in enabling fast pneumonia diagnosis, chest computed tomography (CT) is fundamental to diagnosing and managing COVID-19 patients [3, 4].

The infection can cause mild to moderate COVID-19 disease and COVID-19 pneumonia, leading to intensive care support and even death for some patients [5]. Thus, it is essential to

be able to estimate which individuals will experience the progression of the disease and what their prognosis will be.

*Footnote: World Health Organization (2023). WHO Coronavirus (COVID-19) Dashboard [online]. Website https://covid19.who.int [accessed 12.12.2023].

Studies have identified several risk factors that make individuals more susceptible to severe illness, including age, male sex, diabetes, hypertension, cardiopulmonary diseases, obesity, and sarcopenia [6-12].

In the literature, there is a wealth of academic studies on the subject of sarcopenia, obesity and sarcopenic obesity. In recent years, there have been numerous studies investigating the relation between sarcopenic obesity and long-term illnesses, including cancer and other inflammatory diseases [13, 14]. It has been observed that 10% or more of the global population have sarcopenia and sarcopenic obesity, both of which are associated with prolonged hospital stays and an elevated mortality rate. [15]. Improved thoracic muscle quality has been linked to a decreased rate of hospitalization, invasive mechanical ventilation (IMV), and death [16].

Obesity has almost become a pandemic in developed countries and is a significant risk factor for many diseases [17]. It is widely accepted that there is a direct link between obesity and respiratory diseases such as asthma, obstructive sleep apnea syndrome, and COVID-19 pneumonia [17, 18].

Unenhanced CT scans have been utilized to reveal hepatic steatosis by measuring the liver-to-spleen ratio (L/S). Therefore, liver to spleen ratio may be a useful tool in the analysis of liver damage as it demonstrates alterations in the attenuation of the hepatic tissue [6].

Laboratory studies could be crucial in determining the severity of COVID-19 infection, distinguishing between severe and non-severe cases. Abnormal laboratory findings among COVID-19 patients are frequently characterized by increased levels of lactate dehydrogenase (LDH), alanine aminotransferase (ALT), aspartate aminotransferase (AST), total bilirubin (Bil), creatine kinase (CK), creatinine (Cr), leukocytes and neutrophils counts, as well as a decrease in the levels of albumin and lymphocyte count [19].

The aim of this study is to evaluate the relationship between the clinical, laboratory, and CT-based body composition findings such as visceral fat quantification, muscle mass and hepatic attenuation, and the radiological COVID-19 lung progression. Furthermore, this is the initial article that investigates correlations between body composition, laboratory and clinical results and COVID-19 pneumonia concurrently in the English literature.

2. Materials and methods

2.1. Patients and study design

We identified eligible patients by searching the radiological information from our institutional PACS system retrospectively. From March 2019 to January 2022, among 1791 patients who were suspected of COVID-19 pneumonia, those who had two successive thorax CTs at least 2 weeks apart with consecutive laboratory results were selected for inclusion. Among the total number of patients, only 72 met those criteria. The research was only conducted with participants who were 18 years of age or older. Individuals with RT-PCR tests that yielded positive results, yet who did not receive thorax CT scans were excluded. Also, contrast-enhanced CT scans and abundant artifacts on images that would lead to wrong interpretation were other exclusion criteria. Patient data upon hospital admission were obtained from digital records and encompassed demographics, body mass index, symptoms, comorbidities, and laboratory test results.

Two radiologists (EGV and OC) with 7 years of experience in abdominal radiology reviewed the images and patient histories collectively. The CT scans were examined initially, and subsequently, the medical histories of patients were reviewed in a blinded manner. 72 patients with RT-PCR-confirmed SARS-CoV-2 infection who underwent two consecutive thorax CT at least 2 weeks apart were retrospectively reviewed for assessment of demographical, clinical, and laboratory data, and outcomes on lung CT scores (non-progressive vs progressive) [20, 21]. This retrospective study was given authorization by our institutional organization and approved by local institutional review board.

2.2. Image Acquisition and Analysis

All CT scans were performed using a 128-slice-CT scanner (Somatom Definition AS, Siemens Healthineers; Erlangen, Germany). Each thorax CT scan was performed with the patient supine, and during a single inspiratory breath hold when feasible. Axial images were obtained that ranged from the thoracic inlet to the upper abdomen including the upper or middle pole of the kidneys. All the CT scans were performed without administration of contrast agent.

The degree of the involvement of each lung lobe was assessed, and classified as score 0, no involvement; score 1, less than 5% involvement; score 2, 5%–25% involvement; score 3, 26%–49% involvement; score 4, 50%–75% involvement; and score 5, greater than 75% involvement of the lobe. By adding together, the five lobe scores, an overall lung total severity score was achieved. According to this scoring system, the minimum and maximum values for lung CT scores were 0 and 25 respectively [6, 20,22]. The data were compared in the progressive and nonprogressive groups determined by the lung score. The suggested classification of Frankone et al. [20] for the extent of the disease was used in the present study. In compliance with this scoring system, patients are divided into 2 groups and are

determined as progressive and nonprogressive groups (Figure 1 a,b). The decision of progressive/non-progressive disease was assessed in consensus of two radiologists.

The progressive group was defined as the patients whose lung CT scores increased during the follow-up period whereas non-progressive group defined patients with the same or decreased CT scores. From two consecutive thorax CTs, the skeletal muscle area (SMA) and density of the paravertebral muscles at the level of the T5 and T12 vertebrae (SMD), skeletal muscle index (SMI), subcutaneous fat area (SFA), visceral fat area (VFA), total fat area (TFA) from the abdominal sections, and liver to spleen density ratio (L/S) and abdominal circumference were measured by two radiologists independently using AWI server application (AWI Server, 3.2 Ext 1.0; GE Healthcare). Measurements performed more than one time to check reproducibility and interobserver variability was calculated for measurement of CT parameters.

Calculations of fat content and circumference of the abdomen were measured manually at the first slice caudal to the pleural recess (Figure 2 a, b) [23]. Subcutaneous fat area was calculated by subtracting visceral fat area from total fat area. The fat threshold values were set between –190 and – 30 HU [15].

In order to measure muscle size, an area measurement of the paravertebral muscles at the T5 and T12 vertebra levels was performed (Figure 3 a, b). Muscle outlines were manually contoured. A muscle-specific threshold was then used to determine the SMA. The SMI was calculated by taking the SMA (cm^2) and dividing it by the square of the body height (m^2). The threshold values for muscle were set between –29 and +150 HU [15].

As not all patients had recorded measurements of height and weight, we used the vertebral size as a representation of the body mass index to assess the skeletal muscle indexing. In their

study Waduud et al. demonstrated how to convert vertebral body parameters into estimated height [24].

The calculation of the hepatic attenuation values was done by placing two regions of interest (ROI) with a size of at least 100mm^2 in the right lobe of the liver anteroposteriorly, as well as one ROI in the left lobe with attention to avoid major vascular structures (Figure 4). Splenic attenuation was obtained by placing one ROI, greater than 100 mm^2 in area. The L/S ratio was obtained by taking the mean of the Hounsfield unit (HU) measurements of both liver lobes and dividing it by the HU of the spleen. Careful consideration was taken to place the ROIs in exactly the same location in both CT scans.

2.3. Statistical analysis

The Kolmogorov-Smirnov test was used to determine if the data conformed to the normal distribution. Categorical variables were expressed as percentages, and content showing nonparametric variables as median and range. Chi-square was used to compare qualitative data. Dependent numerical data showing nonparametric distribution were evaluated with the Wilcoxon test. Spearman's Rho analysis was performed to evaluate the relationship between extension of the lung involvement and laboratory findings, and body composition parameters. The intra-class correlation coefficient (ICC) was used for the measurement of CT parameters between two observers. The Spearman's rho values between ±0.2 and ±0.4; ±0.4 and ±0.6; ±0.6 and ±0.8; ±0.8 and ±1 are considered as to be weak, moderate, strong, and very strong association, respectively. P values <0.05 were considered significant for all tests.

3. Results

3.1. Demographic data and clinical features

Of the 72 patients included in the study, 34 (47.2%) were female and 38 (52.8%) were male. The mean age was 59.94 years, standard deviation (SD) ± 16.57, a minimum of 25 and a

maximum of 88 years. The mean body mass index (BMI) was calculated as 23.83 kg/m² ± 1.87 for men, whereas for women it was calculated as 24.09 kg/m² ± 3.13 (p=0.67). Of 8 (11.1%) patients requiring intensive care, 3 were female and 5 were male. The mean length of stay in the ICU was 11.96 days: 11.06 days for women and 12.76 days for men (p=0.531). The minimum length of stay was 2 days, and the maximum length of stay was 35 days. During the study period, 3 (4.1%) patients, 1 female and 2 males died, and 69 (95.9%) patients were discharged. The most common comorbidities were hypertension (n = 27, 37.5%), DM (n = 19, 26.4%), CAD (n = 8, 11.1%), COPD (n = 5, 6.9%), CRF (n = 5, %) 6.9), malignancy (n = 4, 5.6%). Of these, 11 (15.3%) had more than one comorbidity (Table 1). The non-progressive group consisted of 44 (61.1%) patients and the progressive group consisted of 28 (38.9%) patients. Patients in the progressive group had a longer hospital stay (p=0.017). While three patients (5%) died in the progressive group, no patient died in the non-progressive group.

3.2. Laboratory findings

Hemoglobin levels were significantly lower in the progressive group than in the non-progressive group at the time of admission. Hemoglobin levels were significantly lower in the progressive group than in the non-progressive group at both the time of admission and follow-up (Table 2).

At the time of hospital admission, direct bilirubin concentration was significantly higher (p=0.017) and creatinine level was significantly lower (p=0.04) in the non-progressive group compared to the progressive group. At follow-up, CRP values were significantly higher (p=0.044) in the progressive group compared to the non-progressive group. The in-group comparison revealed a significant increase of platelets (p< 0.001) and ALT (p=0.013) from hospital admission to follow-up only in the non-progressive group. Likewise, WBC and

neutrophil counts increased significantly (p=0.006, p=0.015, respectively) only in the progressive group.

3.3. CT Parameters

Inter-observer agreement was almost perfect between the readers for measurement of CT parameters (ICC range 0.849-0.970) except the liver/spleen density with substantial agreement (ICC 0.735) (Table 3).

There was no significant difference between the progressive and nonprogressive groups in any CT parameters at the time of admission (Table 4). Also, no significant differences were found for all CT parameters between the two groups in the follow-up. In the non-progressive group, subcutaneous fat area, visceral fat area, and total fat area decreased significantly from hospital admission to follow-up (p = 0.009, p = 0.009, p = 0.002, respectively) whereas liver density increased significantly (p=0.02). In the progressive group, T12 paravertebral muscle area, and muscle index decreased in follow-up CT.

At initial hospital admission, a weak positive correlation was observed between extent of lung involvement and white blood cell count, direct bilirubin level. In addition, a weak negative correlation was seen between lung involvement and liver density, liver spleen density ratio. Moreover, a moderate positive correlation was found between lung involvement and CRP levels (Table 5). Also, there was a weak negative correlation between lung involvement and liver density (p=0.037). Furthermore, at follow-up, the correlation between lung involvement and neutrophil count, procalcitonin, creatinine levels were found to be weakly positive, whereas there was a moderate positive correlation with CRP levels.

4. Discussion

In this study, we purpose to evaluate the association between clinical, laboratory, and CT-based body composition assessments, including visceral fat estimation, muscle mass, hepatic

attenuation, abdominal circumference, and the radiologic course of COVID-19 pneumonia. The body composition measures were obtained by routinely performed thorax CT scans on COVID-19 patients.

Various studies have shown that patients with obesity are more likely to experience severe COVID-19 symptoms with increased morbidity, such as increased rate of hospitalization and the need for invasive mechanical ventilation [25]. It is well-known that different types of adipose tissue depots cause obesity. This includes visceral adipose tissue and subcutaneous adipose tissue, which bring forth distinct degrees of hazard for metabolic disorders and cardiovascular risks [26]. Petersen et al. reported that visceral adipose tissue and CT-derived upper abdominal circumference are significant indicators of severe courses of COVID-19 [8]. In our study, we did not find any relevance between adipose tissue composition and disease progression. This could be attributed to the fact that the CT scans conducted during the follow-up process were ordered at short time intervals. Also, it is possible that the body composition parameters that are measured from other body levels are not as reliable as those taken from abdominal CT scans at the L3 level. Additionally, it was noted that the visceral fat area diminished in the progressive group at follow up. This could potentially be linked to inadequate nutrition during a severe illness.

Visceral fat accumulation can have a significant impact on the prognosis of diseases. Results from research have suggested that non-alcoholic fatty liver disease can cause an elevated mortality rate in individuals who have community-acquired pneumonia [27]. Our hypothesis in this study was that hepatic steatosis and L/S ratio decrease could worsen COVID-19 outcomes, considering its effects on human metabolism and its correlation with obesity. In a study by Guler et al. [6], decrease in L/S was observed in COVID-19 patients with elevated lung CT scores. In our study, there was weak correlation between liver density, L/S ratio, and disease progression. It is possible that the positioning of the upper arms along

the sides of some patients may have produced arm-related noise that could have influenced the attenuation values in some cases.

Cross-sectional images can be used to measure skeletal muscle mass (SMM) and skeletal muscle index. A range of disorders such as COVID-19 can be impacted by these parameters, which have predictive and prognostic implications. Skeletal Muscle Index (SMI) is used to consider the effect of body height on muscle tissue, which is calculated by dividing the skeletal muscle area by the square of the body height. SMI can be considered as a more standardized parameter [12]. Another hypothesis in this study is that sarcopenia and sarcopenic obesity have a considerable and detrimental effect on the progression of the disease. In our study, we were not able to find any relation between muscle measurements at initial hospital admission and progression of disease. In our opinion, a lack of proper nutrition during a serious illness in combination with the inflammatory changes caused by COVID-19 might have caused decrease in SMA and SMI at level T12 at follow-up.

Multiple laboratory results were proposed to predict mortality in those with COVID-19 based on clinical parameters [19, 28]. A study has demonstrated that increased neutrophils, CRP, procalcitonin, AST, ALT, total bilirubin and decreased lymphocytes, platelets, and albumin has a prognostic value for COVID-19 [19]. In our study, in the progressive group neutrophil counts increased significantly at follow-up ($p=0.006$, $p=0.015$, respectively). Also, CRP levels were higher at follow-up in the progressive group. The increase in serum direct bilirubin concentration was significant ($p=0.017$). There was a weak positive correlation between the extent of lung involvement and white blood cell, direct bilirubin levels, procalcitonin, and creatinine levels. And moderate positive correlation between CRP levels was found.

Our study has several limitations. First, the study was retrospective, conducted at a single center, and has small number of patients. Second, in our study, no baseline images of patients were taken into consideration, and any that were present were not utilized. Therefore, some overlapping features of COVID-19 pneumonia and other diseases may have caused us to misinterpret the images as progression. Third, we measured a single slice of adipose tissue in the area where the lung parenchyma was not visible caudal to the pleural recess. Hence, the level is not validated such as for those obtained at the L3 level. Forth, from a technical standpoint, the positioning of the upper arms along the sides of the patient may have caused arm-related noise that could have impacted the attenuation values. In some cases, this may have led us to measure the density of muscle and fat tissue inaccurately. Additionally, not all patients had recorded heights. As a result, we had to use the anteroposterior diameter of the T12 vertebra to assess the height of some of our patients, a method that had been previously validated [24]. Furthermore, in our hospital, patients with quick health deterioration and transport problems are monitored clinically and with traditional chest X-ray techniques due to its convenient mobility. Thus, a considerable number of patients were excluded from this study.

In conclusion, thorax CT scan plays a crucial role to detect COVID-19. Thorax CT can be used to measure body composition parameters such as the skeletal muscle area (SMA) and skeletal muscle index (SMI) at level T12, and these parameters seem to decrease as the severity of COVID-19 pneumonia increases. Additionally, low level of hemoglobin and increased CRP levels at admission may anticipate the progression of disease. Also, WBC, neutrophil counts, CRP, and procalcitonin that are obtained at follow-up may be associated with progression of disease.

Abbreviations

ACE2: Angiotensin Converting Enzyme 2

COPD: Chronic Obstructive Pulmonary Disease

COVID-19: Corona Virus Disease 2019

HU: Hounsfield Unit

ICU: Intensive Care Unit

IMV: Invasive Mechanical Ventilation

L/S: Liver to Spleen Density Ratio

RT-PCR: Reverse Transcriptase-Polymerase Chain Reaction

SFA: Subcutaneous Fat Area

SMA: Skeletal Muscle Area

SMD: Skeletal Muscle Density

SMI: Skeletal Muscle Index

TFA: Total Fat Area

VFA: Visceral Fat Area

WHO: World Health Organisation

Ethics approval and consent to participate

The study was approved by the Ethics Committee of Izmir Tepecik Training and Research Hospital (No:2022/10-11). Individual consent for this retrospective analysis was waived.

Availability of data and material

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Competing interests

The authors declare that they have no competing interests.

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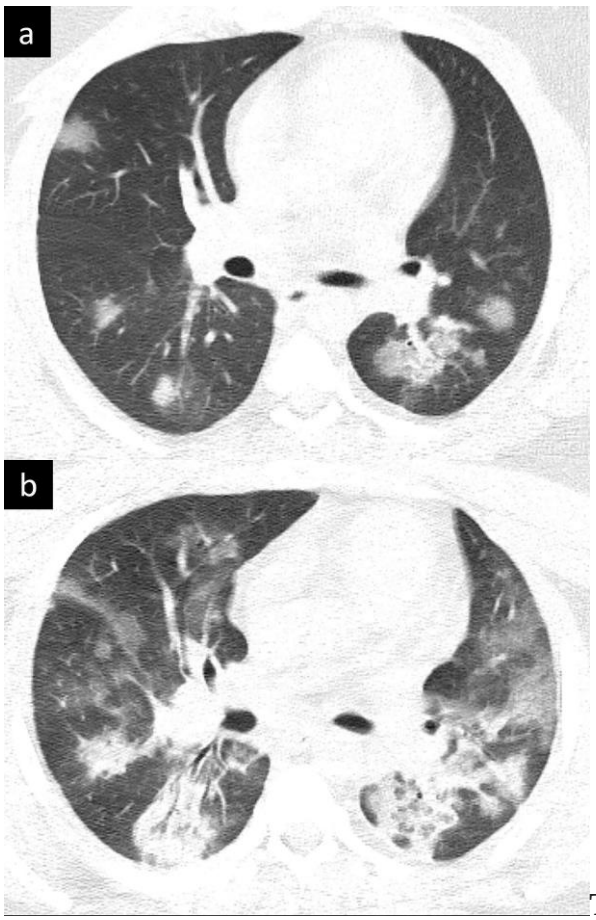

Tables and Figures

Figure 1. CT findings of progressive Covid Pneumonia. **a** 34-year-old man with positive RT-PCR test, axial CT images shows multifocal rounded focal consolidations and ground-glass opacities with predominant peripheral distribution. Initial lung CT score was 10. **b** At follow up image, axial CT scan shows consolidations and ground glass opacities in the corresponding segments became more evident. Lung CT score was scaled up to 20.

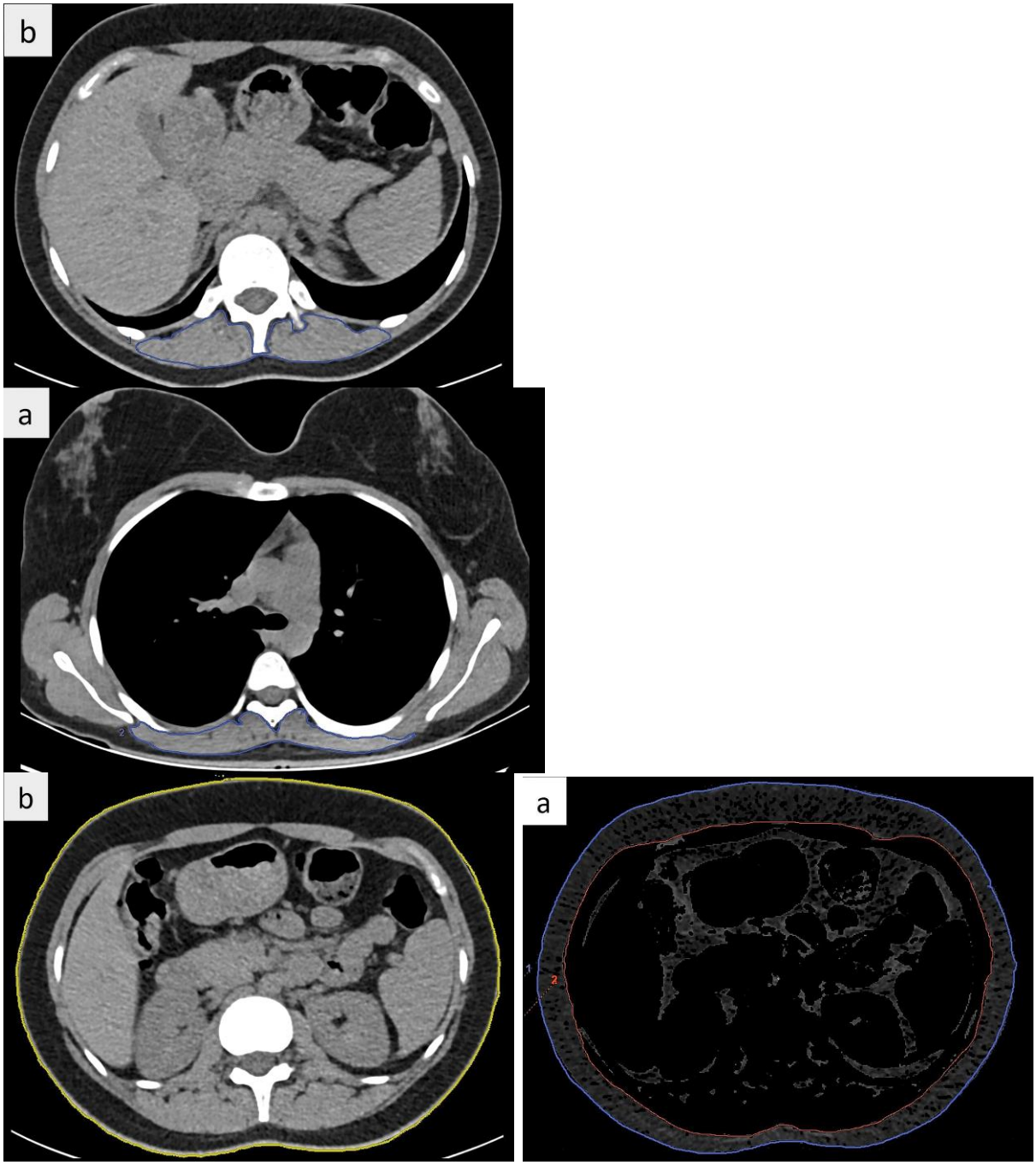

Figure 2. Measurements using the automated post-processing application. **a** Area between blue and red region of interest (ROI) demonstrates subcutaneous adipose tissue. The area within the red ROI indicates visceral adipose tissue Fat is identified as dark grey. **b** Yellow ROI shows abdominal circumference.

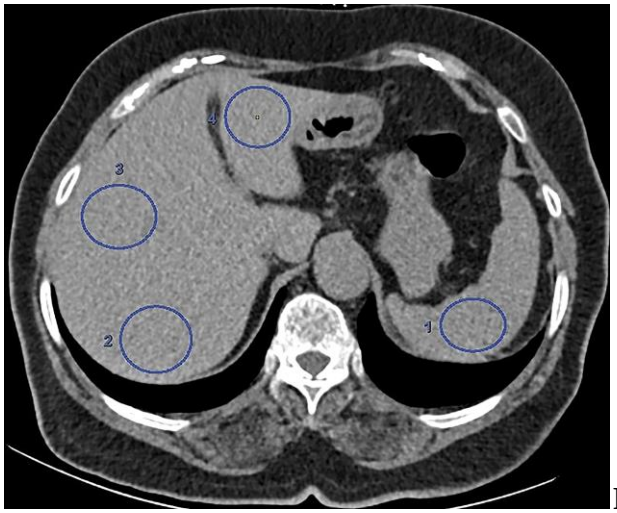

Figure 3. Example of paravertebral muscle delineation with blue drawings. **a** at level of T5. **b** at level of T12.

Figure 4. A single ROI was placed in the left liver lobe (4) to calculate hepatic attenuation values, while two ROIs were placed in the right liver lobe (2 and 3). Splenic attenuation was obtained by placing one ROI (1).

Table 1. Demographic data and clinical features of two groups of COVID-19 patients

Parameters	**Non-progressive group (n = 44)**	**Progressive group (n = 28)**	**p**
Age	62 (25-88)	63.50 (30-86)	0.632
Gender			0.706
Male	24 (54.5%)	14 (50%)	
Female	20 (45.5%)	14 (50%)	
Comorbidities	23 (52.3%)	15 (53.4%)	0.435
Hypertension	18 (40.9%)	9 (32.1%)	
Diabetes mellitus	10 (22.7%)	9 (32.1%)	
Coronary artery disease	3 (6.8%)	7 (25%)	
Malignancy	3 (6.8%)	1 (3.6%)	
Chronic renal failure	3 (6.8%)	2 (7.2%)	
COPD	3 (6.8%)	2 (7.2%)	
Treatment			0.993
Favipiravir	30 (68.2%)	19 (67.9%)	
Hydroxychloroquine	9 (20.4%)	6 (21.4%)	
Oseltamivir	5 (11.4%)	3 (10.7%)	
Length of hospital stay (day)	7 (2-35)	12 (2-75)	0.017
ICU admission	2 (2.8%)	6 (8.3%)	0.049
Dead	0 (0%)	3 (4.1%)	

Data are n (%) or median (minimum–maximum)

COPD: chronic obstructive pulmonary disease, ICU: intensive care unit, CRF: chronic renal failure

Table 2. Comparison of laboratory findings of progressive and non-progressive group COVID-19 patients

Parameter	**Non-progressive group (n = 44)**		**Progressive group (n=28)**		**Between group comparison (p)**		**Hospital admission and follow-up comparison (p)**	
	At hospital admission Median (min-max)	**Follow-up Median (min-max)**	**At hospital admission Median (min-max)**	**Follow-up Median (min-max)**	**At hospital admission[a]**	**Follow-up[b]**	**Non-progressive group[c] (p)**	**Progressive group[d]**
WBC	5.55 (3.10-30.40)	6.70 (1.7-21.9)	5.2 (1.60-13.4)	7.45 (2.10—23.00)	0.79	0.822	0.064	**0.006**
Neutrophil	3.7 (1.4-21.80)	4.7 (1.2-16.7)	3.75 (0.8-11.0)	5.45 (1.0-21.50)	0.876	0.552	0.052	**0.015**
Lymphocyte	1.0 (0.3-26.50)	1.45 (0.20—3.10)	1.0 (0.40-2.0)	1.10 (0.4-2.90)	0.862	0.619	0.169	0.099
Hb	13.4 (10.3-15.70)	13.4 (6.5-15.5)	12.8 (7.3-15.5)	12.25 (7.40—16.00)	**0.03**	**0.025**	0.101	0.07
Platelet	193 (83-374)	232 (34-472)	188 (117-384)	188 (102-571)	0.808	0.296	**<0.001**	0.072
CRP	37.5 (1—327)	24.7 (1.0-200)	31.5 (2-296)	57 (1-226)	0.808	**0.044**	0.131	0.094
Procalcitonin	0.04 (0.01-6.06)	0.06 (0.01-0.73)	0.045 (0.01-1.04)	0.07 (0.01-5.71)	0.744	0.636	0.245	0.247
D-dimer	1000	840	830	1285	0.862	0.236	0.250	0.124

	(190-10410)	(190-12150)	(220—7920)	(250-6610)				
AST	32 (12-503)	30 (0-489)	27 (15-56)	30 (15-168)	0.229	0.853	0.937	0.101
ALT	27 (6-337)	37 (1-651)	19 (7-67)	23 (7-221)	0.080	0.160	**0.013** [c]	0.037
Total bilirubin	0.63 (0.3-3.08)	0.64 (0.07-1.9)	0.5 (0.21—1.25)	0.5 (0.06-1.08)	0.139	0.062	0.316	0.456
Direct Bilirubin	0.16 (0.05-0.49)	0.15 (0.03-0.57)	0.11 (0.05-0.35)	0.11 (0.04-0.34)	**0.017**	0.088	0.638	0.885
Creatinin	1.0 (0.5-11.30)	1.02 (0.6-8.90)	1.2 (0.8—8)	1.0 (0.60—3.20)	**0.04**	0.401	0.801	0.898

A p value of <0.05 was written in bold type.

Data are median (minimum–maximum).

WBC white blood cells (4.5–11 × 10^3/μL), neutrophil count (2.02–7.46 × 10^3/μL), lymphocyte count (1–3.38 × 10^3/μL), Hb hemoglobin (11.7–16 g/dL), platelet count (150–450 × 10^3/μL), CRP C-reactive protein (0–5 mg/L), procalcitonin (0.04-0.1 μg/L), d-dimer (<550 μg/L FEU), AST aspartate amino transferase (normal limits, <35 U/L), ALT alanine aminotransferase (normal limits, <45 U/L), total bilirubin (0.1-1 mg/dL), direct bilirubin (mg/dL), creatinine (0.6–1.1 mg/dL).

[a] At the time of hospital admission, the comparison of progressive and nonprogressive groups.

[b] At the time of follow-up, the comparison of progressive and nonprogressive groups.

[c] In the non-progressive group, the comparison of laboratory parameters obtained at the time of follow-up and hospital admission.

[d] In the progressive group, the comparison of laboratory parameters obtained at the time of follow-up and hospital admission.

Table 3. The evaluation of inter-rater agreement using intraclass correlation

	ICC coefficient	95% CI	p
SMI T5	0.858	0.773-0.911	<0.001
SMI T12	0.840	0.745-0.900	<0.001
AC (cm)	0.970	0.953-0.982	<0.001
Subcutaneous fat area (cm2)	0.945	0.912-0.966	<0.001
Visceral fat area (cm2)	0.914	0.862-0.946	<0.001
Total fat area (cm2)	0.920	0.872-0.950	<0.001
Liver/Spleen density	0.735	0.577-0.834	<0.001
Liver HU	0.875	0.801-0.922	<0.001

ICC: intraclass correlation coefficient, CI: confidence interval

Table 4. CT parameters comparison of progressive and non-progressive group of COVID-19 patients

Parameter	**Non-progressive group (n = 44)**		**Progressive group (n = 28)**		**Between group comparison (p)**		**Hospital admission and follow-up comparison (p)**	
	At hospital admission Median (min-max)	Follow-up Median (min-max)	At hospital admission Median (min-max)	Follow-up Median (min-max)	At hospital admission[a]	Follow-up[b]	Non-progressive group[c] (p)	Progressive group[d]
SMA T5 (cm2)	11.31 (6.28-18.92)	10.73 (4.34 - 21.71)	10.81 (5.96-19.58)	10.87 (6.15-23.59)	0.786	0.738	0.434	0.699
SMI T5	4.00 (2.21-7.31)	3.92 (1.66 - 7.49)	3.81 (1.99-7.06)	3.95 (1.99-7.90)	0.652	0.632	0.424	0.657
SMA T12 (cm2)	30.05 (14.44-49.35)	27.35 (13.45-	31.97 (17.29-52.48)	29.49 (15.03 -	0.619	0.862	0.059	**0.005**

		55.63)		36.48)				
SMI T12	10.47 (5.37-17.14)	9.76 (4.45-21.87)	11.38 (5.86-17.63)	10.33 (4.92-13.96)	0.389	0.954	0.137	**0.004**
AC (cm)	103.95 (73.07-124.93)	102.68 (72.16-123.05)	105.77 (93.44-124.01)	106.25 (94.33-115.58)	0.579	0.556	0.077	0.124
Subcutaneous fat area (cm2)	114.56 (8.49-361.56)	109.59 (12.11-347.45)	128.98 (7.28-335.68)	128.00 (8.99-351.78)	0.278	0.216	**0.009**	0.820
Visceral fat area (cm2)	140.166 (12.61—471.15)	137.41 (7.63—328.73)	160.32 (16.94—338.30)	148.03 (17.63—345.83)	0.862	0.556	**0.009**	0.855
Total fat area (cm2)	275.38 (21.11-642.86)	270.48 (19.75-617.52)	304.88 (24.22-488.19)	288.43 (26.84-520.17)	0.611	0.230	**0.002**	0.964
Liver/Spleen density	1.0 (0.30-1.66)	1.08 (0.35-2.21)	1.03 (0.54-2.26)	1.05 (0.50-1.53)	0.808	0.773	0.061	0.982
Liver HU	58.20 (15.55-74.97)	59.15 (18.55-72.55)	55 (31.75-74.66)	55.53 (21.70-69.30)	0.899	0.053	**0.023**	0.227
Spleen HU	55.15 (36.90-77.10)	54.90 (27.80-70.70)	53.30 (31.20-68.50)	52.50 (12.60-67.40)	0.278	0.178	0.829	0.855

A p value of <0.05 was written in bold type.

Data are median (minimum-maximum).

SMA: Skeletal muscle area, T5: fifth thoracic vertebra, T12: twelfth thoracic vertebra, AC: Abdominal circumference, SMI: Skeletal muscle index

[a] At the time of hospital admission, the comparison of CT parameters in progressive and nonprogressive groups.

[b] At the time of follow-up, the comparison of CT parameters in progressive and nonprogressive groups.

[c] In the non-progressive group, the comparison of the CT parameters obtained at the time of follow-up and hospital admission.

[d] In the progressive group, the comparison of the CT parameters obtained at the time of follow-up and hospital admission.

Table 5. Relationship between laboratory parameters and CT parameters in the extension of the lung involvement at the time of hospital admission and at follow-up.

Variables	**The extension of the lung involvement at the time of hospital admission**		**The extension of the lung involvement at follow-up**	
	Spearman's rho coefficient	**P**	**Spearman's rho coefficient**	**p**
Age	0.164	0.168	0.090	0.452
WBC	**0.241**	**0.042**	0.230	0.051
Neutrophil	0.159	0.182	**0.300**	**0.011**
Lymphocyte	0.175	0.141	-0.187	0.116
Hb	-0.117	0.329	-0.293	0.013
Platelet	0.056	0.639	0.062	0.606
CRP	**0.548**	**<0.001**	**0.460**	**<0.001**
Procalcitonin	0.157	0.189	**0.279**	**0.018**
D-dimer	0.346	**0.003**	0.185	0.126
AST	0.104	0.384	-0.004	0.971
ALT	0.053	0.658	-0.057	0.635
Total bilirubin	0.108	0.367	0.004	0.972
Direct Bilirubin	**0.297**	**0.011**	0.014	0.904
Creatinin	0.159	0.183	**0.288**	**0.014**
SMA T5 (cm2)	-0.132	0.269	-0.068	0.569
SMI T5	-0.122	0.306	-0.045	0.705
SMA T12 (cm2)	-0.055	0.646	-0.014	0.910
SMI T12	-0.108	0.365	-0.004	0.976
AC (cm)	0.384	0.104	0.154	0.196

Visceral fat area	0.598	0.063	0.012	0.923
Subcutaneous fat area	0.015	0.898	0.151	0.204
Total fat area	0.051	0.673	0.113	0.344
Fat densitiy	0.130	0.277	-0.117	0.329
Liver/Spleen density	**-0.271**	**0.021**	-0.150	0.207
Liver density	**-0.323**	**0.006**	**-0.246**	**0.037**
Spleen densitiy	-0.024	0.839	0.034	0.778

A p value of <0.05 was written in bold type.