Research Article (Araştırma Makalesi)

Evaluation of Radiologic Findings and Lung Involvement Ratio in RT-PCR Positive Patients with COVID-19 Pneumonia

RT-PCR Pozitif COVID-19 Pnömonili Hastalarda Radyolojik Bulguların ve Akciğer Tutulum Oranının Değerlendirilmesi

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Özet

Amaç: Bu çalışmanın amacı, COVID-19 pnömonisinin görüntüleme özelliklerini ve kantitatif bilgisayarlı tomografi (BT) ile COVID-19'daki pulmoner tutulumun derecesini gözlemlemek ve hastalık yükünü değerlendirmektir.

Gereç ve Yöntemler: 20 Mart-20 Nisan 2020 tarihleri arasında retrospektif olarak hastalar çalışmaya dahil edildi. Tüm hastalara real time ters transkripsiyon-polimeraz zincir reaksiyonu (RT-PCR) testi uygulandı. PCR ve BT bulguları pozitif olan 257 hasta (yaş ortalaması 50; yaş aralığı ise 18-91) çalışmaya dahil edildi. Tüm hastaların akciğer bilgisayarlı tomografi bulguları ve tutulum oranları belirlendi. Akciğer hastalığının tutulum oranı ile yaş ve cinsiyet arasındaki ilişkiyi incelemek için nonparametrik istatistiksel testler kullanıldı. Seksen yaş üstü grupta yüksek dansitede akciğer volümü daha yüksek bulundu.

Bulgular: SARS-CoV-2 enfeksiyonu olan 257 hasta (147 erkek ve 110 kadın) çalışmaya dâhil edildi. Yüksek dansiteli akciğer volümü erkeklerde kadınlara göre önemli ölçüde daha yüksekti. 40-69 yaş arası hasta grubunda cinsiyetler arasında yüksek yoğunluklu akciğer hacminde anlamlı bir korelasyon gözlendi ve tutulum erkeklerde daha yüksekti.

Sonuç: Sonuç olarak çalışmamızda yaş grupları arasında 80 yaş üstü grupta akciğer tutulumu yüzdesinin daha yüksek olduğunu bulduk. Sonuçlarımız, en yüksek riskli hastaların ve özel tedavi stratejilerine ihtiyaç duyanların belirlenmesine yardımcı olabilir.

Anahtar kelimeler: Akciğer tutulumu, COVID-19 pnömonisi, Kantitatif Bilgisayarlı Tomografi

Abstract

Objective: The purpose of this study was to observe the imaging characteristics of the COVID-19 pneumonia and extent of pulmonary involvement in COVID-19 with quantitative computed tomography (CT) and to assess of disease burden on.

Material and Methods: Patients were retrospectively enrolled in the study from March 20 to April 20, 2020. All patients underwent real-time reverse transcription–polymerase chain reaction (RT-PCR) testing. Two hundred and fifty seven patients (mean age 50 years; range 18-91years) with positive PCR and CT findings were included in the study. Lung computed tomography findings and involvement rates of all patients were determined. Nonparametric statistical tests were used to examine the relationship between the involvement ratio of lung disease and the age or sex.

Results: Two hundred and fifty seven patients (147 males and 110 females) with SARS-CoV-2 infection were enrolled. The high density lung volume was significantly higher in males than in females. A significant correlation was observed in high-density lung volume between the genders in the 40-69 age group and the involvement was higher in males. The high density lung percentage was higher in the group above 80 years old.

Conclusion: As a result, we found that among the age groups in our study, the percentage of lung involvement was higher in the group above 80 years old. Our results may help to identify the highest-risk patients and those who require specific treatment strategies.

Keywords: COVID-19 pneumonia, Lung involvement, Quantitative computed tomography

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INTRODUCTION

The coronavirus disease, which first appeared in the Wuhan, Hubei Province, China in December 2019, is an extremely fast and infectious disease (1). This pneumonia outbreak was attributed to a novel coronavirus, a lipid-enveloped RNA virus, which was named by the International Committee on Taxonomy of Viruses severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) (2).

On January 31, 2020, the World Health Organization declared the outbreak of coronavirus disease (COVID-19) a Public Health Emergency of International Concern (3). In March 11, 2020, Istanbul/Turkey had been reported first cases.

The disease spectrum is wide in patients infected with SARS CoV-2. Patients may be asymptomatic, and the virus can cause upper respiratory tract infection, pneumonia, acute respiratory distress syndrome, multi-organ failure or even death. SARS-CoV-2 can be transmitted from human to human through respiratory droplets and contact.

Imaging plays an important role in the diagnosis and evaluation of the disease. Final diagnosis depend on real-time reverse-transcriptase polymerase chain reaction (RT-PCR) positivity for the presence of coronavirus (4,5). Because of the rapid spread of COVID 19, early diagnosis, treatment and isolation of the patient prevent community contamination. It is important because CT evaluation is faster since RT-PCR results give results in 5-6 hours.

The purpose of our study; the evaluation of imaging features (typical and atypical findings) of new coronavirus pneumonia (COVID-19 pneumonia) and determination of lung parenchymal involvement.

MATERIALS AND METHODS

This study was conducted in accordance with the Declaration of Helsinki. This retrospective study was approved by institutional review board (Approved Number: 2020.07.03) at Demiroglu Bilim University, and written informed consent was waived. According to our hospital protocol, all patients with suspected COVID-19 routinely underwent non-contrast computed tomography (CT) examinations. For each patient, age, sex, and the lung involvement were considered for the analysis. Patients were also divided into seven groups according to age. Nonparametric statistical tests were used to examine the relationship between the involvement ratio of lung disease and the age or sex.

Patients

A retrospective review was made of 455 consecutive adult patients (>18 years old) who underwent chest CT for investigating COVID-19 pneumonia from March 20 to April 20, 2020. Exclusion criteria were: 1) negative RT-PCR assay for SARSCoV-2; 2) negative chest CT; 3) inappropriate CT images including respiratory artifacts or CT images taken in expiratory phase; 4) inadequate segmentation by the software. Finally, a total of 257 patients (mean age 50 years; 147 males and 110 females) were included in the study.

For each patient, age, sex, lung CT findings and the lung involvement ratio were considered for the analysis. The selected patients were divided into seven groups according to age: 18–29 years (group A), 30–39 years (group B), 40–49 years (group C), 50–59 years (group D), 60–69 years (group E), 70–79 years (group F), and ≥80 years (group G).

Imaging Technique

Chest CT examinations were performed on a 16-section scanner (Somatom Go Now, Siemens Healthcare). The scanning parameters were as follows: 120 kV; 250 mAs; rotation time, 0.8 second; pitch, 1.5. Images were reconstructed with a 1 mm slice thickness, using a high frequency reconstruction algorithm. Acquisitions were performed during a deep inspiration breath-hold, without contrast administration and standard dose.

Image Interpretation

Two radiologists (B.K.S. and S.S , with 7 and 5 years of experience in thoracic imaging, respectively) retrospectively reviewed all chest CT images. The visual evaluations were determined by the consensus of two radiologists. On visual evaluation, the pattern of the abnormal attenuation as well as the involved lung lobes were recorded. CT scan of each patient was uploaded to commercial software, Myrian® (Intrasense, Montpellier, France) in DICOM (Digital Imaging and Communication in Medicine) format. All evaluations were performed in new brand COVID-19 protocol. Airways, right and left lung parenchyma and involved hyper-attenuated areas were automatically detected. For evaluation of involved lung volume, lowest and highest HU (Hounsfield Unit) threshold was manually adjusted over intensity histogram of regions provided in the software workspace. For each patient, threshold adjustment was

optimized to cover the maximal involved area and minimal non-involved area and vascular structures with close HU values. Total lung volume, right and left lung volumes, involved total lung volume (hyper dense area), involved right and left lung volumes, involved lung ratio was recorded for each patient.

Chest CT imaging evaluation was done based on the report template created by RSNA for COVID-19 (6). We evaluated imaging features defined: ground-glass opacities (GGO), air space consolidation, mixed GGO and consolidation, crazy paving, reverse halo sign, morphology of GGO, centrilobular nodules, tree-in-bud, solid nodules, pulmonary cavities, bronchial wall thickening and mucoid impaction, smooth interlobular septal thickness severity, sub pleural bands, traction bronchiectasis, intrathoracic lymph node enlargement, vascular enlargement in the lesion, and pleural effusions.

Statistical Analysis

All statistical analyses were undertaken using SPSS v.21 software (IBM, Armonk, NY, USA). Distribution of numerical variables was performed by Colmogrov-Smirnov test. Comparison of non-parametric variables between independent groups was performed by Mann-Whitney-U, Kruskal Wallis and One-way ANOVA tests. A p value of <0.05 were considered statistically significant.

RESULTS

The search identified 257 patients (147 males and 110 females) with PCR confirmed SARS CoV-2 infection. The median age was 50 years (interquartile range, 18–91 years). Of the included patients, 39 (14.8%) were from group A, 39 (15.2%) from group B, 42 (16.4%) from group C, 52 (20.3%) from group D, 49 (19.1%) from group E, 25 (9.8%) from group F and 11 (4.3%) from group G. For each age group, the sex of the patients, CT findings and lung involvement ratio were analysed. Since patients with typical lung CT positive findings were included in our study, ground glass opacity (GGO) involvement pattern was present in all patients. The laterality of the GGO in the 257 patients with confirmed COVID-19 pneumonia was as follows: right lung (43/257, 16.7%), left lung (16/257, 6.2%) and bilateral lung (198/257, 77%). The location of GGO were as follows: peripheral distribution (61/257, 23.7%), central distribution (14/257, 5.4%) and diffuse distribution (182/257, 70.8%). The predominant distribution of GGO were as follows: upper lobe (58/257, 22.6%), mid lobe (35/257, 13.6%) and lower lobe (164/257, 63.8%). The quantity of GGO had single (27/257, 10.2%) and multiple (230/257, 89.8%). Other lung CT findings are shown in **Table 1**.

Pulmonary involvement volumes and percentages were calculated for all patients in our study. These parameters were right lung volume (RLV), left lung volume (LLV), total lung volume (TLV), high density lung volume (HDLV), high density lung percent (HDLP), low density lung volume (HDLV), low density lung percent (HDLP), high attenuation right lung volume (HARLV), high attenuation left lung volume (HALLV). Pulmonary involvement volumes and percentages were compared between age groups and sex **(Figure 1,2 and 3) (Table 2)**.

Table 1. Imaging findings

Imaging Feature	**n (%)**
Pattern of opacities	
GGO	257 (100%)
Mosaic attenuation	37 (14.5%)
Crazy Paving	75 (29.3%)
GGO with Consolidation	94 (36.7%)
Reverse Halo/Atoll sign	22 (8.6%)
Centrilobular Nodules/Tree- in-Bud	12 (4.7%)
Solid Nodules	10 (3.9%)
Air Space Consolidation	17 (6.6%)
Pulmonary cavities	10 (3.9%)
Vascular enlargement	165 (12.6%)
Subpleural bands	75 (29.2%)
Traction bronchiectasis	66 (25.7%)

(continues)

Morphology of GGO	Rounded: 84 (32.6%)
	Not Rounded: 35 (13.6%)
	Both: 138 (53.6%)
Lymphadenopathy	82 (31.9%)
Location of Lymphadenopathy	Hilar Mediastinal :40 (%48.7) Hilar&Mediastinal :42 (%51.3) Other
Pleural Effusion	Small :21 (%8.2)
	Medium :2 (%0.8)
	Large :2 (%0.8)
Mucoid Impaction	12 (4.7%)
Bronchial all thickening	53 (20.6%)
Smooth Interlobular Septal Thickening Severity	Mild :49 (%19.1) Moderate :21(%8.2) Severe :1 (%0.4)

GGO: Ground-glass opacities

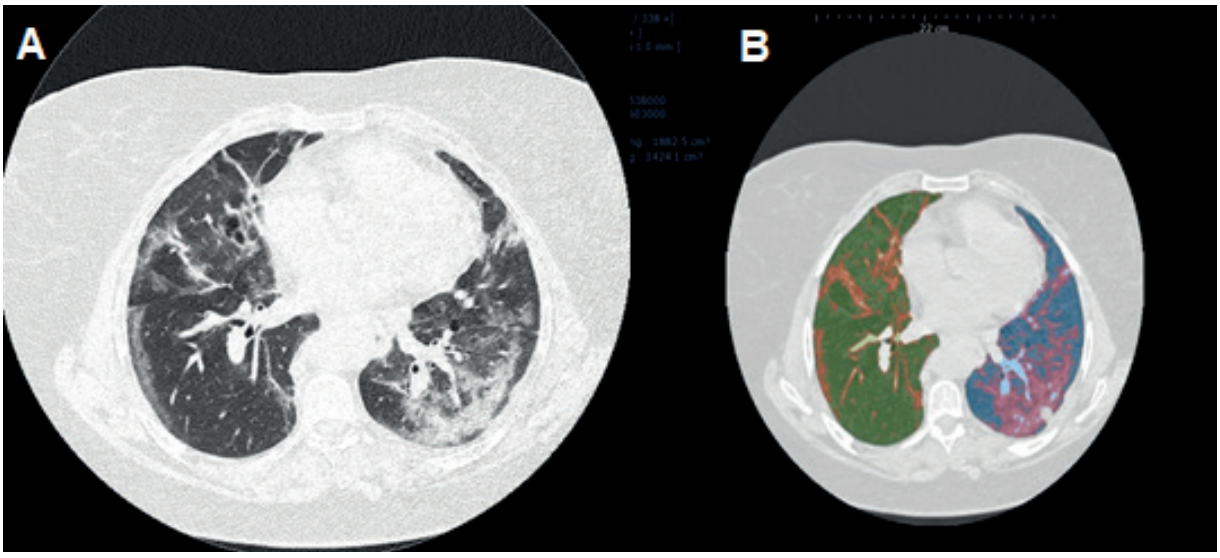

Figure 1: A) Chest CT findings of a 58-year-old female patient with confirmed COVID-19. GGO and left lung consolidation were observed. **B)** Chest CT of a 58 year old female with RT-PCR confirmed COVID-19 pneumonia uploaded in the workspace of Myrian software. Automatic measurement of right and left lung is shown and each area is illustrated with different colour. Areas in pink colour indicate high-attenuation parts which were interpreted as involved lung parenchyma. Right, left, total lung volumes, high density lung volume, high density lung percentage, high attenuation right and left lung volumes were measured 1882.5 ml, 1424.1 ml, 3240.6 ml, 840.4 ml, 25.4%, 372.5 ml and 476 ml respectively.

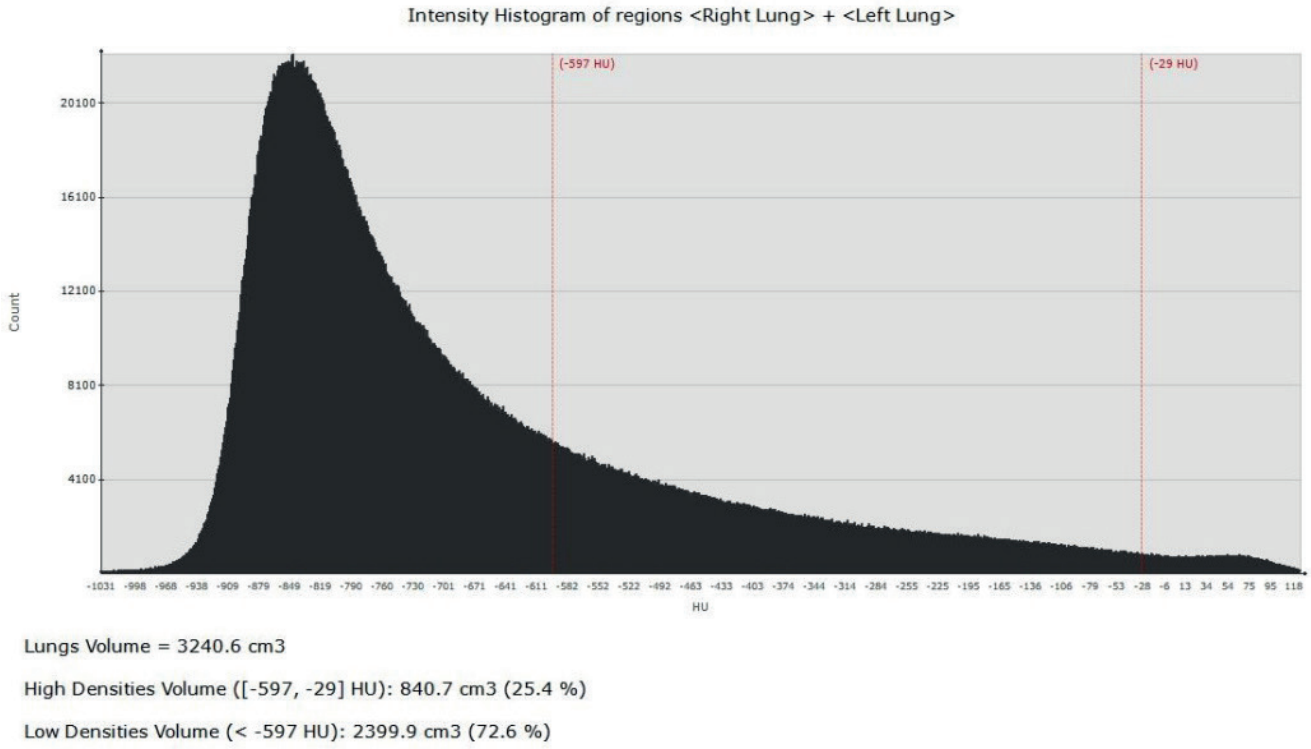

Figure 2: Intensity histogram of the chest CT without contrast in this patient. Minimum and maximum HU thresholds were adjusted manually to completely cover the involved parenchyma and avoid other hyper dens structures. HU value range between -597 and -29 HU was the optimal one for this case.

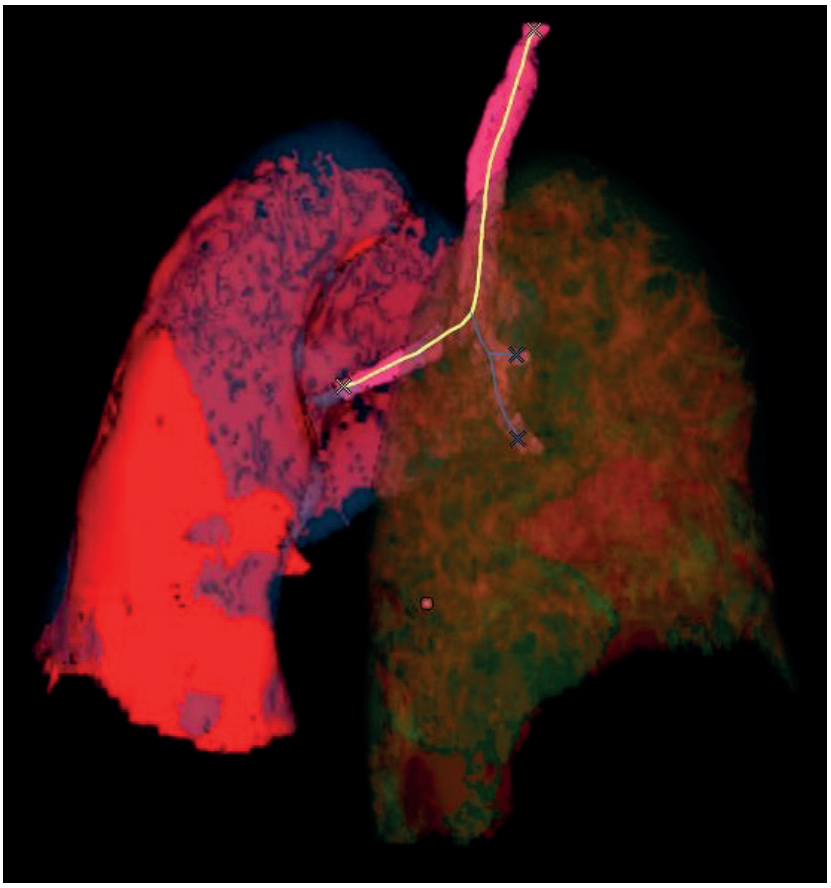

Figure 3: A 3D image of processed chest CT of the patient in Surfacic viewport layout of Myrian software within COVID-19 protocol. Green and blue areas represent intact lung parenchyma, while the hyper-attenuated involved lung is identified as pink and red colour.

Table 2. Lung involvement ratio for each age groups

Age group	Total Lung Volume (mL)	High Density Lung Volume (mL)	High Density Lung Percentage (%)	High Attenuation Right Lung Volume (mL)	High Attenuation Left Lung Volume(mL)
A	4493±1174	429±247	10.06±6.91	224±134	204±120
B	4883±1334	452±248	9.83±8.57	236±133	215±119
C	4378±1307	562±277	13.53±7.97	293±152	270±137
D	4333±1440	614±400	14.82±9.88	345±230	300±199
E	4226±1349	706±377	18.45±12.06	377±193	329±191
F	3680±1197	765±549	21.87±16.18	407±287	356±271
G	2760±778	827±242	30.24±9.33	460±153	364±129

Mann-Whitney-U test showed that there was no significant difference in terms of involvement lung percentage between male and females in all patients (p=0.518) and also in each age groups **(Figure 4)**.

According to one-way ANOVA test, the total lung volume of group G was also significantly lower than that of other groups. The high density lung volume of group E, F and G was also significantly higher than that of groups A and B. The high density lung percent of group G was also significantly higher than that of groups A, B, C, D and E. The high attenuation right lung volume of groups E, F and G was also significantly higher than that of groups A and B. The high attenuation left lung volume of groups E and F was also significantly higher than that of groups A and B.

DISCUSSION

CT imaging has become an efficient tool for screening COVID-19 patients and for assessing the severity of COVID-19. However, we know how important it is to accurately measure the severity of COVID-19, the percentage of infection in the whole lung. In the current study, we performed a quantitative CT analysis to assess the radiologic burden of COVID-19.

There are many studies evaluating the relationship between CT-based semi-quantitative score of pulmonary involvement in COVID-19 pneumonia with clinical staging and laboratory findings of the disease, and also investigating whether CT findings can predict the outcome of the disease (7).

There is currently no prognostic and quantitative biomarker available to identify patients requiring immediate medical attention and to predict mortality rates (8). Therefore, CT scoring systems play an important role in determining disease severity. Since semi-quantitative scoring systems are visual assessment, quantitative assessment may be a better method for evaluating pulmonary involvement. We think that quantitative analysis is more valuable in determining lung involvement.

Yu et al. quantitatively analysed lung CT (QCT) findings in 52 patients infected with COVID-19 pneumonia, evaluated the importance of QCT in detecting and segmenting lesions, and investigated the relationship between QCT and disease development. The quantitative parameters included the lung volume (LV), total lesion volume (TLV), and percentage of abnormal opacity volume (lesion %).By histogram analysis, pixel ratio measurements related to mean density (MD) and ground glass opacity (GGO) were made. They found that the parameters related to QCT were related to the time of onset of symptoms (9).

QCT can provide quantitative indexes to describe both extent and density of abnormal opacity. In addition, the changes of QCT-related parameters can provide reference data for evaluating the progress of disease.

Cheng et al. evaluated semi-quantitative CT scoring with pneumonia severity index (PSI) in their study on 30 patients with COVID 19 pneumonia and lung CT involvement. In this study, the quantitative method-based ground glass opacity, consolidation and total lesion ratio show positive correlation with the semi-quantitative CT score. Specifically, it was concluded that both the percentage of consolidation and the percentage of total infection were higher in patients with PSI grade II-IV than

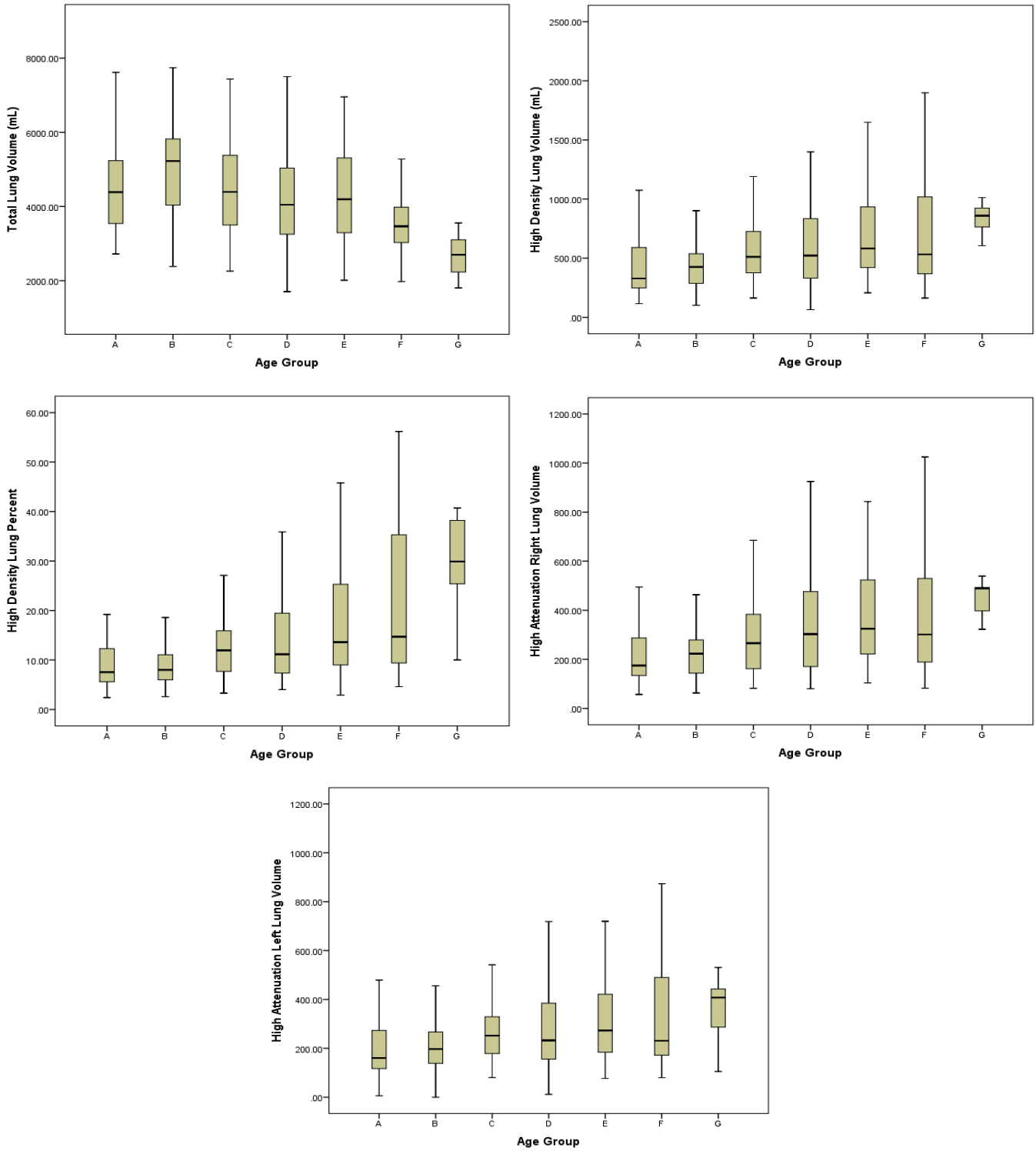

Figure 4. Box-and-Whisker plots showing the distribution of chest CT lung involvement parameters by age group.

the other group. This shows that the CT involvement percentage of the disease correlates with the severity of the disease (10).

In a study conducted with the X-ray semi-quantitative scoring system in 783 Italian patients, the Chest X-ray score was found to be higher in men over 50 years of age and women over 80 years old (11). However, as stated in many studies, lung CT is more sensitive in COVID-19 involvement compared to X-ray and provides quantitative measurements.

Our study has several limitations. First, the study population was relatively small. Second, it was a retrospective study, and that among them, it could not be compared between pulmonary involvement and patient comorbidities (hypertension, diabetes, cardiovascular disease, and oncological history), laboratory results or final outcome (recovery versus death).

Conclusion

As a result, we found that among the age groups in our study, the quantitative value of lung involvement percentage was higher in the group above 80 years old. These quantitative results can be a guide for clinicians in disease progression and follow-up.

Conflict of Interest and Financial Status: Our study has not been financed by an institution and institution. In this study, there is no conflict of interest among the authors on any subject.

Author Contribution: All authors contributed equally to the article.

Ethical Statement: This retrospective study was approved by institutional review board (Approved Number: 2020.07.03) at Demiroglu Bilim University

REFERENCES

1. Zhu N, Zhang D, Wang W, Li X, Yang B, Song J et al. A novel coronavirus from patients with pneumonia in China, 2019. N Engl J Med. 2020 Feb 20;382(8):727-733.
2. Lai CC, Shih TP, Ko WC, Tang HJ, Hsueh PR. Severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) and Coronavirus disease-2019 (COVID-19): the epidemic and the challenges. Int. J. Antimicrob. Agents. 2020;55(3):105924.
3. World Health Organization website. Statement on the second meeting of the International Health Regulations (2005) Emergency Committee regarding the outbreak of novel coronavirus (2019- nCoV). www.who.int/news-room. Published January 30, 2020. Accessed February 25, 2020.
4. Corman VM, Landt O, Kaiser M, Molenkamp R, Meijer A, Chu DKW et al. Detection of 2019 novel coronavirus (2019-nCoV) by real-time RT-PCR. Euro Surveill. 2020 Jan;25(3):2000045.
5. Rubin EJ, Baden LR, Morrissey S, Campion EW. Medical Journals and the 2019-nCoV Outbreak. N Engl J Med. 2020 Feb 27;382(9):866.
6. https://radreport.org/home/50820/2020-04-16%2015:00:13
7. Francone M, Iafrate F, Masci GM, Coco S, Cilia F, Manganaro L et al. Chest CT score in COVID-19 patients: correlation with disease severity and short-term prognosis. European Radiology 2020 Jul 4:1-10.
8. Yan L, Zhang HT, Goncalves J, Xiao Y, Wang M, Guo Y et al. An interpretable mortality prediction model for COVID-19 patients. Nat Mach Intell 2020;2:283–288.
9. Yu N, Shen N, Yu Y, Dang M, Cai S, Guo Y. Lung involvement in patients with coronavirus disease19 (COVID19): a retrospective study based on quantitative CT findings. Chinese Journal of Academic Radiology 2020(3):102-107.
10. Cheng Z, Qin L, Cao Q, Dai J , Pan A, Yang W et al. Quantitative computed tomography of the coronavirus disease 2019 (COVID-19) pneumonia. Radiol Infect Dis. 2020 Jun;7(2): 55–61.
11. Borghesi A, Zigliani A, Masciullo R, Golemi S, Maculotti P, Farina D et al. Radiographic severity index in COVID19 pneumonia: relationship to age and sex in 783 Italian patients. Radiol Med 2020;125(5): 461-464.