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RESEARCH

Evaluation of the cross-sectional area and densities of the pectoralis muscles and diameters of the pulmonary artery and aorta in the axial plane in COVID-19 patients

COVID-19 hastalarında aksiyel planda pektoral kasların kesit alanı ve densititesi ile pulmoner arter ve aorta çaplarının değerlendirilmesi

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Abstract

Purpose: This paper aimed to investigate and compare diameter of the pulmonary arteries, and aorta, cross sectional area and density of the pectoralis muscles before and after COVID-19.

Materials and Methods: The axial Computed Tomography (CT) images of the chest areas of 20 individuals (12 females and 8 males) aged between 18-69 years were used. Pulmonary artery diameter (PAD), right pulmonary artery diameter (PADR), left pulmonary artery diameter (PADL), Ascending aorta diameter (AAD), the ratio of PAD to AAD, pectoralis major and minor area (PMAM) and muscle density (PMDM) before and after COVID-19 were evaluated on both healthy and COVID-19 CT images belonging to the same individuals and taken in the same year.

Results: The mean age of 20 subjects participating in the study were 48.00±11.43 years, while the mean age of 12 females was 57.80±1.64 years, and the mean age of 8 males's was measured as 44.00±10.08 years. Also, the pectoralis major and minor area, ascending aorta diameter, left pulmonary artery diameter and right pulmonary artery diameter were higher in post-COVID 19 than pre-COVID 19. Except for the pectoralis major and minor density and truncus pulmonalis diameter, other measurements showed a decrease in patients who had COVID-19, although not significant, compared to the period before COVID-19.

Conclusion: These findings have shown that how COVID-19 affects the pulmonary artery and ascending aorta and especially the pectoralis muscles and these findings may be a sign of a change caused by COVID-19.

Öz

Amaç: Bu çalışmanın amacı, COVID-19 öncesi ve sonrasında pulmoner arter ve aorta'nın çapı ve pektoral kaslarının kesit alanı ile densitesini araştırmak ve karşılaştırmaktır.

Gereç ve Yöntem: Yaşları 18-69 arasında değişen 20 bireyin (12 kadın ve 18 erkek) Toraks aksiyal Bilgisayarlı Tomografi (BT) görüntüleri alındı. Aynı bireylere ait ve aynı yıl içinde çekilmiş hem sağlıklı hem de COVID-19 BT görüntüleri üzerinde truncus pulmonalis çapı (PAD), sağ pulmoner arter çapı (PAÇS), sol pulmoner arter çapı (PAÇSo), aorta ascendens çapı (AAÇ), PAD'nin AAÇ'ye oranı, pectoralis major ve minor alanı (PMA) ve kas densititesi (PKD) ölçümleri değerlendirilmiştir.

Bulgular: Çalışmaya katılan 20 kişinin yaş ortalaması 48,00±11,43 yıl iken 12 kadının yaş ortalaması 57,80±1,64 yıl ve 8 erkeğin yaş ortalaması 44,00±10,08 yıl olarak ölçülmüştür. Ayrıca, pektoralis major-minor alanı, aort ascendens çapı, sol pulmoner arter çapı ve sağ pulmoner arter çapı COVID-19 sonrası dönemde COVID-19 öncesine göre daha yüksekti. Bu da bize pectoralis major ve minor densitite ve trunkus pulmonalis çapı dışında diğer ölçümlerin COVID-19 geçiren hastalarda COVID-19 öncesi döneme kıyasla anlamlı olmasa da azalma gösterdiğini ortaya koymuştur.

Sonuç: Bu bulgular, COVID-19'un pulmoner arter ve aorta ascendens ve özellikle pektoral kasları nasıl etkilediğini göstermiş olup COVID-19'un neden olduğu bir değişikliğin işareti olabilir.

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Anahtar kelimeler: COVID-19, pectoralis major and minor kesit alanı, arteria pulmonalis, aorta ascendens

INTRODUCTION

SARS-Cov-2, which started in Wuhan, China, on December 31, 2019, and spread all over the world, is an infectious disease that passes from human to human[1-4], and this severe acute respiratory syndrome, has become a life-threatening health crisis[2,5,6]. This presents severe clinical manifestations ranging from asymptomatic symptoms to death following multisystem dysfunctions. The most common symptoms begin with fever, cough, fatigue and myalgia, and can progress to severe pneumonia, acute respiratory distress syndrome (ARDS) and even death. It appears mainly directly to affect the respiratory system and tract (RT) and leads to infection of the lungs. It has also been noted it damages structural and functional integrity of the vascular endothelium[2,4-9]. For this reason, there are many methods to diagnose; Polymerase chain reaction (PCR) is used as a key method in detection of the disease, and also, the Computed Tomography (CT) is an another method. This play a critical role in disease's diagnosis and follow-up[9]. However, the CT is very important in terms of the information which provides about the course of the disease and treatment. CT findings are divided into three categories. At the first level, the lung parenchyma is normal or may be accepted normal. It is characterized by an increased ground-glass opacities at the second level. At the third level, consolidation, the presence of linear opacities and crazy-paving pattern are observed[4,10]. Thus, CT emerges as one of the most frequently used methods to evaluate disease severity, parenchymal and vascular pathology[4,11,12].

From the ventriculus dexter to the lungs, the truncus pulmonalis divides into right and left pulmonary artery below the arcus aortae. Its length up to the bifurcatio trunci pulmonalis which divides into two is 4-5 cm and its diameter is 3 cm. Pulmonary artery (PA) may be one of the noteworthy changed structures because of the inflammation and hypoxia related to pneumonia[4,13,14]. Also, a pulmonary arterial diameter >29 mm has a sensitivity of 87% and specificity of 89% for pulmonary hypertension[9,15]. There are few studies on pulmonary artery, or aortic artery diameter[4,16]. Moreover, the aorta starts from the ventriculus sinister. Initially, it is located on the posterior left side of the truncus pulmonalis, then it rises upwards, forwards and to the right and passes behind the truncus pulmonalis to the posterior right side. This part of the aorta is called pars escendens aorta. It is 5-6cm long and 3cm to 3.5cm in diameter[13,14]. Studies have shown that there is a correlation between muscle quality and general health status, and the change in muscle volume may provide information about the prognosis of some diseases such as lung diseases, some cancers, or surgery outputs[3,17-19]. Furthermore, there are many studies about pectoralis muscles area and density and pulmonary diseases[17,20,21], whereas, there are few studies about pectoralis muscle area and density and COVID-19[3,22]. Muscle mass loss causes to reduction of the skeletal muscle function and exercise capacity, raised energy expenditure, and deterioration in general health status and contribute to increased mortality in subjects having chronic obstructive pulmonary disease[17].

The hypothesis of this study is whether COVID-19 causes changes in the cross-sectional area and densities of the pectoralis major and minor muscle and the diameters of the pulmonary artery and aorta. Also, the findings may provide insights into the assessment of the cross-sectional area and densities of the pectoralis major and minor muscles and the diameters of the pulmonary artery and aorta in patients with COVID-19. At the same time, we think that knowing the morphology of this region in COVID-19 patients will provide vital data to clinicians, especially in surgical interventions or rehabilitation process. Therefore, we aimed to determine how COVID-19 affects pulmonary artery diameter and pectoral muscle area. Furthermore, we aimed to show whether there is a correlation between pulmonary artery diameter and pectoral muscle area and how it's changes with COVID-19.

MATERIALS AND METHODS

Study design

The axial CT images of the chest areas of 20 individuals (12 females and 8 males) aged between 18-69years, who applied to Bozyaka Education and Research Hospital, Department of Radiology before 2019 for various reasons, and the axial CT images of same subjects diagnosed with COVID-19. The test

procedures were approved from Çukurova University Non-invasive Clinical Research Ethics Committee to conduct the study (Decision No: 2023;136:44).

The CT images were evaluated from two specialist radiologists with electronic caliper (M.Ö., and Z.A.) and an specialist anatomist (SP) (TOSHIBA Alexion Advance Multislice CT). For intraobserver variability, all measurements were randomly performed by consensus in different sessions separated from the first evaluations by at least 3 weeks to minimize recall bias.

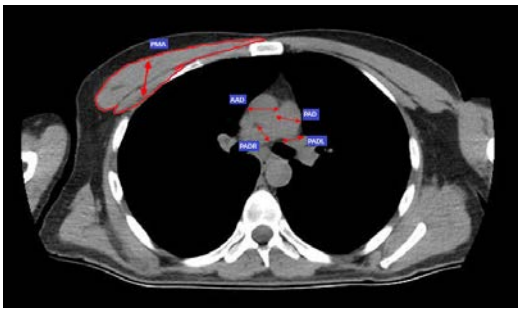

Figure 1. Demonstration of measurements on the CT image of a Covid-19 patient. PMA; Pectoralis muscles area, AAD; Ascending aortic diameter, PAD; Main pulmoner arter diameter, PADR; Pulmoner arter diameter right, PADL; Pulmoner arter diameter left.

Sample

The study was carried out 20 individuals (12 females and 8 males) aged between 18-69 years. Inclusion criteria for subjects were diagnosed with COVID-19, no history of cardiopulmoner surgery, no deformity in the region of interest and no history of a systemic disease which affected cardiopulmoner system. Only images that were clearly visible and free of artifacts were selected. Power analysis was performed to find out the minimum number of data to be used and it was determined that taking measurements from 20 people would be sufficient for 95% confidence interval (α=0.05, d=0.05 and p=0.50*).

Measurements

The Pulmonary artery diameter (PA_D), right pulmonary artery diameter (PA_{DR}), left pulmonary artery diameter (PA_{DL}), Ascending aorta diameter (AA_D), the ratio of PA_D to AA_D, pectoralis major and minor area (PMA_M) and muscle density (PMD_M) were evaluated on both healthy and COVID-19 CT images belonging to the same individuals and taken in the same year. Also, the pneumonia severity score (PSS) was determined.

Statistical analysis

The SPSS statistics 21.0 program was used for statistical analysis of the measurements results. Normality assumption was decided to Shapiro Wilk test. From these results, means, standard deviations (SD), frequencies and percentages were calculated. Paired samples T test were used. The results were assessed at the 95% Confidence Interval and the significance level was taken as $p<0.05$. To determine the CT severity index, we evaluated according to Pan et al's description. The score was calculated for each of the lungs considering the extent of anatomic involvement, as follows: 0=no involvement; 1, <5% involvement; and 5, >75% involvement[23].

For determining the correlation coefficent, the following scale was accepted: $0<r\leq0.19$ = very weak; $0.2\leq r\leq0.39$ = weak; $0.40\leq r\leq0.59$ = moderate; $0.6\leq r\leq0.79$ = strong or high; and $0.8\leq r\leq1$ = very strong or very high relationship [24]. The Pearson Correlation Analysis was used to determine the correlation coefficient.

RESULTS

After the application of exclusion criteria, the remaining 20 patients were categorized according to the pre-COVID-19 and post-COVID-19. The mean age of the subjects were 48.00±11.43 years, the mean age of females was 57.80±1.64 years (55 yr. min.; 59.00yr max.), and 8 males's mean age was measured as 44.00±10.08 years (24.00yr min.; 59.00yr max.), respectively. In Table 1, PMA_M, PMD_M, AA_D, PA_D, PA_{DR}, PA_{DL}, the ratio of PA_D/AA_D were found as 23.52±10.12cm^2, 58.12±14.04mm, 32.89±5.14mm, 25.81±3.54mm, 18.20±2.64mm, 18.55±2.18mm and 0.7968±0.135 in pre-COVID-19. The same values were 25.83±9.88cm^2, 57.90±13.19mm, 33.18±5.26mm, 25.73±3.46mm, 18.48±2.74mm, 18.67±2.74mm and 0.7884±0.133mm in post-COVID-19, respectively. No significant difference between pre-post COVID-19 was no found ($p>0.05$). When we analyzed these scores, the PMA_M, AA_D, PA_{DR}, PA_{DL} were higher in post-COVID 19 than pre-COVID 19. On contrary, the PMD_M, PA_D, and PA_D/AA_D were higher in pre-COVID 19 than post-COVID 19. This showed us that except for the

pectoralis muscle density and truncus pulmonalis diameter, other measurements showed a decrease in patients who had COVID-19, although not significant, compared to the period before COVID-19. In Table 2, the means, SD, min. and max. values of measurements in terms of pneumonia degree were shown. According to this table, all measurements were higher in subjects having pneumonia than in subjects having no pneumonia (excluding pectoralis muscle densitity, and the PA_D/AA_D).

Table 1. The means, standard deviation, minimum, maximum values of measurements in pre-COVID 19 and post-COVID 19.

Measurements	Mean±SD	Min.	Max.	p value	Correlation and p value
Pectoralis muscle area (pre-COVID-19)	23.52±10.12	13.16	44.10	0.193	r=0.709 p<0.001
Pectoralis muscle area (Post-COVID-19)	25.83±9.88	13.16	46.65		
Pectoralis muscle density (pre-COVID-19)	58.12±14.04	24.32	78.58	0.923	r=0.740 p<0.001
Pectoralis muscle density (Post-COVID-19)	57.90±13.19	23.34	88.91		
Ascending aortic diameter (pre-COVID-19)	32.89±5.14	23.20	44.90	0.470	r=0.943 p<0.001
Ascending aortic diameter (Post-COVID-19)	33.18±5.26	23.30	45.10		
Main pulmoner artery diameter (pre-COVID-19)	25.81±3.54	19.50	33.20	0.854	r=0.831 p<0.001
Main pulmoner artery diameter (Post-COVID-19)	25.73±3.46	20.03	31.40		
Right pulmoner artery diameter (pre-COVID-19)	18.20±2.64	13.80	22.40	0.720	r=0.836 p<0.001
Right pulmoner artery diameter (Post-COVID-19)	18.48±2.74	13.20	22.10		
Left pulmoner artery diameter (pre-COVID-19)	18.55±2.18	10.70	21.70	0.398	r=0.855 p<0.001
Left pulmoner artery diameter (Post-COVID-19)	18.67±2.73	13.00	23.00		
The ratio of main pulmonary artery diameter to ascending aorta diameter (pre-COVID-19)	0.7968±0.135	0.58	1.16	0.540	r=0.898 p<0.001
The ratio of main pulmonary artery diameter to ascending aorta diameter (Post-COVID-19)	0.7884±0.133	0.61	1.16		

Table 2. The means, standard deviation, minimum, maximum values of measurements in terms of pneumonia degree

Measurements (n=16 for mild pneumonia; and n=4 for severe pneumonia)	Mean±SD	p value
Pectoralis muscle area (mild pneumonia)	26.47±10.93	0.574
Pectoralis muscle area (severe pneumonia)	23.25±3.21	
Pectoralis muscle density (mild pneumonia)	56.97±14.39	0.541
Pectoralis muscle density (severe pneumonia)	61.64±6.66	
Ascending aortic diameter (mild pneumonia)	34.54±4.36	0.016
Ascending aortic diameter (severe pneumonia)	27.75±5.56	
Main pulmoner artery diameter (mild pneumonia)	26.30±2.78	0.143
Main pulmoner artery diameter (severe pneumonia)	23.43±5.34	
Right pulmoner artery diameter (mild pneumonia)	18.96±2.36	0.117
Right pulmoner artery diameter (severe pneumonia)	16.55±3.65	
Left pulmoner artery diameter (mild pneumonia)	19.40±2.01	0.012
Left pulmoner artery diameter (severe pneumonia)	15.75±3.61	
The ratio of main pulmonary artery diameter to ascending aorta diameter (mild pneumonia)	0.77±0.14	0.366
The ratio of main pulmonary artery diameter to ascending aorta diameter (severe pneumonia)	0.84±0.07	

DISCUSSION

The clinical semptoms of the COVID-19 differs from asymptomatic to many complication. These symptoms may be similar to other respiratory diseases, however, the disease progression through pneumonia are very fast and multiorgan failure and death may develop. Pneumonia are one of the main reason affected to disease's condition and clinical outcomes[4, 25]. Advanced age, male sex, and comorbid diseases are poor prognostic factors for COVID-19[3,26]. Inflammation is a defence mechanism against a number of agents. Due to pro-inflammatory cytokines dominating the early inflammatory process, vascular permeability increases secondary to vasodilatation and oedema-exudate is formed in the intercellular space. Endothelial damage caused by inflammation and oedema at the alveolar level disrupts the ventilation-perfusion balance and hypoxia develops. It activates mediators such as protein kinase C that trigger pulmonary arterial vasoconstriction by a lung-specific mechanism. If this condition becomes severe or persistent, acute respiratory distress syndrome (ARDS), pulmonary hypertension and heart failure may develop clinically[4, 26]. Yildiz et al reported that prolonged hypoxaemia may be associated with the severity of pneumonia and this may lead to increased pulmonary vascular resistance and increased pulmonary artery diameter, and symptoms about liver. Enhanced inflammation may result in a reduction in lung capacity and increased in PA pressure [4]. Differences in pulmonary artery measurements have a special importance in terms of patient follow-up. A pulmonary artery diameter >29 mm has 87% sensitivity and 89% specificity for pulmonary hypertension[9,15,16].

In a retrospective study conducted by Yildiz et al. in 101 patients with COVID-19 and CT images, while the AA_D was found as 33.94 mm, the PA_{DR}, 18.31 mm; the PA_{DL}, 19.59 mm; and the PA_D, 26.11 mm in the non-pneumonia group, truncus pulmonary diameter, 26.11mm, respectively, the same values were 34.63mm, 18.98mm, 19.4mm and 26.65mm, respectively in individuals with moderate pneumonia. In subjects with severe pneumonia, the values 34.43mm, 19.61mm, 20.16mm and 28.59mm, respectively. These findings demonstrated that the increased PA diameter may be a sign of the pneumonia severity[4]. In a retrospective study performed on chest CT with COVID-19 patients, the truncus pulmonary artery (PA_D) was found as 24.9mm and 30.8mm in subjects suffer from severe COVID-19, and survivor, and non-survivor, respectively. AA_D and the PA_D/ AA_D were measured as 32.2mm and 35.3mm; and 0.78 and 0.88 in subjects suffer from severe COVID-19, and survivor, and non-survivor, respectively. Also, pulmonary artery might be a sign in the demonstration of prognostication of COVID-19[2]. In our study, aortic diameter was found as 32.89mm in pre COVID-19 and 33.18mm in post COVID-19. These findings were close to the two literature findings. We can remark that COVID-19 caused an increase in aortic diameter, although not significant. Also, right pulmonary artery and left pulmonary artery diameters showed an increase for post COVID-19. On the contrary, main pulmonary artery diameter showed a decrease for post COVID-19. We have only 4 subjects with severe pneumonia, there was 16 subjects with mild pneumonia. When we investigated the vessel diamter 4 subjects with severe pneumonia, all four measurements were higher in values of the post COVID-19 than pre COVID-19. In a study performed with Ongen et al., subjects were separated into three groups in terms of CT severity index: Group 1, mild-mild infiltration (MP), Group 2, mild-severe (MS) and Group 3, severe-severe (SS). No significant difference was found in the PAD, PADR and PADL of Group 1. In Group 2, there were significant increases in the same measurements. However, significant increases in the only PADR and PADL in Group 3 ($P<0.05$). (for example, in Group 3, PADR and PADL areas were increased from 4.7 (1.29) cm2 to 5.3 (0.98) cm2 and from 4.11 (2.88) cm2 to 5.02 (3.42) cm2, and the PAD, from 6.68 (2.64) cm2 to 8.12 (3.42) cm2[9]. Moreover, Ongen et al. reported that the increased severity of disease involvement in COVID-19 patients with pneumonia may be associated with an increase in pulmonary artery area, hypoxemia and infiltration. In non-survivor subjects, the PA area's changes were seen along with the CT severity index [4]. The other remark is that the reason of ARDS's develop may be thromboembolism and viral pneumonia. These develop secondary to endothelial injury and deteriorations in the coagulation cascade[9, 16]. The pulmonary vascular structures's involution may be related with the thinness in the muscular layer of pulmonary arteries and veins[9, 25]. It is stated that the increase in the diameter of the pulmonary artery and the accompanying course of pulmonary hypertension may be related to the severity of vasoconstriction of the pulmonary artery parenchyma[4, 9, 27].

PA dimension obtained with CT is used to evaluate Pulmonary Hypertension degree in clinic practice. However, it is reported that a fully standardized or accepted reference range has not been determined. Also, in an other study, the mean of PA_D was measured as 26.1±2.4mm and 22.9±1.9mm for healthy males and females, respectively[2,28]. Framingham Heart Study reported normal reference values of PA_D as 24.7±2.7mm and PA_D/AA_D ratio as 0.80±0.09 in the healthy population and the other study found as 25.1±2.8 mm and 0.77±0.09, respectively[2,29]. Li et al. declared the $PA_D \geq 37.7$mm was a sign of 5year all-cause mortality in connective tissue disease associated with Pulmonary hypertension[30]. However, in Zyłkowska et al.'s study, the $PA_D \geq 48$mm is a important sign of unexpected death in these patients[31].

Muscle mass is measured by many techniques an one of them is CT, and CT permits accurately differentiate and provides the very detailed knowledge and widely used for diagnostic purposes in COVID-19[2,8,32,33]. It was reported that in the literature, several studies examined the relationship between low muscle size and mortality in different populations with many lung diseases such as cancer, idiopathic pulmonary fibrosis, anemi and surgery outcomes[3]. Also, It provides an estimate of an subject's sarcopenia degree by measuring the cross sectional area of skeletal muscle[8,34]. Sarcopenia is a forecaster of undesirable outcomes, but its main and real impact on COVID-19 is not well defined. In a study performed with Italian subjects suffer from COVID-19, the pectoralis muscles area and density were evaluated. The patients have undergone a successful extubation had higher pectoralis major and minor area (42.1cm^2) than subjects with unsuccessful extubation (37.8cm^2). Also, patients with the presence of severe pneumonia's PMA had 40.4cm^2 and patients with the low degree pneumonia's PMA was found as 38.9cm^2. There was no statistically significant difference in two different degrees of pneumonia[8]. In this paper, pectoralis major and minor area was measured as 23.52cm^2 and 25.83cm^2 in pre COVID-19 and post COVID-19, respectively. In fact, it was accepted that muscle volume and density may be different between age, and gender, and COVID-19. However, our PA parameter showed change or decrease in terms of pneumonia presence, whereas the PD value were higher in pneumonia presence than absence of pneumonia, The possible reason may be that the age of our group was less than 60 years and the age group of males was less than that of women or that the prognosis was not severe.

The study has several limitations. The small sample size of the study was the main limitation. However, the small size of our sample was due to the fact that the patients were healthy people who were healthy on chest CT with images at least 6 months ago and who had CT for any reason, and that these people met the criteria of having had COVID-19 before 6 months passed. In our study, we wanted to determine whether COVID-19 affected the same parameters in the same patients and if so, how severely. However, the COVID-19 patients were not clinically followed up for example, post COVID-19.

In conclusion, these findings revealed that the pectoralis major and minor area, ascending aorta diameter, left pulmonary artery diameter, and right pulmonary artery diameter were all greater following the onset of the Covid-19 infection than they were prior to the infection. We think that the findings may provide insights into the assessment of the cross-sectional area and densities of the pectoralis major and minor muscles and the diameters of the pulmonary artery and aorta in patients with COVID-19. At the same time, we think that knowing the morphology of these regions in COVID-19 patients will provide vital data to clinicians, especially in surgical interventions or rehabilitation process. In this way, the pectoralis major and minor muscles can be used as a parameter to monitor the progress of post-covid patients receiving treatment to assist their recovery.

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