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Original Article

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Evaluation of the Effect of COVID-19 on Pulmonary Artery and Aortic Diameter and the Relationship Between These Vessels and Lung Volume

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Abstract

Aim: Coronavirus disease-2019 (COVID-19) has primarily affected the respiratory system since its first emergence in China. Therefore, we aimed to evaluate the possible effects of this disease on pulmonary vessels and aortic diameter and the relationship between these vessels and lung volumes as it affects lung capacity.

Materials and Methods: In our study, the diameter of the pulmonary trunk (PT) at its origin and at the point where it divides into two, the diameters of the right and left pulmonary arteries, the diameters of the ascending aorta, aortic arch, descending aorta, and lung volumes were evaluated. Computed tomography (CT) images of 30 patients (18 men, 12 women) were obtained retrospectively, and the first measurement was performed on thorax CT images at Stage 1 (days 0-4) and the second measurement was performed on thorax CT images at Stage 6 (>day 28).

Results: We found a statistically significant difference in pulmonary artery and aortic diameters between Stage 1 and Stage 6 images due to the progression of COVID-19 disease ($p<0.05$). The difference between Stages 1 and 6 was higher in older individuals. A statistically significant difference was found between lung volumes and the PT.

Conclusion: We found that COVID-19 disease caused an increase in the pulmonary artery and aortic diameter due to its poor prognosis, and there was a significant relationship between lung volume and pulmonary vessels.

Keywords: COVID-19, diameter, pulmonary trunk, aorta

Introduction

Coronavirus disease (COVID-19), which originated in China, started in early 2020 and has become a highly virulent pandemic. COVID-19 is a highly contagious disease that mainly causes acute respiratory distress syndrome (ARDS), vascular damage, microangiopathy, angiogenesis, and disseminated thrombosis. Common symptoms include fever, cough, fatigue, and shortness of breath (1,2). Patients may have an asymptomatic stage following infection or only mild upper respiratory symptoms may be observed. In addition, pneumonia and severe ARDS requiring intubation develop, and complications resulting in death occur. In the later stages of the disease, a worsening clinical scenario occurs with the development of severe pulmonary lesions leading to vascular thrombosis and pulmonary arterial and venous vasculopathy, as well as disseminated intravascular coagulation (3,4).

Distinctive features of COVID-19 include vascular changes associated with the disease. Diffuse intravascular coagulation and multisystem organ failure have been observed in many patients. Therefore, the risk of disease-causing pneumonia and therefore death is also high (5).

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COVID-19 is also likely to affect the heart and cardiac vessels, resulting in strain on lung capacity and impairment of small circulation. Possible cardiac damage includes increased cardiac stress due to respiratory failure and hypoxemia, pulmonary embolism, and myocardial infection. Similar to pulmonary hypertension, pulmonary artery pressure is likely to increase following heart failure (2,3).

While the diagnosis of COVID-19 is determined by polymerase chain reaction, computed tomography (CT) is used for the rapid diagnosis of COVID-19 and determination of lung involvement, especially in emergency departments. Therefore, CT has an essential role in the early diagnosis of COVID-19 pneumonia, and pathophysiological vascular changes in patients affected by COVID-19 can be easily detected by CT (3,5). Diffuse lung consolidation and ARDS that develop with the disease may lead to pulmonary hypertension by changing the properties of pulmonary vessels (6).

Pulmonary hypertension is a term used to describe disorders characterized by abnormally high pressures in the pulmonary arteries. Pulmonary hypertension is rarely caused by chronic thromboembolism or primary vasculopathy (7,8). Similar to pulmonary hypertension, COVID-19 patients may have an increase in the diameter of the pulmonary arteries and a change in the diameter of the aorta and its parts due to heart failure, which may occur indirectly. Therefore, we evaluated the diameter changes in the pulmonary arteries, aorta, and its parts in COVID-19 patients.

Materials and Methods

Patients

The study was approved by the Ordu University Clinical Research Ethics Committee (decision no: 2023/45, date: 23.02.2023) and the Provincial Directorate of Health affiliated to the Ministry of Health. Thorax CT images of patients hospitalized with a preliminary diagnosis of COVID-19 were obtained retrospectively from the imaging system of the Training and Research Hospital. The images obtained were the first CT scan taken on days 0-4 (Stage 1) and the second CT scan taken on day >28 (Stage 6) of the patient hospitalized with the diagnosis of COVID-19. Patients without any lung or vascular pathology and those diagnosed with COVID-19 were included in the study. Patient characteristics (gender and age) and clinical diagnoses were extracted from the images. Measurements were performed on 30 patients (18 males, 12 females, mean age 54.33 years).

Measurements

CT imaging was performed using a multi-detector CT scanner (Canon Aquilion Lightning Core 128, Japan). 1.5-mm-thick CT images were obtained during deep inspiration, and participants were instructed to remain in that position to minimize motion artifacts Measurements were performed on an axial thorax CT image in accordance with the standards specified in the literature using the RadiAnt Digital Imaging and Communications in Medicine (DICOM) Viewer software in Stages 1 and 6. The widest diameter of the pulmonary trunk (PT) after leaving the right ventricle (RV), the widest diameter of the PT where it splits into two (PTS), the widest diameter of the right (RPA) and left pulmonary arteries (LPA), the widest diameter of the aortic arch at its highest point, the widest diameter at the beginning of the ascending aorta, and the widest diameter of the first part of the descending aorta (thoracic aorta) were measured (Figure 1a). Lung volumes were calculated using the ImFusion Suite program. First, the “dcm2niigui” software was used to convert the original CT images in DICOM format into SPM8 (3D Niftii) format. These images were then used for lung-volume calculation using the ImFusion Suite program (Figure 1b).

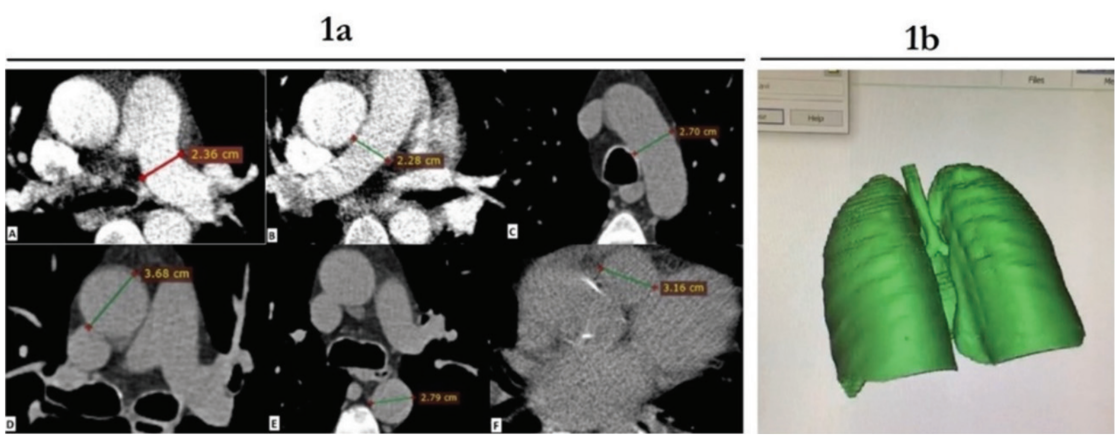

Figure 1. a) Measurement of vessel diameters (A: left pulmonary artery, B: right pulmonary artery, C: aortic arch, D: ascending aorta, E: descending aorta, F: pulmonary trunk beginning). **b)** Measurement of lung volume using software

Statistical Analysis

Descriptive data are expressed as mean and standard deviation. The Shapiro-Wilk test was used to assess the distribution of continuous variables. For non-normally distributed variables, the Wilcoxon signed-rank test was used to compare the differences. Pairwise comparisons of the continuous variables between independent groups were performed using the Mann-Whitney U test. A p value of <0.05 was considered statistically significant. All statistical tests were performed using Statistical Package for the Social Sciences 28.0 software.

Results

Thirty participants (12 females, 18 males) with a diagnosis of COVID-19 were included in our study. The average age of the participants was 54.33±16.38 (between 22 and 90 years old). The mean values of the parameters and comparisons according to gender and age were evaluated. The minimum and maximum values of the parameters in Stages 1 and 6 of COVID-19 are given in Table 1.

The vessel diameter values measured in Stage 6 were significantly increased compared with those measured in Stage 1. Except for the PTS diameter (p=0.056), we found a statistically significant difference between Stage 1 and Stage 6 (p<0.05). All parameters demonstrated a high positive correlation (Table 2).

Table 1. The minimum and maximum values of vessels in Stage 1 and Stage 6 of COVID-19 disease

Vessels	n	Stage 1	Stage 6
PT, cm	30	2.80-4.56	2.85-4.75
PTS, cm	30	2.35-4.33	2.42-4.45
RPA, cm	30	1.57-2.97	1.58-3.17
LPA, cm	30	1.48-2.80	1.55-2.95
Ascending aorta, cm	30	2.47-4.55	2.51-4.80
Aortic arch, cm	30	1.95-3.28	2.09-3.45
Descending aorta, cm	30	1.84-3.68	1.89-3.72

COVID-19: Coronavirus disease-2019, PT: Pulmonary trunk, LPA: Left pulmonary artery, PTS: Pulmonary trunk seperation, RPA: Right pulmonary artery

The mean values of the parameters in Stages 1 and 6 are shown in Table 3 according to gender. Vascular diameters were higher in males than in females. However, when the parameters were compared between Stage 1 and Stage 6 according to gender, no statistically significant difference was determined except for the descending aorta and RPA (Table 4).

We evaluated the effect of age on the increase in vessel diameter in Stages 1 and 6. We found that COVID-19 caused a statistically significant increase in the diameters of LPA, RPA, aorta, and its parts in Stage 1 and Stage 6 due to aging (p<0.05). Because the prognosis of the disease is worse in elderly people, we would report that the effect on the increase in vessel diameter is greater.

The total lung volumes calculated in Stages 1 and 6 are shown in Table 5. Accordingly, right and left lung volumes decreased with the progression of COVID-19 disease. There was no statistically significant difference in lung volumes between Stage 1 and Stage 6 (p=0.125 and p=0.189). The relationship between the pulmonary artery and the right and left lung was evaluated in Stages 1 and Stage 6 and a moderate positive correlation was found, except for the relationship between the pulmonary artery and the left lung in Stage 1 (Table 5).

Discussion

Coronavirus binds to receptors in the alveoli in the lungs, enters the cell, damage. As the disease progresses, pulmonary hemodynamics deteriorate and consolidated areas of the lungs develop. These are followed by abnormal dilation of the pulmonary vessels and a high thromboembolic risk. Therefore, lung capacity is strained, and the possibility of dilatation increases in parallel with increased pressure in the pulmonary

Table 2. Changes in pulmonary vessels and aortic diameter in Stage 1 and Stage 6 of COVID-19 disease and statistical analysis

Vessels	n	Stage 1	Stage 6	p	r	Test
PT, cm	30	3.64±0.44	3.85±0.48	<0.001	0.772	**
PTS, cm	30	2.96 (2.35-4.33)	3.03 (2.42-4.45)	0.056	0.901	*
RPA, cm	30	2.15±0.31	2.22±0.33	0.017	0.913	**
LPA, cm	30	2.06±0.30	2.14±0.33	0.001	0.940	**
Ascending aorta, cm	30	3.50±0.51	3.59±0.55	<0.001	0.987	**
Aortic arch, cm	30	2.66±0.38	2.78±0.39	<0.001	0.981	**
Descending aorta, cm	30	2.59±0.41	2.67±0.43	0.002	0.958	**

*Spearman's Rho correlation, **Pearson correlation, r: Correlation coefficient, p: Significance values (p<0.05 indicates significant difference). The non-parametric data are presented as median (minimum-maximum). The parametric data are presented as mean±standard deviation.
COVID-19: Coronavirus disease-2019, PT: Pulmonary trunk, LPA: Left pulmonary artery, PTS: Pulmonary trunk seperation, RPA: Right pulmonary artery

vessels and indirectly in the aorta. The pulmonary artery diameter may also increase in pathological conditions such as pulmonary hypertension and RV enlargement (2,6,9).

The identified cardiac effects of COVID-19 include myocarditis, myocardial infarction, heart failure, and RV dysfunction. Studies have shown that RV dysfunction occurs in 20-40% of patients with ARDS and lung damage. RV enlargement and pulmonary artery dilatation affect each other. Because of lung injury and vascular inflammation, the load of the RV increases; therefore, an increase in diameter may develop with an increase in pulmonary artery pressure (10,11). Therefore, in our study, we have evaluated all of these issues, which are missing in the literature, on a large scale.

In COVID-19 disease, we found a significant increase in PT, RPA, LPA, and diameters of the aorta and its parts and a statistically significant difference in Stage 1 and Stage 6 COVID-19 CT images. We also observed that this statistical difference increased with age. We evaluated the relationship between lung volume and pulmonary vessels and the aorta and its parts and found a positive correlation.

Spagnolo et al. (6), in their study evaluating PT and aortic diameter in patients with COVID-19, measured a mean PT diameter of 31 mm and found a statistically significant difference between PT and aorta and showed that PT diameter increase was associated with the risk of death in patients with patients. In another study, PT and its branches were evaluated on CT images of patients with pulmonary hypertension, and an increase in the diameter of

Table 3. Evaluation of pulmonary vessels and aortic diameters according to gender and statistical analysis

Vessels	Men (n=18)	Women (n=12)	p
	Stage 1 - Stage 6	Stage 1 - Stage 6	Stage 1 - Stage 6
PT, cm	3.72±0.48 - 3.96±0.50	3.52±0.36 - 3.69±0.41	0.241* - 0.125*
PTS, cm	3.05-3.09	2.80-2.87	0.205** - 0.086**
RPA, cm	2.25±0.35 - 2.29±0.40	2.00±0.16 - 2.10±0.15	0.031* - 0.123*
LPA, cm	2.15±0.35 - 2.22±0.37	1.93±0.14 - 2.03±0.24	0.051* - 0.140*
Ascending aorta, cm	3.54±0.52 - 3.65±0.58	3.43±0.51 - 3.50±0.50	0.578* - 0.494*
Aortic arch, cm	2.74±0.39 - 2.86±0.41	2.55±0.35 - 2.65±0.33	0.170* - 0.154*
Descending aorta, cm	2.75±0.41 - 2.83±0.43	2.36±0.28 - 2.44±0.35	0.010* - 0.017*

p: Significance value between men and women in Stage 1 and Stage 6 ($p<0.05$ indicates significant difference).
All parametric data are presented as mean±standard deviation. Independent samples t-test was applied for gender comparison in parametric data*.
All non-parametric data are presented as median. Mann-Whitney U test was applied for gender comparison in non-parametric data**.
COVID-19: Coronavirus disease-2019, PT: Pulmonary trunk, LPA: Left pulmonary artery, PTS: Pulmonary trunk seperation, RPA: Right pulmonary artery

Table 4. The effect of age on changes in aorta and pulmonary vessels in COVID-19 disease

	Stage 1 - Stage 6						
	PT*	PTS**	RPA*	LPA*	Ascending aorta*	Aortic arch*	Descending aorta*
r	-0.102 0.021	0.238 0.270	0.466 0.385	0.469 0.547	0.749 0.712	0.723 0.706	0.697 0.706
p	0.590 0.912	0.206 0.149	0.009 0.036	0.009 0.002	<0.001 <0.001	<0.001 <0.001	<0.001 <0.001

p: Significance value ($p<0.05$ indicates significant difference), r: Correlation coefficient.
Pearson correlation coefficient* was used to show age-related change in parametric data and Spearman's correlation coefficient** was used in non-parametric data.
COVID-19: Coronavirus disease-2019, PT: Pulmonary trunk, LPA: Left pulmonary artery, PTS: Pulmonary trunk seperation, RPA: Right pulmonary artery

Table 5. Lung volumes measured at Stage 1 and Stage 6 in COVID-19 patients and correlation of pulmonary trunk with lung volumes

	n	Right lung (cm^3)	Pearson correlation coefficient (PT)	Left lung (cm^3)	Pearson correlation coefficient (PT)
Stage 1	30	2369.00±798	p=0.013** r=0.490	2095.00±696	p=0.065 r=0.375
Stage 6	30	2187.00±765	p=0.008** r=0.517	1958.00±779	p=0.021** r=0.459
p*		0.125		0.189	

p*: Significance value between right and left lung in Stage 1 and Stage 6. p**: Significance value between lung volume and pulmonary trunk, r: Pearson correlation coefficient.
All parametric data are presented as mean±standard deviation.
COVID-19: Coronavirus disease-2019, PT: Pulmonary trunk

these vessels was demonstrated (7). In our study, the PT diameter was calculated as 3.64 cm in Stage 1 and the PTS diameter was found to be 2.96 cm on average.

As we found in our study, the relationship between PT diameter and COVID-19 disease has been observed similarly in men and women in other studies (6). A statistically significant difference was found between genders, especially in the diameter of the descending aorta in Stage 1 and Stage 6.

Pulmonary hypertension is one of the pathologies in which PT diameter is of most importance, and there is a large body of literature demonstrating that main pulmonary artery diameter exceeding 29 mm by contrast-enhanced CT is a marker of pulmonary hypertension (7). In our measurements, PT (2.80-4.75) and PTS diameter (2.35-4.33) were found in a wide range due to the wide age range (22-90 years).

Lung volume measured on CT images is closely related to pulmonary function test results (12). Decreased lung volume may be an important sign of COVID-19 infection and prognosis of ARDS. Studies have reported that lung volume reduction detected on CT in COVID-19 cases is associated with more alveolar collapse (13,14). However, in our study, we did not detect a significant decrease in lung volume between Stages 1 and 6. The reason for the lack of a significant lung volume difference may be that lung involvement improves until Stage 6 of the disease or the most severe level of the disease develops after the first 10 days (15).

Study Limitations

The limitation of the study presented here is that the images could not be obtained easily due to the pandemic situation; therefore, the number of patients was low.

Conclusion

In conclusion, COVID-19 directly affects the lungs and indirectly affects the vessels that supply the lungs. We found a statistically significant abnormal vasodilatation in the pulmonary arteries in Stage 6 with COVID-19-induced lung dysfunction and a severe prognosis of the disease. We found that this dilatation is more effective, especially in elderly individuals. RV enlargement may develop with abnormal dilatation of the pulmonary arteries. Therefore, when we examined the aorta and its branches originating from the heart, we found a statistically significant increase between Stages 1 and 6. We found that gender had no effect on the development of pulmonary arteries due to COVID-19 disease. We also found a moderate positive correlation between total lung volume and pulmonary artery diameter. Based on these results, we suggest that COVID-19 disease adversely affects the lungs, pulmonary vessels, and aorta.

Ethics

Ethics Committee Approval: The study was approved by the Ordu University Clinical Research Ethics Committee (decision no: 2023/45, date: 23.02.2023) and the Provincial Directorate of Health affiliated to the Ministry of Health.

Informed Consent: Retrospective study.

Peer-review: Externally peer-reviewed.

Authorship Contributions

Surgical and Medical Practices: M.D., Concept: M.D., İ.U., M.S.C., Design: M.D., İ.U., M.S.C., Ş.T.S., Data Collection or Processing: M.D., Ş.T.S., A.A., Analysis or Interpretation: M.D., Literature Search: M.D., Writing: M.D.

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