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Original Article

Investigation of Pulmonary Artery and Ascending Aorta Morphology in the Coronavirus Disease 2019: A Radioanatomical Study

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Abstract

OBJECTIVE: This study aimed to determine the maximum diameters of the pulmonary artery and ascending aorta and their ratio to each other to enable early diagnosis and treatment of possible pulmonary hypertension and to prevent possible complications in patients infected with severe acute respiratory syndrome coronavirus 2.

MATERIAL AND METHODS: A total of 120 patients aged 40 years and older, 60 patients (30 females and 30 males) with severe acute respiratory syndrome coronavirus 2 infection and 60 individuals (30 females and 30 males), were included in this retrospective study. Maximum pulmonary artery and maximum ascending aorta diameters were measured at the level of bifurcatio trunci pulmonalis in the transverse axial plane by computed tomography, and their ratios to each other were determined.

RESULTS: Our study revealed a statistically significant increase in maximum pulmonary artery and maximum ascending aorta diameters in both genders in patients with coronavirus disease 2019 compared to the control group and a statistically significant increase was found in the maximum pulmonary artery–maximum ascending aorta ratio in women with coronavirus disease 2019 compared to the control group ($P < .05$).

CONCLUSIONS: Knowing the diameters of maximum pulmonary artery and maximum ascending aorta and the maximum pulmonary artery–maximum ascending aorta ratio in hospitalized severe acute respiratory syndrome coronavirus 2-infected patients is a valuable predictive marker of pulmonary hypertension and a guide in determining the appropriate treatment. These data, which are easy to calculate from thorax computed tomography, may be beneficial in the prognosis of the disease.

KEYWORDS: COVID-19, pulmonary artery, ascending aorta, thorax, computed tomography
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INTRODUCTION

The coronavirus disease 2019 (COVID-19) pandemic continues to affect the entire world due to new variants emerging over time.[1,2] Severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) primarily affects the lungs and respiratory system. At the same time, it exerts detrimental effects on the vascular endothelium by disrupting its functional and structural integrity.[3] The virus usually presents with hypercoagulation, as it increases the load of the ventricular dexter (VD), causing deterioration of its functions. One study reported that COVID-19 pneumonia increases pulmonary artery (PA) pressure, resulting in VD dysfunction.[4] Another study showed that this relationship between PA and VD could cause mortality in hospitalized COVID-19 patients.[5] Pathophysiological changes in the lungs of COVID-19 patients are easily detectable by computed tomography (CT), and all possible clinical presentations, from viral pneumonia to acute respiratory distress syndrome (ARDS), can be distinguished from CT images.[6-12] Bilateral interstitial abnormalities initially present as subpleural ground-glass opacities (GGOs). In later stages, progressive consolidations and reticular patterns may arise, and the development of cytokine dysregulation, diffuse ARDS, and alveolar and interstitial damage may exacerbate the condition.[6,8,10] Diffuse lung consolidation and ARDS may alter pulmonary vascular features,[13] yielding pulmonary hypertension,[14,15] which in COVID-19 patients may also result from an overlap of these processes with increasingly reported pulmonary arterial thrombosis.[16-20] The ratio between the maximum diameters of the PA and the ascending aorta (Ao) on CT is a very practical and noninvasive way of diagnosing pulmonary hypertension. Patients with COVID-19 can also be given iodinated contrast material for CT pulmonary angiography, which will facilitate the diagnosis of pulmonary arterial thrombosis during the CT scan.[14,15,21,22] Several studies have shown that maximum PA diameter (MPA), maximum Ao diameter (MAo), and MPA–MAo ratio indices obtained from thoracic CT are useful parameters in predicting clinical outcomes in various lung diseases and COVID-19.[23] This study aimed to reveal the relationship between MPA, MAo, and MPA–MAo to enable early diagnosis and treatment of pulmonary hypertension in patients infected with SARS-CoV-2 and to prevent possible complications.

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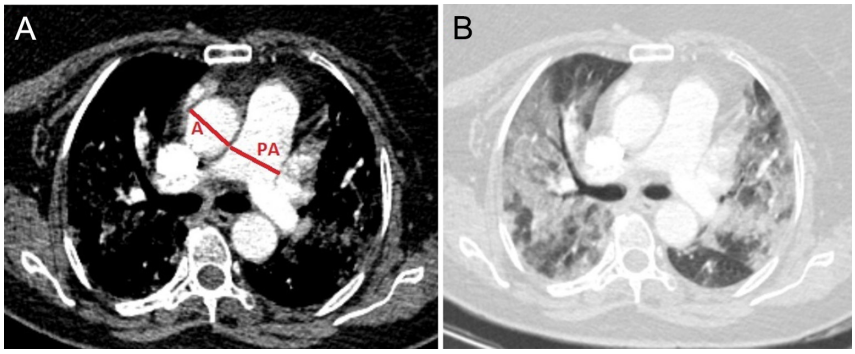

Figure 1. (A) Pulmonary artery (PA) and ascending aorta (A) measurement on contrast-enhanced thoracic computed tomography (CT) in a patient with COVID-19 pneumonia. (B) View of COVID-19 pneumonia in thoracic CT parenchymal window.

MATERIAL AND METHODS

The Malatya Clinical Researches Ethical Board (2021/25)E approved the study (2021/25). All procedures were applied in accordance with the Declaration of Helsinki.

Study Population

Individuals aged 40 and over who were diagnosed with COVID-19 in the Radiology Department between March 2019 and December 2021 and who underwent CT scans were included in the COVID-19 group, and individuals without COVID-19 with CT scans taken between January and December 2018 were included in the control group. Retrospective measurements were taken from a total of 120 people, 30 women and 30 men in the COVID-19 group and 30 women and 30 men in the control group. The study was conducted at a single center and by a specialist radiologist.

Patients aged 40 years and older who were diagnosed with COVID-19 by real-time reverse transcriptase-polymerase chain reaction test and examined with contrast-enhanced CT imaging were included in the study. Patients aged 40 years and younger, those who did not have contrast-enhanced CT imaging, pregnant women, and outpatients were excluded. Other exclusion criteria were any history of primary pulmonary arterial hypertension, chronic thromboembolism, interstitial lung disease, and severe chronic obstructive pulmonary disease (COPD). Patients with missing data were also excluded from the study.

Thoracic Computed Tomography Imaging and Analysis

Thoracic CT examinations were performed in the supine position. During inspiration, 80-100 mL of low-osmolarity non-ionic iodinated contrast material was administered with an automatic pump with an injection rate of 4-5 mL/s, followed by 40 mL of serum physiological solution injected for homogeneous distribution. A separate room was prepared for CT imaging of COVID-19 patients. Passive air ventilation was performed for at least 30 minutes after each CT scan, and machine surfaces were disinfected with ethanol and didec yldimethylammonium chloride. All CT images were evaluated in axial, sagittal, and coronal planes. Patients' CT scans were interpreted by a single radiologist to increase the reliability of the study.

Images were obtained from a dual-source spiral CT named Somatom Definition Flash, Siemens Healthcare, Forchheim, Germany. Scanning parameters were as follows: 120 kV; 250 mAs: return time, 0.35 seconds; pitch, 1.5. Images were reconstructed at a slice thickness of 2 mm using a high-frequency reconstruction algorithm. Images were acquired during a deep inspiratory breath-hold without applying contrast.

The presence of unilateral or bilateral GGO, patchy infiltration, pleural effusion, and fibrotic changes was evaluated on CT images. Maximum pulmonary artery was measured at the level of bifurcatio trunci pulmonalis perpendicular to the vessel direction on transverse axial images, and MAo was measured at its maximal diameter using the same CT section. The data obtained were recorded in millimeters. The MPA–MAo ratio was then calculated by dividing MPA by MAo (Figure 1). The study was carried out in collaboration with an anatomist and a radiologist. Radiological examinations were performed by a specialist radiologist with 10 years of experience.

Statistical Analysis

IBM Statistical Package for the Social Sciences Statistics for Windows version 25.0 (IBM Corp., Armonk, NY, USA) software package was used for statistical data analysis. The conformity of the data to the normal distribution was tested with

MAIN POINTS

- Evidence from several patient populations showed that pulmonary artery (PA) enlargement, which can be calculated easily with computed tomography (CT) scanning, is a parameter that can predict negative results.
- Studies on pulmonary hypertension have reported that a maximum pulmonary artery (MPA)–maximum ascending aorta (MAo) ratio of >0.9 to 1.0 is associated with a poor prognosis and is considered a more useful marker than the peak gradient of tricuspid regurgitation measured by echocardiography.
- The diagnosis of pulmonary hypertension brings many complications. Nevertheless, these complications can be prevented by early intervention thanks to early diagnosis with CT, which allows MPA and MPA/MAo ratio to be determined even in large populations.
- The maximum diameters of PA, ascending aorta, and their ratio, which can be easily obtained from thoracic CT, can be very beneficial in the prognosis of the disease by allowing early diagnosis of symptoms that may adversely affect the patient, such as pulmonary hypertension.

Table 1. Comparison of COVID-19 and Control Group by Gender

	Female			Male		
	COVID-19 Group (n = 26)	Control Group (n = 25)	*P*	COVID-19 Group (n = 30)	Control Group (n = 25)	*P*
Age	50.33 ± 12.09	47.00 ± 9.85	.220	48.73 ± 13.99	45.56 ± 8.80	.299
MPA (mm)	30.3 ± 2.87	24.8 ± 2.60	.000	30.00 ± 2.80	24.7 ± 2.65	.000
MAo (mm)	32.01 ± 3.14	29.03 ± 3.54	.003	32.39 ± 4.18	28.00 ± 3.52	.000
MPA/MAo	0.9 ± 0.08	0.8 ± 0.06	.000	0.9 ± 0.08	0.89 ± 0.09	.870

COVID-19, coronavirus disease 2019; MAo, maximum ascending aorta; MPA, maximum pulmonary artery.

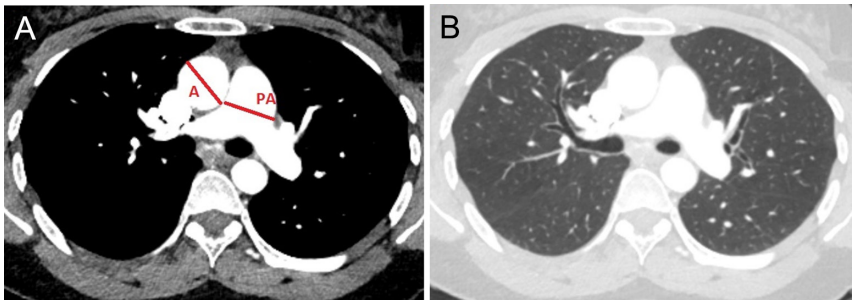

Figure 2. (A) Measurement of pulmonary artery (PA) and ascending aorta (A) in contrast-enhanced thoracic computed tomography (CT) in the control group without lung pathology. (B) Thoracic CT image of normal lung parenchyma.

the Kolmogorov–Smirnov test. Mean and standard deviation were used for numerical data, number and percentage values were used for categorical data, and independent sample *t*-test and Mann–Whitney *U*-test were used for group comparisons. A *P*-value equal to or less than .05 was considered statistically significant for all analyses.

RESULTS

The mean age of the analyzed COVID-19 patients, 50.33 ± 12.09 mm in women and 48.73 ± 13.99 mm in men, was not statistically significantly different ($P = .429$). The mean MPA diameter was 30.17 ± 2.81 mm in COVID-19 patients, 30.36 ± 2.87 mm in women, and 30.0 ± 2.8 mm in men, and the difference was not statistically significant ($P = .637$). The mean MAo diameter was also not statistically significantly different, with 32.21 ± 3.71 mm in COVID-19 patients, 32.01 ± 3.14 mm in women, and 32.39 ± 4.18 mm in men ($P = 1.710$). Finally, the mean MPA/MAo ratio was 0.94 ± 0.82 and did not differ statistically significantly by gender, with 0.94 ± 0.08 in women and 0.93 ± 0.08 in men ($P = .485$).

There was no statistically significant difference between the ages of COVID-19 and control groups in both genders ($P > .05$). The MPA and MAo mean diameters of both male and female COVID-19 patients were statistically significantly higher than that of the control groups ($P < .05$). Although the MPA/MAo ratio of men exposed to COVID-19 was higher than the control groups, the difference was not statistically significant ($P > .05$). On the other hand, this ratio was statistically significantly higher in women with COVID-19 compared to the control group ($P < .001$) (Table 1 and Figure 2).

The comparison of the COVID-19 and control groups revealed statistically significantly higher MPA, MAo, and MPA/MAo values in the COVID-19 patients than in the control group ($P < .001$) (Table 2).

Table 2. Comparison of COVID-19 and Control Group

	COVID-19 Group (n = 56)	Control Group (n = 50)	*P*
MPA (mm)	30.17 ± 2.81	24.81 ± 2.60	.000
MAo (mm)	32.21 ± 3.71	28.51 ± 3.53	.000
MPA/MAo	0.94 ± 0.82	0.87 ± 0.08	.000

COVID-19, coronavirus disease 2019; MAo, maximum ascending aorta; MPA, maximum pulmonary artery.

DISCUSSION

Besides being a primary lung disease, COVID-19 is an infectious pathology that damages the endothelial system by activating many inflammatory and prothrombotic steps. Acute lung injury and respiratory distress syndrome are the most severe forms of the disease and are related to pulmonary vascular function disorders. Therefore, pulmonary hemodynamics, vascular anatomic changes, and pulmonary hypertension development can provide prognostic clues in COVID-19 patients. Evidence from several patient populations showed that PA enlargement, which can be calculated easily with CT scanning, is a parameter that can predict negative results.[14,22] A study conducted in a healthy population reported MPA as 26.1 ± 2.4 mm in men and 22.9 ± 1.9 mm in women.[24] Another study reported the normal reference values of MPA diameter as 24.7 ± 2.7 mm in healthy individuals.[25] Similar to these studies, our study found the MPA diameter to be 24.8 ± 2.6 mm in women and 24.7 ± 2.6 mm in men in the control group. The MPA diameter was reported as 35.3 mm in patients with COPD[22] and 29 mm in patients with cystic lung disease.[26] Another study conducted on patients with COVID-19 found the MPA diameter to be 26.3 ± 4.4 mm.[27] The mortality rate of individuals with pulmonary hypertension was

reported to be high in the last 5 years in individuals with MPA diameter measurements of ≥37.7 mm,[28] while this rate was determined as ≥48 mm in another study.[29] In our study, the MPA diameter was 30.3 ± 2.87 mm in women and 30.0 ± 2.8 mm in men. The findings of our study were similar to previous studies, yet they also demonstrated an increase in MPA diameter in both genders compared to the control group. We cannot directly conclude that PA enlargement is secondary to SARS-CoV-2 infection. The contribution of right ventricular systolic dysfunction in pathogenesis should also be considered. D'Alto et al[30] reported that patients with COVID-19 showed depressed right ventricular functions with a slight increase in PA pressure. Therefore, we believe that right ventricular functions should also be evaluated in COVID-19 patients with an increase in PA diameter.

A study conducted with COPD patients found the MAo diameter to be 35.8 ± 4.9 mm.[22] Erdoğan et al[27] reported the mean MAo diameter in COVID-19 patients as 32.9 ± 5.2 mm. They also examined the patients by categorizing them according to their survival status and showed that those who died from COVID-19 had higher MAo diameters than those who survived. Another study showed that patients with cystic lung disease had a MAo diameter of 31 mm.[26] In our study, the diameter was 32.01 ± 3.14 mm in women and 32.39 ± 4.18 mm in men, with a mean value of 32.21 ± 3.71 mm. Our findings were consistent with the results of these previous studies[22,26,27]; the MAo diameter increased in the patient groups compared to the control group in both genders. Ground-glass opacity, pulmonary consolidation, air bronchogram and airway changes, pulmonary vascular enlargement, reticular pattern and linear opacification, pleural effusion, and pulmonary thromboembolism are considered the main chest CT findings of COVID-19.[15,31] The results not only show that COPD affects the MAo diameter more, but they also reveal an increase in the MAo diameter due to COVID-19 that should not be ignored by clinicians. Impairment of pulmonary hemodynamics after large-scale consolidation with inflammatory and vascular changes, referred to as vascular enlargement,[32] may also be a concern in COVID-19 patients with weak intravascular structure and high thromboembolic risk.[20,33-39]

Studies on pulmonary hypertension have reported that an MPA–MAo ratio of >0.9 to 1.0 is associated with a poor prognosis and is considered a more useful marker than the peak gradient of tricuspid regurgitation measured by echocardiography.[40,41] Other studies on patients with pulmonary hypertension reported that an MPA–MAo ratio of 1.0 or higher predicts worse outcomes.[42,43] Baldi et al[26] reported the MPA–MAo ratio as 0.95 in patients with cystic lung disease. Erdoğan et al[27] found the MPA–MAo ratio in patients with COVID-19 as 0.80 ± 1.2. Another study determined the MPA–MAo ratio as 0.80 ± 0.09.[25] Spagnolo et al[23] showed in 45 COVID-19 patients with thoracic CT scan that the MPA–MAo ratio increased after SARS-CoV-2 infection and was significantly correlated with the extent of pneumonia. In our study, the mean MPA–MAo ratio was 0.94 ± 0.82 and increased statistically significantly in women. This outcome may be associated with a poor prognosis, as in the previous studies. The diagnosis of pulmonary hypertension brings many complications.[13-15,21,22] Nevertheless, these complications can be prevented by early intervention thanks to early diagnosis with CT, which allows MPA and MPA/MAo ratio to be determined even in large populations.[14,22]

Our study lacks data from transthoracic echocardiography and right heart catheterization, which would provide more definitive conclusions about hemodynamic status and PA enlargement. Additionally, CT scan follow-ups could have yielded more beneficial results.

CONCLUSION

In conclusion, our findings reveal a significant increase in the MPA and MAo values in COVID-19 patients compared to the control group. The MPA–MAo ratio in women with COVID-19 was also significantly higher than the control group. These parameters, which are easy to obtain from thoracic CT, can be very beneficial in the prognosis of the disease by allowing early diagnosis of symptoms that may adversely affect the patient, such as pulmonary hypertension.

Ethics Committee Approval: This study was approved by the Malatya Clinical Researches Ethical Board (2021/25).

Informed Consent: Written informed consent was obtained from the patients who agreed to take part in the study.

Peer-review: Externally peer-reviewed.

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Declaration of Interests: The authors have no conflict of interest to declare.

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