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Research Article

Aortic Arch Angle and Aortic Arch Morphometry in COVID 19 Patients: A Radioanatomical Study

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Abstract

Aim: In endovascular surgery, knowing the morphometry of the aortic arch increases the success of surgery. The aim of this study was to examine the angle and morphometry of aortic arch in COVID 19 patients and to compare these with healthy individuals to find out the effect of the disease on the vessel.

Material and Methods: A total of 120 individuals - 60 COVID 19 (30 females, 30 males) patients and 60 healthy (30 females, 30 males) individuals participated in the study. In the study, the parameters of aortic arch angle (AAA), aortic arch diameter (AAD), aortic arch (AA) branches of brachiocephalic trunk diameter (BTD), left common carotid artery diameter (LCCAD), left subclavian artery diameter (LSAD), transverse superior thoracic aperture length (TR-STAL) and anteroposterior superior thoracic aperture length (AP-STAL), transverse inferior thoracic aperture length (TR-ITAL) and anteroposterior inferior thoracic aperture length (AP-ITAL) were measured from thoracic computed tomography images.

Results: As a result of the study, when female and male patients with COVID-19 were compared, LCCAD, LSAD, AP-ITAL, TR-ITAL values were found to be higher in favour of male patients. While Proximal AAD, BTD, LCCAD and LSAD values were higher in female patients with COVID 19 when compared with control group female patients, Proximal AAD, BTD, LCCAD, LSAD, AP-STAL, TR-STAL, AP-ITAL, TR-ITAL values were higher in male patients with COVID 19 when compared with control group male patients. When the measurements of COVID 19 and control group individuals were compared, Proximal AAD, BTD, ACCS, LSAD, TR-STAL, AP-ITAL and TR-ITAL values were found to be higher in favour of COVID 19 patients.

Conclusion: COVID 19 is an important disease that causes dilatation of the AA and its branches. We think that diseases that can change oxygen saturation such as COVID19 can change aortic morphology.

Keywords: COVID 19, aortic arch, superior-inferior thoracic aperture, morphometry, thoracic computed tomography

INTRODUCTION

Aortic arch (AA) and its branches develop with a complicated process in the first few weeks of the foetal life. Anatomically, AA is the second part of the aorta and has three branches as brachiocephalic trunk (BT), left common carotid artery (LCCA) and left subclavian artery (LSA). It is responsible for the blood supply of the head, neck and upper extremity (1). Differences in aortic morphology have been shown in some studies conducted among various patient populations; however, these differences should be well-known. Morphology of the aortic arch is also very important to choose the appropriate graft/stent sizes and identify the appropriate devices, especially in cases when stent/graft application is required (2). Knowing the morphology of aortic arch will be of great help in correct pre-procedural planning and determining the treatment of aortic pathologies in the next stage (4). It is also very important to know the anatomical formations of this artery, to know its adjacent structures and to consider the possible anomalies of these structures in terms of preventing unpredictable complications (5). Acute and chronic pathologies involving the aortic arch are vitally important. The effects of a disease like coronavirus (COVID 19), which affected large masses, on the morphology of aortic arch still remains unclear (6).

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COVID 19 is a viral respiratory disease caused by severe acute respiratory syndrome coronavirus 2 (SARS-Cov-2); it was first identified in Wuhan, China and later declared as pandemic by World Health Organization (7). Although the findings related to Covid-19 are related to the respiratory system, cardiovascular features of the disease have also started to be taken into account since it has caused cardiac problems in a significant number of patients (6, 8, 9).

Understanding the morphology of the aortic arch and its branches is important in terms of planning surgical procedures. Radiological imaging methods are the gold standard in identifying the morphology of this artery (10). Although aortic arch morphology is examined with methods such as magnetic resonance (MR) imaging and echocardiography (ECO), we can reach the most critical images with contrasted thoracic computed tomography (CT) (11). Imaging methods have a very important place in detecting these anomalies and pre-operative evaluation (12).

To date, the effects of COVID 19 on most veins have been examined, while its effect on the aortic arch has remained unclear. Knowing the morphology of aortic arch is crucial especially in terms of determining brain and upper extremity vascular pathologies (8,13). The aim of our study was to examine the angle and morphometry of aortic arch in COVID 19 patients, to compare these with healthy individuals to find out the effect of the disease on the vessel.

MATERIAL AND METHOD

In the power analysis performed to determine the research sample, when the analysis was made as Type I error (α) 0.05, power (1-β) 0.80, effect size 1.3, it was found that there should be at least 40 participants, 20 COVID 19 patients and 20 healthy individuals, in the study (9). COVID 19 patients aged 40 and older who did not have a cardiovascular disease diagnosis were included in our study. Those who had a lung mass or who had received lung surgery were excluded. As a result, a total of 120 individuals - 60 COVID 19 (30 Females, 30 Males) patients and 60 healthy (30 Females, 30 Males) individuals participated in the study.

In this retrospective study, ethics committee approval was taken from Malatya Turgut Özal University Non-interventional clinical research ethics committee with 2021/22 protocol number. The examinations were carried out by an expert radiologist with 12 years of experience in the field by using thoracic CT.

CT examination

Radiological images of patients who received COVID 19 treatment in our hospital between March 2019 and December 2019 were examined from Picture Archiving and Communication Systems (PACS). 60 patients who received COVID 19 diagnosis and who had contrast-enhanced thoracic computed tomography (CT) (Somatom Definition Flash, Siemens Healthcare, Forchheim, Germany) were included in the study. The other group consisted of 60 patients who had received contrast-enhanced CT but did not have a COVID 19 history. CT scans in the measurements were made in 128 slices, 0.5 mm thickness and 0.5 mm increments in the axial plane.

The parameters used in the measurements were age, gender, height, weight, body mass index, aortic arch angle (AAA), aortic arch diameter (AAD), aortic arch branches of brachiocephalic trunk diameter (BTD), left common carotid artery diameter (LCCAD), left subclavian artery diameter (LSAD), transverse superior thoracic aperture length (TR-STAL) and anteroposterior superior thoracic aperture length (AP-STAL), transverse inferior thoracic aperture length (TR-ITAL) and anteroposterior inferior thoracic aperture length (AP-ITAL)

CT Scanning: Proximal aortic arch diameter and diameters of aortic arch branches (BT, LCCA, ASS) in axial reformat images and AA coronal plane (CD) angle (AA-CD angle) were measured. ATSD and ATID measurements were made from axial sections. Multiplanar images were used in determining the vertebral levels of some anatomical structures. Proximal AAD was measured from the right 2nd sternocoastal joint level and from the outer wall to the outer wall (Figure 1A). AA branches were measured inwardly from the level of the arch originating from the aorta on the proximal (Figure 1B). AAA was measured between the horizontal line drawn to the anterior of the vertebral corpus and the line drawn parallel to the arcus aorta in axial sections. (Figure 2). TR-STAL was measured from the axial section in the bone window. It was measured anteroposteriorly between the sternum and T1 vertebral body at the level of the upper edge of the manubrium of sternum. It was measured transversely between the inner edges of the first rib (Figure 2).

Figure 1A. Diameter measurement proximal to the aortic arch, **1B.** Measurement of aortic arch branches. Brachiocephalic trunk, left CCA, and left subclavian artery from the right to the left

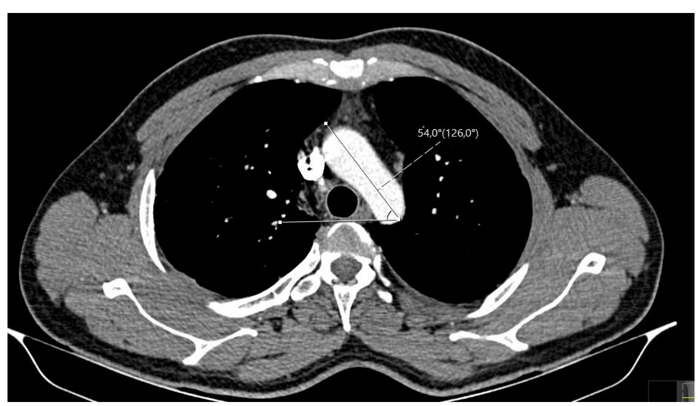

Figure 2. Angle measurement of the aortic arch with the coronal plane

TR-ITAL measurements were made at T12 vertebral level. In the multiplanar reformat images, the location of the sternum xiphoid part was found and a transverse line was drawn to this level at the T12 level. AP measurement was made between this line and the vertebra. Transverse measurement was made by measuring the widest diameter in the same section. (Figure 3A-B).

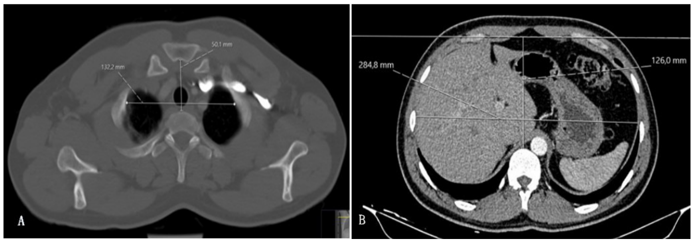

Figure 3A: Anteroposterior superior thoracic aperture and transverse diameter measurement, **3B.** Anteroposterior inferior thoracic aperture and transverse diameter measurement

Statistical analysis

For statistical analysis of the data, IBM SPSS Statistics for Windows, version 25.0 (IBM Corp., Armonk, NY, USA) package program was used. The conformity of the data to the normal distribution was tested with Kolmogorov Smirnov test. Mean and standard deviation were used for numerical data, number and percentage values were used for categorical data, and independent t test and Mann Whitney U test were used for group comparisons. In evaluating the level of significance in the analysis, a p-value of ≤0.05 was considered statistically significant.

RESULTS

In the COVID 19 group, mean age of women was 50.76±12.73 years, while the mean age of men was 47.65±12.91 years and the difference between was not statistically significant (p=0.379). Statistically significant difference was found between women and men in terms of LCCAD, LSAD, AP-ITAL, TR-ITAL lengths (p<0.05). The results of morphological measurements obtained from COVID 19 patients are shown in Table 1.

Mean age of women in COVID 19 group was 50.76±12.73 years, while the mean age of women in the control group was 42.60±11.89 years and there was a statistically significant difference between the two groups (p=0.023). Mean age of men in COVID 19 group was 47.65±12.91 years, while the mean age of men in the control group was 38.56±12.74 years and the difference between was statistically significant (p=0.012).

Proximal AAD, BTD, LCCAD and LSAD were found to be statistically higher in female patients with COVID 19 compared to women in the control group (p<0.05). Proximal AAD, BTD, LCCAD, LSAD, AP-STAL, TR-STAL, AP-ITAL, TR-ITAL lengths were found to be statistically significantly higher in male patients with COVID 19 compared to men in the control group (p<0.05) (Table 2).

When the morphometric measurements of AA and its branches were compared in COVID 19 and Control group individuals, a statistically significant difference was found in Proximal AAD, BTD, LCCA, LSAD, TR-STAL, AP-ITAL and TR-ITAL values in favour of the COVID 19 group (p<0.05) (Table 3).

In the correlation analysis, we found a moderate correlation between BTD and Proximal AAD and between LCCAD and BTD. In addition, we found a weak correlation between LCCAD and proximal AAD; between LSAD and proximal AAD; between LSAD and BTD. While we found a good level of correlation between AP-STAL and AAA, we found a weak correlation between AP-ITAL and BTD and AP-STAL. While there was a weak correlation between TR-ITAL and AAA, we found a good level of positive correlation between TR-ITAL and BTD, TR-STAL and an excellent positive correlation between TR-ITAL and AP-ITAL (Table 4).

Table 1. Distribution of morphological measurements of COVID 19 patients by gender

	COVID 19 group		
	Women	Men	p
Age	50.76±12.73	47.65±12.91	0.379
AAA	63.74±6.72	60.03±7.82	0.070
Proximal AAD	30.28±3.38	31.13±3.29	0.353
BTD	11.6±1.42	12.56±1.43	0.17
LCCAD	7.48±0.85	8.68±1.28	0.001
LSAD	8.64±1.59	10.37±1.33	0.001
AP-STAL	52.36±5.32	70.44±78.05	0.253
TR-STAL	109.00±9.87	113.51±10.17	0.105
AP-ITAL	115.60±13.03	140.34±19.42	0.001
TR-ITAL	252.88±10.51	289.17±13.73	0.001

AAA: aortic arch angle, Proximal AAD: aortic arch proximal diameter, BTD: brachiocephalic trunk diameter, LCCAD: left common carotid artery diameter, LSAD: left subclavian artery diameter, AP-STAL: antero-posterior superior thoracic aperture length, TR-STAL: transverse superior thoracic aperture length, AP-ITAL: antero-posterior inferior thoracic aperture length, TR-ITAL: transverse inferior thoracic aperture length

Table 2. Comparison of morphometric measurements of AA and its branches in COVID 19 and Control group

	Female			Male		
	COVID 19 group 1	Control group 2	p	COVID 19 group	Control group	p
Age	50.76±12.73	42.60±11.89	0.023	47.65±12.91	38.56±12.74	0.012
AAA	63.74±6.72	62.20±7.47	0.447	60.03±7.82	62.66±8.11	0.233
Proximal AAD	30.28±3.38	27.82±3.57	0.016	31.13±3.27	26.38±3.43	0.001
BTD	11.60±1.42	10.14±1.41	0.001	12.56±1.43	10.40±1.53	0.001
LCCAD	7.48±0.85	6.70±0.99	0.001	8.68±1.28	7.02±1.29	0.001
LSAD	8.64±1.59	7.76±1.20	0.032	10.37±1.33	8.70±1.86	0.001
AP-STAL	52.36±5.32	51.44±6.99	0.603	70.44±8.05	53.88±5.93	0.295
TR-STAL	109.00±9.87	106.52±8.85	0.348	113.51±10.17	107.00±9.5	0.019
AP-ITAL	115.60±13.03	111.92±17.24	0.399	140.34±19.42	124.52±20.36	0.005
TR-ITAL	252.88±10.51	250.76±16.36	0.588	289.17±13.73	267.24±23.11	0.001

AAA: aortic arch angle, Proximal AAD: aortic arch proximal diameter, BTD: brachiocephalic trunk diameter, LCCAD: left common carotid artery diameter, LSAD: left subclavian artery diameter, AP-STAL: antero-posterior superior thoracic aperture length, TR-STAL: transverse superior thoracic aperture length, AP-ITAL: antero-posterior inferior thoracic aperture length, TR-ITAL: transverse inferior thoracic aperture length

Table 3. Comparison of morphometric measurements of AA and its branches in all individuals of COVID 19 and Control group

	COVID 19 group	Control group	p
AAA	61.75±7.50	62.43±7.72	0.651
Proximal AAD	30.73±3.33	27.10±3.54	0.001
BTD	12.12±1.50	10.27±1.46	0.001
LCCAD	8.12±1.25	6.86±1.04	0.001
LSAD	9.57±1.69	8.23±1.62	0.001
AP-STAL	62.07±7.57	52.66±6.53	0.253
TR-STAL	111.42±10.19	106.76±10.17	0.015
AP-ITAL	128.88±20.76	118.22±19.73	0.009
TR-ITAL	272.37±21.98	259.00±21.49	0.001

AAA: aortic arch angle, Proximal AAD: aortic arch proximal diameter, BTD: brachiocephalic trunk diameter, LCCAD: left common carotid artery diameter, LSAD: left subclavian artery diameter, AP-STAL: antero-posterior superior thoracic aperture length, TR-STAL: transverse superior thoracic aperture length, AP-ITAL: antero-posterior inferior thoracic aperture length, TR-ITAL: transverse inferior thoracic aperture length

Table 4. Correlation analysis of morphometric measurements of AA and its branches in all individuals in COVID 19 and control group

Parameters	Test	AAA	Proximal AAD	BTD	LCCAD	LSAD	AP-STAL	TR-STAL	AP-ITAL	TR-ITAL
Proximal AAD	r	-.100								
	p	.449								
BTD	r	.032	.664							
	p	.810	.000**							
LCCAD	r	.045	.306	.440						
	p	.733	.018*	.000**						
LSAD	r	.155	.366	.297	.600					
	p	.237	.004*	.021*	.000**					
AP-STAL	r	.501	-.049	.114	.232	.219				
	p	.000**	.709	.384	.074	.093				
TR-STAL	r	-.043	.090	.162	.030	.068	.115			
	p	.743	.496	.217	.820	.605	.381			
AP-ITAL	r	.252	.229	.343	.142	.135	.487	.189		
	p	.052	.079	.007*	.279	.305	000**	148		
TR-ITAL	r	.288	.347	.521	.275	.387	.319	.518	.655	
	p	.026*	.007*	000**	.034*	002**	.013*	.000**	.000**	

AAA: aortic arch angle, Proximal AAD: aortic arch proximal diameter, BTD: brachiocephalic trunk diameter, LCCAD: left common carotid artery diameter, LSAD: left subclavian artery diameter, AP-STAL: antero-posterior superior thoracic aperture length, TR-STAL: transverse superior thoracic aperture length, AP-ITAL: antero-posterior inferior thoracic aperture length, TR-ITAL: transverse inferior thoracic aperture length

DISCUSSION

In this study which aimed to examine aortic arch angle and aortic arch morphometry in COVID 19 patients, to compare with healthy individuals and to determine the effects of the disease on the vessel, when female and male patients with COVID-19 were compared, LCCAD, LSAD, AP-ITAL, TR-ITAL values were higher in favour of male patients. While Proximal AAD, BTD, LCCAD and LSAD values were higher in female patients with COVID 19 when compared with females in the control group; Proximal AAD, BTD, LCCAD, LSAD, AP-STAL, TR-STAL, AP-ITAL, TR-ITAL values were higher in male patients with COVID 19 when compared with males in the control group. When the measurements of COVID 19 and control group individuals were compared, Proximal AAD, BTD, LCCA, LSAD, TR-STAL, AP-ITAL and TR-ITAL values were higher in favour of COVID 19 patients.

In our study, we found that Proximal AAD increased with the increase in BTD, and there was an excellent correlation between LSAD and LCCAD and between TR-ITAL and AP-ITAL.

Although there is evidence that COVID-19 can be considered a systemic inflammatory disease resulting in multi-organ failure, there still no strong data about aortic pathologies as a possible expression of this infection (14). The present study provides data to show the damage of COVID 19 on AA and its branches in COVID 19 patients.

In one study, AAA was examined in patients with aortic dissection and healthy individuals and the angle was found to be wider in patients with dissection when compared with healthy individuals (15). In another study, AAA was reported to be wider in men (59.8±5.5 degrees) when compared with women (55.9±3.8 degrees) (16). In our study, the angle was found to be wider than the literature in COVID 19 patients. At the same time, AAA was wider in female COVID 19 patients when compared with male COVID 19 patients. Our results showed that COVID 19 affected the vessel more than aortic dissection. In addition to this, COVID 19 caused more enlargement in AAA in women.

In a study conducted on cadavers in literature, Proximal AAD, BTD, LCCAD measurements were found to be 18.3 mm, 9.5 mm and 10.6 mm, respectively (3). In another study, AAD, BTD, LCCAD were examined in patients with trauma, dissection and aneurism and these arteries were found to be 17.7 mm, 11.7 mm, 14.1 mm, respectively in trauma patients and higher values were found in dissection patients (2). In our study, diameter measurements of these arteries were found to be wider in COVID 19 patients. The measurements were in parallel with the literature. As a result of these studies, we can say that COVID 19 virus causes great destruction on the artery diameter.

Aortic chemoreceptor tissue is found along the aorta, pulmonary artery trunk, and subclavian artery (17). The partial recovery of chemoreflex function has been attributed to augmented aortic body responses to hypoxia (18). Like the carotid body, hypercapnia increases the aortic body chemoreceptor activity, albeit of lesser magnitude, and the effects of CO2 are augmented by hypoxia (19, 20). Whereas metabolic acidosis stimulates the aortic chemoreceptor response, metabolic alkalosis reduces the response to hypoxia and CO2 (21). Carbondioxide increased and oxygen decreased in the blood gas of our COVID 19 patients who were treated in the hospital. We also thought that the increase in aortic diameter in COVID 19 patients was due to hypoxia and hypercapnia due to the mentioned literature.

LSA is an important artery that originates from the AA and is responsible for feeding the left upper extremity. In a study conducted on healthy individuals, LSAD was reported to be larger in women than in men (22). In the present study, LSAD measurement was higher in favour of women in both COVID 19 patients and control group individuals. In the control group, in parallel with the literature, while it was larger in females than males, it was narrower in both genders in COVID 19 patients.

ATSD, which is known as the thoracic inlet, connects the neck root to the rib cage and has great importance on the vessels in this region. In the reviewed literature, it has been reported that the size of TR-STAL is 10 cm and the size of AP-STAL is 5 cm (23,24). In our study, while results parallel to the literature were found in control group individuals, it was found that the size of this structure tended to increase in COVID 19 patients.

ATID, also known as thoracic outlet, connects the thorax and the abdomen. In studies conducted, while TR diameter of ATID is larger than its AP diameter, it is wider than ATSD (25,26). In our study, we found it to be wider in COVID 19 patients when compared with control group patients.

CONCLUSION

COVID 19 is a major disease that causes enlargement of the aorta, the main artery of the body. Knowing the AA morphology in COVID 19 patients, especially in vascular surgery, will positively affect the success of the surgery and will provide vital data to the clinician, especially in procedures such as stent placement. Future studies are needed to examine the effects of different pathologies on AA morphology.

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Conflict of Interest: *The authors declare that they have no competing interest.*

Ethical approval: *In this study, ethics committee approval was taken from Malatya Turgut Özal University Non-interventional clinical research ethics committee with 2021/22 protocol number.*

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