Evaluation of the Trachea and Bronchi in COVID-19 Patients Using the 3-dimensional Reconstruction Method

Ayse Erkaya[1], Zafer Kutay Coskun[2], Seda Akyol[3] and Tuncay Veysel Peker[2]

[1]*Department of Anatomy, Faculty of Medicine, Lokman Hekim University, Ankara, Turkey*
[2]*Department of Anatomy, Faculty of Medicine, Gazi University, Ankara, Turkey*
[3]*Department of Radiology, Faculty of Medicine, Lokman Hekim University, Ankara, Turkey*

ABSTRACT

Objective: To evaluate changes in the trachea and bronchi of COVID-19 patients using the 3-dimensional reconstruction images obtained from chest CT (computed tomography) scans.
Study Design: An observational study.
Place and Duration of the Study: Departments of Anatomy and Radiology, Faculty of Medicine, Lokman Hekim University, Ankara, Turkey, between March 2021 and January 2022.
Methodology: There were 150 COVID-19 patients in the acute period and 150 individuals as the control group. The CT images were transferred to Mimics software, and a 3-dimensional reconstruction was performed. COVID-19 patients were grouped separately by gender, and their total lung severity score was classified as absent (Grade 0), mild (Grade 1), moderate (Grade 2), and severe (Grade 3).
Results: The cross-sectional area and diameter of the right upper lobar bronchus decreased as the grade increased ($p<0.05$ and $p<0.001$, respectively). The circumference of the right upper lobar bronchus and the cross-sectional area and circumference of the left lower lobar bronchus were found to be narrower in Grade 1-2-3 COVID-19 patients compared to those of the control group ($p<0.01$, $p<0.05$, and $p<0.05$, respectively). The cross-sectional area, circumference, and diameter of the middle lobar bronchus were found to be narrower in Grade 3 COVID-19 patients ($p<0.05$, $p<0.05$, and $p<0.05$, respectively).
Conclusion: Although mostly independent of the grade increase, narrowing of the trachea and bronchi was observed in COVID-19 patients in the acute period. Further research is required with to reveal whether the narrowings are permanent.

Key Words: *COVID-19, Trachea, Bronchus, 3-dimensional reconstruction*.

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INTRODUCTION

Severe acute respiratory syndrome coronavirus 2 (*SARS-CoV-2*) infecting humans was detected in December 2019. The disease was called COVID-19 by the World Health Organization.[1]

Alterations in airways, *e.g.*, bronchiectasis, endobronchial mucus plugging, and bronchial wall thickening, may be observed in COVID-19 patients.[2,3] The prevalence of bronchial wall thickening in COVID-19 subjects having severe clinical features is significantly higher compared to COVID-19 subjects having mild clinical features.[3] The pathogenesis may be inflammatory damage of the bronchial wall, resulting in the bronchial wall structure destruction, fibrosis, proliferation of fibrous tissue, and tractional bronchiectasis.[4] Traction bronchiectasis due to fibrosis may occur in the late period.[5]

Correspondence to: Dr. Ayse Erkaya, Department of Anatomy, Faculty of Medicine, Lokman Hekim University 06510 Çankaya/Ankara, Turkey
E-mail: ayse.erkaya@lokmanhekim.edu.tr
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Most studies have investigated lung parenchymal damage from COVID-19 disease. There is not enough information about the impacts of COVID-19 disease on the bronchi and trachea. Therefore, the aim of this study was to evaluate the effects of COVID-19 disease on the bronchi and trachea using 3-dimensional reconstruction images obtained from chest CT scans of COVID-19 patients.

METHODOLOGY

One hundred fifty COVID-19 patients older than 18 years of age who had a positive RT-PCR test result and presented to the outpatient and emergency departments of Lokman Hekim University Ankara Hospital with fever, cough, and/or muscle and joint pain between April 2020 and February 2021. Similar number of individuals over 18 years of age who were examined at Lokman Hekim University Ankara Hospital between the same dates, who did not have any chronic disease and fever, and who did not have any pathology on tomography were enrolled as the control group in this observational study. Individuals with chronic obstructive pulmonary disease (COPD), pulmonary fibrosis, interstitial lung disease, mass compressing the trachea and bronchus, a history of tracheobronchial surgery or tracheal intubation, and tracheobronchial tumour in both groups were excluded from the study.

DICOM formatted-CT images were obtained retrospectively from hospital archives using the PACS system (ClearCanvas Workstation, Version 2.0). CT images of the COVID-19 subjects enrolled in the research were images taken in the first week, namely during the acute period.

CT images were taken with the individual lying in the supine position and with arms up by breathing deeply and holding the breath using the Siemens Somatom Emotion 16 Slice Multidetector CT [110 kV, 134 mAs, rotation time 0.5 sec, pitch 1.0, section thickness 4 mm (1.5 mm in reformat images)] in Lokman Hekim University Ankara Hospital.

CT images that were archived in the PACS system and saved in the DICOM format were transferred to Mimics Innovation Suite 24.0 (Leuven-Belgium) software. A 3-dimensional reconstruction of the trachea and bronchi was performed in the Mimics Innovation Suite 24.0 (Leuven-Belgium) software. The measurements of the trachea and bronchi were performed on the obtained 3-dimensional model. The measurements were made on magnified images to avoid an error. The air inside the trachea and bronchus was reconstructed. In this way, lumen measurements of the trachea and bronchus were performed, and the wall structure was not measured.

Trachea measurements were carried out at three different levels. The first level is the apex of the jugular notch in the manubrium of the sternum. The second level is the level of the sternal angle. The third level is just above the tracheal bifurcation. The cross-sectional area, circumference (Figure 1), anteroposterior diameter, and transverse diameter were measured at all the three levels. The measurements were performed at the proximal and distal levels in the right and left main bronchus (Figure 2). The cross-sectional area, circumference, anteroposterior diameter, and transverse diameter were measured at both levels. The circumference, cross-sectional area, and diameter were measured at the proximal level in the right and left upper lobar bronchus, intermediate bronchus, middle lobar bronchus, and right and left lower lobar bronchus (Figure 3).

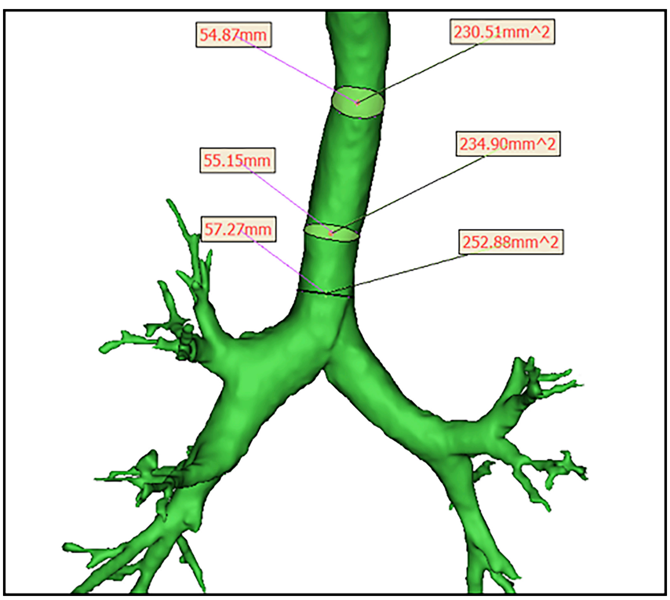

Figure 1: The cross-sectional area and circumference measurement of the trachea at the first, second, and third levels (front view).

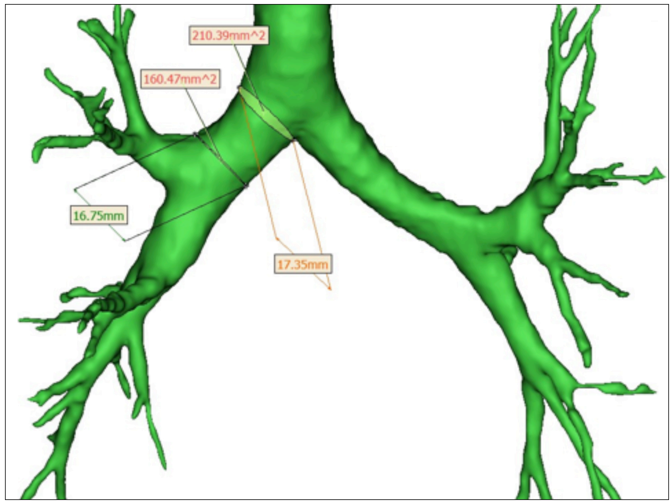

Figure 2: The cross-sectional area and transverse diameter measurement at the proximal and distal levels in the right main bronchus (front view).

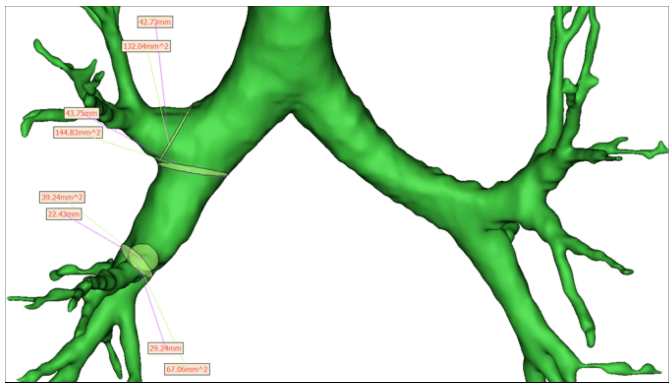

Figure 3: The cross-sectional area and circumference measurement at the proximal level in the right upper lobar bronchus, intermediate bronchus, middle lobar bronchus, and right lower lobar bronchus (front view).

An experienced radiologist evaluated lung involvement in COVID-19 patients. The right lung was considered as three lobes, and the left lung was considered as two lobes. Scores varying between 0 and 4 were given to every of the five lung lobes depending on the percentage of involvement. Zero points were given for no involvement in one lobe (0%), one point was given for minimal involvement (1-25%), two points were given for mild involvement (26-50%), three points were given for moderate involvement (51-75%), and four points were given for severe involvement (76-100%). The total lung severity score was acquired due to summing the scores of the five lung lobes (0-20). The lung involvement severity was classified on a 4-level scale. While the total lung severity score of 0 points was classified as Grade 0 (no involvement), the score of 1-5 points was classified as Grade 1 (mild), the score of 6-15 points was classified as Grade 2 (moderate), and the score of 16-20 points was classified as Grade 3 (severe).[6]

The data obtained were analysed in the SPSS for Windows 11.5 (Chicago Inc.) statistical package program. In the evaluations, the effect of age on quantitative variables was removed regardless of whether it was statistically significant or not (new measurement value=old measurement value-b*(age-mean age), where "b" represents the regression coefficient). Then, for the new variable values obtained, the independent samples t-test was performed to compare two-group quantitative variables, one-way ANOVA and the Bonferroni test were used for more than two group comparisons. Furthermore, the relationships between continuous variables were analysed by the Pearson moment-product correlation analysis. The categorical variables were expressed as counts and percentages while the continuous variables were expressed as mean and standard deviation (SD). The statistical significance level was considered 0.05 ($p<0.05$).

RESULTS

One hundred fifty patients with COVID-19 (79 males and 71 females) and 150 control group participants (79 males and 71 females) were included in this research. The age range was 21-90 in the COVID-19 group and 20-87 in the control group. The COVID-19 group's mean age (52.8±15.6 years) was higher than that of the control group (46.8±15.8 years, $p<0.001$).

While only one lobe was affected in 25 cases (16.7%), it was observed that all lobes were involved in 70 cases (46.7%). The most common involvement was detected in the right lower lobe in 130 cases (86.7%), and the rarest involvement was identified in the right middle lobe in 89 cases (59.3%). The mean total lung severity score was 6.8±4.8, and the range of the total lung severity score was 1-19. There was no participant with Grade 0. There were 71 participants with Grade 1, 62 participants with Grade 2, and 17 participants with Grade 3.

A statistically significant and similar relationship was revealed between the total lung severity score and the ages of the patients diagnosed with COVID-19 ($p<0.001$).

The cross-sectional area and diameter measurements of the right upper lobar bronchus decreased as the grade increased ($p<0.05$, $p<0.001$). The circumference measurement of the right upper lobar bronchus and the cross-sectional area and circumference measurements of the left lower lobar bronchus were found to be narrower in Grade 1, Grade 2, and Grade 3 COVID-19 patients than in the control group ($p<0.01$, $p<0.05$, $p<0.05$). The diameter measurements of the left lower lobar bronchus were narrower in Grade 2 and Grade 3 COVID-19 patients in comparison with the control group ($p<0.001$). The cross-sectional area, circumference, and diameter measurements of the middle lobar bronchus were revealed to be narrower in Grade 3 COVID-19 patients than in the control group ($p<0.05$, $p<0.05$, $p<0.05$) (Table I).

It was revealed that the cross-sectional area and anteroposterior diameter measurements at the 1st level of the trachea were narrower in Grade 1, Grade 2, and Grade 3 female COVID-19 patients ($p<0.05$ and $p<0.05$, respectively). The circumference measurement was narrower in Grade 1 and Grade 2 female COVID-19 patients compared to the control group ($p<0.05$). The anteroposterior diameter measurement at the proximal level of the left main bronchus was found to be narrower in Grade 1, Grade 2, and Grade 3 female COVID-19 patients in comparison with the control group ($p<0.05$, Table II).

In female COVID-19 patients, the cross-sectional area, circumference, anteroposterior diameter, and transverse diameter measurements at the first level of the trachea were narrower than those of the control group ($p<0.01$, $p<0.01$, $p<0.01$, $p<0.01$, and $p<0.05$, respectively). Nevertheless, the cross-sectional area, circumference, and anteroposterior diameter measurements at the proximal level of the left main bronchus were found to be significantly narrower in female COVID-19 patients compared to the control group ($p<0.05$, $p<0.05$, and $p<0.01$).

The cross-sectional area, circumference, and diameter measurements of the left upper lobar bronchus were narrower in female COVID-19 patients than in the control group ($p<0.05$, $p<0.05$, and $p<0.05$, respectively). The cross-sectional area, circumference, and diameter measurements of the right upper lobar bronchus and left lower lobar bronchus were significantly narrower in male COVID-19 patients than in the control group ($p<0.05$, $p<0.01$, $p<0.001$, $p<0.01$, $p<0.01$, and $p<0.001$, respectively) (Table III).

DISCUSSION

The epithelial cells that line the respiratory tract are among the first cell types that the inhaled virus encounters.[7] *SARS-CoV-2* enters cells as a result of binding to the angiotensin-converting enzyme 2 (ACE2) receptor on the ciliary respiratory epithelium's apical surface.[8,9] The cell type in question is especially present in the distal airways, lungs, supraglottic area, glottis, and trachea.[8,10]

Coronavirus may lead to difficulties in tracheal intubation and extubation by causing symptomatic inflammation in the lungs, bronchi, and trachea. COVID-19-associated laryngotracheitis may occur. The narrowing of the airway can make the placement of tracheostomy tubes more challenging because of the mucosa thickening and increased local secretions.[11] In their research, Ünlü *et al*. assessed the trachea of 326 COVID-19 patients. In the study, the anteroposterior and transverse diameters of the trachea were measured at the thyroid and tracheal bifurcation levels. The measurements were performed using the images of CT data at the axial section. It is not prudent to perform diameter measurements in a 2-dimensional cross-section since the trachea is oblique in most people rather than upright. The researchers graded the COVID-19 patients included in the study according to the severity of lung involvement and examined changes in tracheal diameters depending on the increase in severity. In the study, they reported that increased tracheal diameters were detected in proportion to pneumonia severity, subjects with the most severe pneumonia had the greatest anteroposterior and transverse diameters, and severe inflammation might lead to an increase in trachea diameters by causing oedema in the trachea.[8] Whereas inflammation and oedema in the trachea lead to increased tracheal diameter, it may lead to stenosis in the tracheal lumen.[8]

Table I: Comparisons in the measurements of the lobar bronchi and intermediate bronchus according to the severity of lung involvement of the control group and COVID-19 patients regardless of gender.

	Control (n=150) Mean±SD	Grade 1 (n=71) Mean±SD	Grade 2 (n=62) Mean±SD	Grade 3 (n=17) Mean±SD	p
Right upper lobar bronchus					
Cross-sectional area (mm²)	92.7±31.8	84.0±29.3	88.4±31.9	71.4±23.2	<0.05*
Circumference (mm)	35.3±6.8	34.0±5.8	34.8±6.1	34.5±4.4	<0.01*
Diameter (mm)	13.4±2.6	12.3±2.1	12.2±2.2	10.7±1.8	<0.001*
Intermediate bronchus					
Cross-sectional area (mm²)	122.9±33.0	124.2±34.4	130.8±44.5	119.2±32.3	>0.05
Circumference (mm)	41.0±5.5	41.1±5.9	42.0±6.9	39.9±5.2	>0.05
Diameter (mm)	14.6±2.1	14.7±2.2	14.5±2.5	14.0±2.1	>0.05
Middle lobar bronchus					
Cross-sectional area (mm²)	41.1±16.7	39.2±17.7	42.4±17.2	29.2±11.9	<0.05*
Circumference (mm)	23.2±4.7	22.4±5.0	23.5±5.1	19.8±4.3	<0.05*
Diameter (mm)	7.4±1.8	7.0±1.7	7.2±1.8	6.1±1.5	<0.05*
Right lower lobar bronchus					
Cross-sectional area (mm²)	58.2±19.3	55.4±18.7	57.1±22.7	46.0±14.6	>0.05
Circumference (mm)	27.7±5.0	27.0±5.0	27.0±5.5	24.4±4.3	>0.05
Diameter (mm)	8.8±1.7	8.6±1.6	8.6±1.7	8.0±1.2	>0.05
Left upper lobar bronchus					
Cross-sectional area (mm²)	64.5±23.7	58.0±20.1	60.6±21.1	64.5±29.9	>0.05
Circumference (mm)	29.8±5.4	28.0±4.8	28.8±4.9	30.0±6.5	>0.05
Diameter (mm)	10.3±2.1	9.7±1.7	9.7±1.8	10.2±2.2	>0.05
Left lower lobar bronchus					
Cross-sectional area (mm²)	58.9±21.2	53.5±19.6	50.3±19.2	51.3±23.3	<0.05*
Circumference (mm)	27.9±5.1	26.5±4.6	25.6±5.0	26.0±6.0	<0.05*
Diameter (mm)	9.7±1.9	9.3±1.7	8.4±1.8	8.5±1.7	<0.001*

** Significant at 0.05 level according to the one-way ANOVA test.*

Table II: Comparisons in the measurements of the trachea, right main bronchus, and left main bronchus according to the severity of lung involvement in the control group and cases diagnosed with COVID-19 among females.

	Control (n=150) Mean±SD	Grade 1 (n=71) Mean±SD	Grade 2 (n=62) Mean±SD	Grade 3 (n=17) Mean±SD	p
1st level of the trachea					
Cross-sectional area (mm²)	215.1±50.8	197.4±31.3	190.2±36.2	196.0±39.8	<0.05*
Circumference (mm)	52.7±5.7	50.5±3.9	49.5±4.6	51.5±4.3	<0.05*
Anteroposterior diameter (mm)	16.5±2.1	15.8±1.7	15.1±1.8	16.4±1.8	<0.05*
Transverse diameter (mm)	16.32±2.1	15.8±1.4	15.7±1.3	16.5±1.5	>0.05
2nd level of the trachea					
Cross-sectional area (mm²)	205.8±41.1	205.2±33.9	196.6±36.6	218.1±40.6	>0.05
Circumference (mm)	51.6±5.3	51.6±4.1	50.8±4.4	54.0±5.2	>0.05
Anteroposterior diameter (mm)	16.7±2.2	16.1±1.6	15.6±1.6	16.9±2.2	>0.05
Transverse diameter (mm)	16.3±1.7	16.4±1.5	16.2±1.5	16.6±1.4	>0.05
3rd level of the trachea					
Cross-sectional area (mm²)	212.1±44.9	208.9±34.4	200.1±34.5	224.5±43.1	>0.05
Circumference (mm)	52.7±5.5	52.4±4.2	51.4±3.9	54.8±5.7	>0.05
Anteroposterior diameter (mm)	16.4±2.6	16.2±1.4	15.6±1.7	17.1±2.3	>0.05
Transverse diameter (mm)	16.7±1.8	16.6±1.7	16.5±1.5	17.0±1.6	>0.05
Proximal level of the right main bronchus					
Cross-sectional area (mm²)	154.9±32.9	151.5±30.7	146.2±29.6	159.7±38.4	>0.05
Circumference (mm)	45.3±4.8	44.9±4.2	44.3±4.0	46.8±5.9	>0.05
Anteroposterior diameter (mm)	13.8±1.6	13.5±1.3	13.1±1.7	14.2±1.5	>0.05
Transverse diameter (mm)	14.6±1.8	14.4±1.8	14.5±1.9	15.6±2.5	>0.05
Distal level of the right main bronchus					
Cross-sectional area (mm²)	141.3±32.3	149.5±31.9	136.9±25.0	161.9±42.2	>0.05
Circumference (mm)	44.0±4.8	45.6±5.0	43.7±4.0	47.8±6.6	>0.05
Anteroposterior diameter (mm)	12.0±1.8	12.0±1.3	11.7±1.7	13.2±2.6	>0.05
Transverse diameter (mm)	15.5±2.0	16.6±2.2	15.8±1.9	16.6±2.5	>0.05
Proximal level of the left main bronchus					
Cross-sectional area (mm²)	123.6±26.9	112.9±25.3	117.1±17.7	110.1±28.9	>0.05
Circumference (mm)	40.4±4.3	39.7±4.1	39.5±2.9	39.9±5.1	>0.05
Anteroposterior diameter (mm)	12.00±1.7	11.2±1.4	11.5±1.4	11.0±1.7	<0.05*
Transverse diameter (mm)	13.3±1.6	12.8±1.6	13.3±1.2	13.4±1.7	>0.05
Distal level of the left main bronchus					
Cross-sectional area (mm²)	78.9±27.2	74.6±29.9	83.3±49.1	91.2±48.7	>0.05
Circumference (mm)	32.9±5.2	31.7±3.9	30.2±5.9	31.7±6.2	>0.05
Anteroposterior diameter (mm)	10.1±1.6	10.2±1.5	9.6±1.8	10.3±1.6	>0.05
Transverse diameter (mm)	10.9±2.0	10.5±1.5	9.8±2.2	10.3±1.9	>0.05

** Significant at 0.05 level according to the one-way ANOVA test.*

Table III: Comparisons in the measurements of the lobar bronchi and intermediate bronchus in the control group and cases diagnosed with COVID-19 among gender groups.

	Male			Female		
	Control Mean±SD	COVID-19 Mean±SD	p	Control Mean±SD	COVID-19 Mean±SD	p
Right upper lobar bronchus						
Cross-sectional area (mm²)	105.2±32.2	95.2±30.9	<0.05*	78.8±25.2	72.4±24.0	>0.05
Circumference (mm)	38.8±6.3	36.1±5.8	<0.01*	33.4±6.2	31.8±5.0	>0.05
Diameter (mm)	14.2±2.6	12.6±2.2	<0.001*	12.5±2.4	11.5±1.9	<0.01*
Intermediate bronchus						
Cross-sectional area (mm²)	142.4±28.9	148.0±37.6	>0.05	101.3±21.9	102.2±21.9	>0.05
Circumference (mm)	44.3±4.5	44.9±5.6	>0.05	37.3±3.9	37.5±4.3	>0.05
Diameter (mm)	15.6±1.9	16.7±2.3	>0.05	13.4±1.5	13.3±1.8	>0.05
Middle lobar bronchus						
Cross-sectional area (mm²)	44.9±16.4	43.8±18.6	>0.05	36.9±16.2	34.5±14.3	>0.05
Circumference (mm)	24.4±4.4	23.9±5.1	>0.05	21.9±4.7	21.1±4.6	>0.05
Diameter (mm)	7.7±1.8	7.3±1.8	>0.05	7.1±1.8	6.6±1.6	>0.05
Right lower lobar bronchus						
Cross-sectional area (mm²)	64.8±19.0	61.6±20.5	>0.05	50.9±17.0	47.8±17.5	>0.05
Circumference (mm)	29.4±4.9	28.3±5.3	>0.05	25.9±4.5	24.9±4.5	>0.05
Diameter (mm)	9.3±1.7	9.0±1.6	>0.05	8.3±1.6	8.1±1.5	>0.05
Left upper lobar bronchus						
Cross-sectional area (mm²)	73.1±23.4	70.5±21.4	>0.05	54.9±20.3	47.9±15.1	<0.05*
Circumference (mm)	31.7±5.0	30.9±4.6	>0.05	27.7±5.1	25.9±4.6	<0.05*
Diameter (mm)	10.6±2.0	10.3±1.8	>0.05	8.8±1.7	8.3±1.6	<0.05*
Left lower lobar bronchus						
Cross-sectional area (mm²)	68.1±19.9	59.1±18.9	<0.01*	48.7±17.7	44.0±17.6	>0.05
Circumference (mm)	30.1±4.6	27.9±4.5	<0.01*	25.4±4.4	24.1±4.6	>0.05
Diameter (mm)	10.4±1.8	9.3±1.8	<0.001*	8.8±1.7	8.3±1.6	>0.05

** Significant at 0.05 level according to the independent samples t-test.*

In this study, the air inside the trachea was reconstructed. Lumen measurements of the trachea were performed, and the wall structure was not measured. Therefore, in cases with thickening and/or mucus accumulation in the airway wall, it is expected that the cross-sectional area, circumference, and diameter measurements measured in the study will narrow. The third level of the trachea in this study was similar to the level of the tracheal bifurcation in the study by Ünlü *et al*.[8] They reported that anteroposterior and transverse tracheal diameters also increased at the level of the tracheal bifurcation as the severity of the disease increased.[8] In the present research, no statistically significant results were identified at the third level of the trachea. It was found that the cross-sectional area and anteroposterior diameter measurements at the first level of the trachea were narrower in Grade 1, Grade 2, and Grade 3 female COVID-19 patients, and the circumference measurement was narrower in Grade 1 and Grade 2 female COVID-19 patients than in the control group.

Xu *et al*. defined the features of airway wall dimensions in COVID-19 subjects by utilising quantitative CT measurements to present pieces of evidence of airway wall thickening during early recovery in COVID-19 patients and revealed that airway wall thicknesses were significantly greater in COVID-19 patients during the disease course.[12] In the present study, since the lumen was measured when there was wall thickening or mucus accumulation in the bronchus, it is expected that the circumference, cross-sectional area, and diameter measurements will narrow. These measurements of the left upper lobar bronchus were found to be narrower in female COVID-19 patients in comparison with the control group. The same measurements of the right upper lobar bronchus and left lower lobar bronchus were narrower in male COVID-19 patients than in the control group.

Bronchial wall thickening in COVID-19 patients was found to be approximately 9-29%.[5,13-15] The studies found that the prevalence of bronchial wall thickening in COVID-19 patients with a severe clinical picture was higher in comparison with COVID-19 patients with a mild clinical picture.[16-18] The visual assessment of disease severity on chest CT may demonstrate the clinical classification (mild, moderate, severe) and prognosis of subjects with COVID-19 pneumonia.[3,14,17,19] Hence, in the current study, the lung involvement severity in COVID-19 patients was visually evaluated and graded. In this study, the cross-sectional area and diameter measurements of the right upper lobar bronchus decreased as the grade increased. However, the circumference measurement of the right upper lobar bronchus and the cross-sectional area and circumference of the left lower lobar bronchus were found to be narrower in Grade 1, Grade 2, and Grade 3 COVID-19 patients compared to the control group. The diameter measurements of the left lower lobar bronchus were significantly narrower in Grade 2 and Grade 3 COVID-19 patients. The cross-sectional area, circumference, and diameter measurements of the middle lobar bronchus were observed to be narrower in Grade 3 COVID-19 patients.

The airway wall is not primarily targeted in the COVID-19 lung infection despite its thickening. The pulmonary interstitium is impacted the most in the lung during COVID-19 infection. *SARS-CoV-2* mainly damages the pulmonary vessels and leads to airway wall swelling. It eventually causes pulmonary interstitial and alveolar oedema.[12] Ninety-eight COVID-19 patients were enrolled in the research in which Zhou *et al*. examined CT images of subjects with COVID-19. The mean age of these subjects was found to be 53.3, which was close to the mean age of the COVID-19 patients in this research. The mean total lung severity score was 8.6, which was higher than in the present study (6.8). In their study, the researchers classified the lung involvement severity of COVID-19 patients, similar to this research. They reported that this radiological grading was significantly in line with the clinical classification, and therefore chest CT series could assist with classifying patients.[6]

Fifty COVID-19 patients were enrolled in the research in which Gu *et al*. examined CT images in COVID-19 subjects. The mean age of these patients was 44.84±16.26 years. The mean total lung severity score was 6.61±4.40, which was very close to that in the present study (6.8±4.8). They reported that this score was significantly correlated with age, and therefore, older people might be more prone to have greater pulmonary involvement.[20] In this study, there was an increase in the total lung severity score with increasing age in COVID-19 patients.

The present research has a few limitations. First of all, the study group included only adult patients. Thus, additional studies with child patients are needed. Secondly, in this study, COVID-19 patients mostly had mild and moderate lung involvement (88.6%). The number of patients with severe lung involvement was less (11.4%). The effect of severe lung involvement on the trachea and bronchus can be better evaluated with studies that include a large number of patients with severe lung involvement.

CONCLUSION

Although mostly independent of the grade increase, narrowing of the trachea, main bronchus, and lobar bronchus was observed in COVID-19 patients compared to the control group in the acute period. Further research is required for the purpose of determining whether the mentioned narrowings are permanent.

ETHICAL APPROVAL:
The Non-Interventional Clinical Research Ethics Committee of Lokman Hekim University granted the ethics committee approval for the current research (Decision No. 2021/028 dated: March 10, 2021).

COMPETING INTEREST:
No competing interest was declared by the authors.

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AUTHORS' CONTRIBUTION:
AE: Conception and designing of the study, creating the study plan, data processing, and writing the manuscript.
ZKC, TVP: Design of the work and critical revision of the manuscript.
SA: The acquisition, analysis, and interpretation of data for the work.
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REFERENCES

1. Bertolini M, Brambilla A, Dallasta S, Colombo G. High-quality chest CT segmentation to assess the impact of COVID-19 disease. *Int J Comput Assist Radiol Surg* 2021; **16(10)**: 1737-47. doi:10.1007/s11548-021-02466-2.
2. Bernheim A, Mei X, Huang M, Yang Y, Fayad ZA, Zhang N, *et al*. Chest CT findings in coronavirus Disease-19 (COVID-19): Relationship to duration of infection. *Radiology* 2020; **295(3)**:200463. doi:10.1148/radiol.2020200463.
3. Ufuk F, Savas R. Chest CT features of the novel coronavirus disease (COVID-19). *Turk J Med Sci* 2020; **50(4)**:664-78. doi:10.3906/sag-2004-331.
4. Hansell DM, Bankier AA, MacMahon H, McLoud TC, Müller NL, Remy J. Fleischner Society: glossary of terms for thoracic imaging. *Radiology* 2008; **246(3)**:697-722. doi:10. 1148/radiol.2462070712.
5. Zhao W, Zhong Z, Xie X, Yu Q, Liu J. Relation between chest CT findings and clinical conditions of coronavirus disease (COVID-19) pneumonia: A multicentre study. *AJR Am J Roentgenol* 2020; **214(5)**:1072-7. doi: 10.2214/AJR.20. 22976.
6. Zhou H, Xu K, Shen Y, Fang Q, Chen F, Sheng J, *et al*. Coronavirus disease 2019 (COVID-19): Chest CT characteristics benefit to early disease recognition and patient classification-a single center experience. *Ann Transl Med* 2020; **8(11)**:679. doi:10.21037/atm-20-2119a.
7. Martines RB, Ritter JM, Matkovic E, Gary J, Bollweg BC, Bullock H, *et al*. Pathology and pathogenesis of *SARS-CoV-2* associated with fatal coronavirus disease, United States. *Emerg Infect Dis* 2020; **26(9)**:2005-15. doi:10.3201/eid 2609.202095.
8. Ünlü S, Ilgar M, Akçiçek M. The evaluation of the trachea as a new parameter in determining the prognosis of COVID-19: First pilot study. *Eur Rev Med Pharmacol Sci* 2021; **25(14)**:4835-40. doi:10.26355/eurrev_202107_ 26397.
9. Zhou P, Yang XL, Wang XG, Hu B, Zhang L, Zhang W, *et al*. A pneumonia outbreak associated with a new coronavirus of probable bat origin. *Nature* 2020; **579(7798)**:270-3. doi: 10.1038/s41586-020-2012-7.
10. To KF, Lo AW. Exploring the pathogenesis of severe acute respiratory syndrome (SARS): the tissue distribution of the coronavirus (SARS-CoV) and its putative receptor, angiotensin-converting enzyme 2 (ACE2*). J Pathol* 2004; **203(3)**: 740-3. doi:10.1002/path.1597.

11. Oliver CM, Campbell M, Dulan O, Hamilton N, Birchall M. Appearance and management of COVID-19 laryngo tracheitis: two case reports. *F1000Res* 2020; **9**:310. doi:10.12688/f1000research.23204.2.

12. Xu J, Liang Z, Jian W, Li J, Tang G, Mo X, *et al*. Changes of quantitative CT-based airway wall dimensions in patients with COVID-19 during early recovery. *J Thorac Dis* 2021; **13(3)**:1517-30. doi: 10.21037/jtd-20-2790.

13. Bai HX, Hsieh B, Xiong Z, Halsey K, Choi JW, Tran TML, *et al*. Performance of radiologists in differentiating COVID-19 from Non-COVID-19 viral pneumonia at chest CT. *Radiology* 2020; **296(2)**:E46-54. doi: 10.1148/radiol.2020200823.

14. Li K, Wu J, Wu F, Guo D, Chen L, Fang Z, *et al*. The clinical and chest CT features associated with severe and critical COVID-19 pneumonia. *Invest Radiol* 2020; **55(6)**:327-31. doi:10.1097/rli.0000000000000672.

15. Parry AH, Wani HA, Choh NA, Shah NN, Jehangir M. Spectrum of chest CT manifestations of coronavirus disease (COVID-19): A pictorial essay. *Indian J Radiol Imaging* 2021; **31**:S170-7. doi: 10.4103/ijri.IJRI_303_20.

16. Hashemi-Madani N, Emami Z, Janani L, Khamseh ME. Typical chest CT features can determine the severity of COVID-19: A systematic review and meta-analysis of the observational studies. *Clin Imaging* 2021; **74**:67-75. doi: 10.1016/j.clinimag.2020.12.037.

17. Li K, Fang Y, Li W, Pan C, Qin P, Zhong Y, *et al*. CT image visual quantitative evaluation and clinical classification of coronavirus disease (COVID-19). *Eur Radiol* 2020; **30(8)**:4407-16. doi:10.1007/s00330-020-06817-6.

18. Wu J, Wu X, Zeng W, Guo D, Fang Z, Chen L, *et al*. Chest CT findings in patients with coronavirus disease 2019 and its relationship with clinical features. *Invest Radiol* 2020; **55(5)**:257-61. doi:10.1097/rli.0000000000000670.

19. Chung M, Bernheim A, Mei X, Zhang N, Huang M, Zeng X, *et al*. CT imaging features of 2019 novel coronavirus (2019-nCoV). *Radiology* 2020; **295(1)**:202-7. doi:10.1148/ radiol. 2020200230.

20. Gu Q, Ouyang X, Xie A, Tan X, Liu J, Huang F, *et al*. A retrospective study of the initial chest CT imaging findings in 50 COVID-19 patients stratified by gender and age. *J Xray Sci Technol* 2020; **28(5)**:875-84. doi: 10.3233/XST- 200709.

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