ABDOMINAL IMAGING

ORIGINAL ARTICLE

Evaluation of abdominal computed tomography findings in patients with COVID-19: a multicenter study

Mehmet Ruhi Onur ⓘ, Yakup Özbay ⓘ, İlkay İdilman ⓘ, Ali Devrim Karaosmanoğlu ⓘ, Selma Uysal Ramadan ⓘ,
Funda Barlık ⓘ, Sonay Aydın ⓘ, Hüseyin Odaman ⓘ, Canan Altay ⓘ, Işıl Başara Akın ⓘ, Oğuz Dicle ⓘ,
Özgür Appak ⓘ, Başak Gülpınar ⓘ, Ayşe Erden ⓘ, Sezer Kula ⓘ, Ayşegül Gürsoy Çoruh ⓘ, Diğdem Kuru Öz ⓘ,
Melahat Kul ⓘ, Çağlar Uzun ⓘ, Erdal Karavaş ⓘ, Akın Levent ⓘ, Hakan Artaş ⓘ, Hasan Eryeşil ⓘ, Onur Solmaz ⓘ,
Türkkan Öztürk Kaygusuz ⓘ, Mustafa Faraşat ⓘ, Ahmet Burak Kale ⓘ, Fatih Düzgün ⓘ, Gökhan Pekindil ⓘ,
F. Demir Apaydın ⓘ, Meltem Nass Duce ⓘ, Yüksel Balcı ⓘ, Kaan Esen ⓘ, Ayşegül Sağır Kahraman ⓘ, Leyla Karaca ⓘ,
Zeynep Maraş Özdemir ⓘ, Bayram Kahraman ⓘ, Mesude Tosun ⓘ, Mehmet Selim Nural ⓘ, İlkay Çamlıdağ ⓘ,
Mustafa Arda Onar ⓘ, Kaan Ballı ⓘ, Ezgi Güler ⓘ, Mustafa Harman ⓘ, Nevra Zehra Elmas ⓘ, Cansu Öztürk ⓘ,
Özlem Güngör ⓘ, Duygu Herek ⓘ, Ahmet Baki Yağcı ⓘ, Cengiz Erol ⓘ, Mehmet Şeker ⓘ, İrem İşlek ⓘ, Yusuf Can ⓘ,
Serdar Aslan ⓘ, M. Yasemin Karadeniz Bilgili ⓘ, Alper Göncüoğlu ⓘ, Hatice Keleş ⓘ, Pelin Zeynep Bekin Sarıkaya ⓘ,
Barış Bakır ⓘ, Merve Gülbiz Dağoğlu Kartal ⓘ, Görkem Durak ⓘ, Gülşen Yücel Oğuzdoğan ⓘ, Fatih Alper ⓘ,
Ahmet Yalçın ⓘ, Safiye Gürel ⓘ, Bircan Alan ⓘ, Elif Gündoğdu ⓘ, Nevin Aydın ⓘ, Ayşegül Cansu ⓘ,
Ceyda Civan Kuş ⓘ, Elif Ofluoğlu Tuncer ⓘ, Ferhat Can Pişkin ⓘ, Hale Çolakoğlu Er ⓘ, Bumin Değirmenci ⓘ,
Mustafa Nasuh Özmen ⓘ, Mecit Kantarcı ⓘ, Muşturay Karçaaltıncaba ⓘ

From the Department of Radiology (M.R.O. ✉ ruhionur@yahoo.com, Y.Ö., İ.İ., A.D.K., M.N.Ö., M.K. ✉ musturayk@yahoo.com), Hacettepe University Faculty of Medicine, Ankara, Turkey;
Clinic of Radiology (S.U.R., C.Ö., Ö.G.), University of Health Sciences Turkey, Ankara Atatürk Sanatorium Training and Research Hospital, Ankara, Turkey; Department of Radiology (F.B., H.O.,
C.A., I.B.A., O.D., Dokuz Eylül University Faculty of Medicine, İzmir, Turkey; Department of Radiology (S.A., E.K., A.L., Me.K.), Binali Yıldırım University Faculty of Medicine, Erzincan, Turkey;
Department of Medical Microbiology (Ö.A.), Dokuz Eylül University Faculty of Medicine, İzmir, Turkey; Department of Radiology (B.G., A.E., S.K., A.G.Ç., D.K.Ö., Mel.K., Ç.U., Ankara University
Faculty of Medicine, Ankara, Turkey; Department of Radiology (H.A., H.E., O.S.), Fırat University Faculty of Medicine, Elazığ, Turkey; Department of Infectious Diseases and Clinical Microbiology
(T.Ö.K.), Fırat University Faculty of Medicine, Elazığ, Turkey; Department of Radiology (M.F., A.B.K., F.D., G.P.), Celal Bayar University Faculty of Medicine, Manisa, Turkey; Department of
Radiology (F.D.A., M.N.D., Y.B., K.E.), Mersin University Faculty of Medicine, Mersin, Turkey; Department of Radiology (A.S.K., L.K., Z.M.Ö., İnönü University Faculty of Medicine, Malatya, Turkey;
Clinic of Radiology (B.K.), Specialist Doctor Bayram Kahraman Radiology Clinic, Malatya, Turkey; Department of Radiology (M.T.), Kocaeli University Faculty of Medicine, Kocaeli, Turkey;
Department of Radiology (M.S.N., İ.Ç., M.A.O.), Ondokuz Mayıs University Faculty of Medicine, Samsun, Turkey; Department of Radiology (K.B., E.G., M.H., N.Z.E.), Ege University Faculty of
Medicine, İzmir, Turkey; Department of Radiology (D.H., A.B.Y.), Pamukkale University Faculty of Medicine, Denizli, Turkey; Department of Radiology (C.E., M.Ş., İ.İ., Y.C.), Medipol University
Faculty of Medicine, İstanbul, Turkey; Department of Radiology (Se.A.), Giresun University Faculty of Medicine, Giresun, Turkey; Department of Radiology (M.Y.K.B.), Lokman Hekim University
Faculty of Medicine, Ankara, Turkey; Department of Radiology (A.G., P.Z.B.S.), Kırıkkale University Faculty of Medicine, Kırıkkale, Turkey; Department of Internal Medicine (H.K.), Kırıkkale
University Faculty of Medicine, Kırıkkale, Turkey; Department of Radiology (B.B., M.G.D.K., G.D.), İstanbul University, İstanbul Faculty of Medicine, İstanbul, Turkey; Clinic of Radiology (G.Y.O.),
University of Health Sciences Turkey, Başakşehir Çam and Sakura City Hospital, İstanbul, Turkey; Department of Radiology (F.A., A.Y.), Atatürk University Faculty of Medicine, Erzurum, Turkey;
Department of Radiology (S.G., B.A.), Bolu Abant İzzet Baysal University Faculty of Medicine, Bolu, Turkey; Department of Radiology (E.G., N.A.), Eskişehir Osmangazi University Faculty of
Medicine, Eskişehir, Turkey; Department of Radiology (A.C.), Karadeniz Technical University Faculty of Medicine, Trabzon, Turkey; Clinic of Radiology (C.C.K.), Marmara University Training and
Research Hospital, İstanbul, Turkey; Clinic of Radiology (E.O.T.), University of Health Sciences Turkey, Sultan 2. Abdulhamid Han Training and Research Hospital, İstanbul, Turkey; Department
of Radiology (F.C.P.), Çukurova University Faculty of Medicine, Adana, Turkey; Department of Radiology (H.Ç.), Ufuk University Faculty of Medicine, Ankara, Turkey; Clinic of Radiology (B.D.),
Antalya ASV Life Hospital, Antalya, Turkey.

PURPOSE
To evaluate the frequency of abdominal computed tomography (CT) findings in patients with coronavirus disease-2019 (COVID-19) and interrogate the relationship between abdominal CT findings and patient demographic features, clinical findings, and laboratory test results as well as the CT atherosclerosis score in the abdominal aorta.

METHODS
This study was designed as a multicenter retrospective study. The abdominal CT findings of 1.181 patients with positive abdominal symptoms from 26 tertiary medical centers with a positive polymerase chain-reaction test for severe acute respiratory syndrome coronavirus 2 were reviewed. The frequency of ischemic and non-ischemic CT findings as well as the association between CT findings, clinical features, and abdominal aortic calcific atherosclerosis score (AA-CAS) were recorded.

RESULTS
Ischemic and non-ischemic abdominal CT findings were detected in 240 (20.3%) and 328 (27.7%) patients, respectively. In 147 patients (12.4%), intra-abdominal malignancy was present. The most frequent ischemic abdominal CT findings were bowel wall thickening (n = 120; 10.2%) and perivascular infiltration (n = 40; 3.4%). As for non-ischemic findings, colitis (n = 91; 7.7%) and small bowel inflammation (n = 73; 6.2%) constituted the most frequent disease processes. The duration of hospital stay was found to be higher in patients with abdominal CT findings than in patients without any positive findings (13.8 ± 13 vs. 10.4 ± 12.8 days, $P < 0.001$). The frequency of abdominal CT findings was significantly higher in patients who did not survive the infection than in patients who were discharged after recovery (41.7% vs. 27.4%, $P < 0.001$). Increased AA-CAS was found to be associated with a higher risk of ischemic conditions in abdominal CT examinations.

CONCLUSION
Abdominal symptoms in patients with COVID-19 are usually associated with positive CT findings. The presence of ischemic findings on CT correlates with poor COVID-19 outcomes. A high AA-CAS is associated with abdominal ischemic findings in patients with COVID-19.

KEYWORDS
COVID-19, abdomen, computed tomography, abdominal aorta, arteriosclerosis

Since the first appearance of severe acute respiratory syndrome-coronavirus 2 (SARS-CoV-2) toward the end of 2019, global scientific interest in the clinical progress and course of patients with this infection has grown rapidly. The disease is typically characterized by pneumonia and severe respiratory distress. Imaging features, both typical and atypical, of coronavirus disease-2019 (COVID-19) pneumonia have been described in detail in several papers.[1,2] Cough, shortness of breath, fever, myalgia, and generalized fatigue have been frequently observed as the dominant clinical features of infection.

However, with the relentless spread of the disease and rapid increase in the number of patients worldwide, the abdominal, cardiac, neurologic, and musculoskeletal symptoms of these patients have also become clinically recognized.[3-6] With all these newly detected symptoms, the medical community identified the multisystemic disease underlying the virus, even in the relatively early stages of the pandemic.

The multisystemic nature of the COVID-19 virus is mostly attributed to its ability to attach to angiotensin-converting enzyme 2 (ACE-2) receptors in the body. Since ACE-2 receptors are widely disseminated in the body, including in the lungs, vascular endothelium, small intestine, colon, spleen, liver, and kidney, the systemic dissemination of the virus appears to be inevitable.[7] The virus may exert both cytotoxic and thrombotic effects on the abdominal vascular endothelium, causing widespread vascular dysfunction in the abdomen. Thromboembolism in the abdominal aorta or its branches may occur as early as 12–13 days after the start of the infection.[8]

Since the start of the pandemic, the abdominal manifestations of COVID-19 have been described in detail in several excellent papers.[9-11] However, there is still a gap that needs to be investigated in assessing the relationship between abdominal imaging findings and disease outcomes. In this study,

we aimed to investigate the frequency of abdominal computed tomography (CT) findings in patients with symptomatic COVID-19 and outline the association between abdominal CT findings and patients' clinical progress and outcomes.

Methods

This multicenter retrospective study was conducted in compliance with the Health Insurance Portability and Accountability Act and the Declaration of Helsinki. Approvals were obtained from both the local institutional board and the board of the Ministry of Health. Informed consent was waived due to the retrospective nature of the study (Erzincan Binali Yildirim University Ethics Committee 04/01, Health Ministry of Turkey Ethics Committee 2021-02-23T11_43_57).

Patients: Cohort selection

After reviewing the electronic and written medical charts of the contributing centers, a total of 1.564 patients who had confirmed COVID-19 infection and abdominal symptoms and who had undergone abdominal CT between April and December 2020 were assessed as eligible for this study. The inclusion criteria of the study were as follows: adult patients (>18 years) with a positive real-time reverse transcriptase-polymerase chain-reaction (RT-PCR) test result using throat swabs

<div style="border:1px solid #000;">

Main points

- The coronavirus disease-2019 (COVID-19) virus may give rise to a wide variety of ischemic and non-ischemic abnormalities in the abdomen.

- Patients with COVID-19 and abdominal computed tomography (CT) findings had a longer hospital stay and higher mortality rate than patients without positive findings.

- The detection of positive abdominal CT findings reveals a positive correlation with extended hospital stay and increased mortality.

- Patients with an active COVID-19 infection and high abdominal aortic calcific atherosclerosis score appear to demonstrate more ischemic findings in CT.

</div>

for COVID-19 who had undergone abdominal CT studies for various clinical symptoms within 15 days following the positive PCR test. The exclusion criteria were as follows: patients who had undergone abdominal CT 15 days before or after the PCR test; patients who tested as COVID-19 (+) when they were hospitalized following an investigation into abdominal pathologies; patients with insufficient anamnesis and symptom history and with poor CT image quality; patients <18 years; and patients with no positive PCR test. In total, 1.181 adult patients from 26 tertiary medical centers were enrolled in this study (Figure 1).

Clinical data collection

Patient electronic medical records were used to obtain the following data: (1) demographic characteristics of patients (age, sex, smoking habit, and comorbidities); (2) clinical information including the date of the COVID-19 diagnosis; (3) abdominal symptoms including diarrhea, anorexia, nausea, vomiting, epigastric pain, upper gastrointestinal (GI) bleeding, (4) duration of hospital stay, and disease outcome; and (5) laboratory results [PCR and liver function tests such as aspartate transaminase (AST), alanine transaminase (ALT), indirect and direct bilirubin, and D-dimer values]. The COVID-19 period was assessed in terms of days in the hospital and disease outcome (recovery or death). Comorbidities were defined as diabetes mellitus (DM), hypertension (HT), heart failure (HF), chronic renal failure (CRF), and intra-abdominal malignancy.

Computed tomography image acquisition

Abdominal CT scans of patients were performed without (n = 436, 36.9%) and with (n = 745, 63.1%) intravenous (IV) contrast administration. Contrast-enhanced CT studies were multiphasic in 116 (9.3%) patients. The scanned area was between the dome of the diaphragm and the ischial tuberosity. Contrast-enhanced single-phase CT scans were obtained through the acquisition of abdominopelvic images in the portal venous phase after an IV injection of 80–120 mL of iodinated contrast media (300–350 mg of iodine per mL) with a flow rate of 3–5 mL/sec. The IV contrast injection was followed by a 40 mL saline chaser at the same injection rate as the IV contrast. All CT studies were conducted using various multidetector CT scanners from different vendors (16–392 detector rows). The CT acquisition parameters varied within a narrow range in accordance with the local institutional protocols: tube voltage: 100–130 kV, tube current: automatic tube current modulation used, collimation thickness: 0.5–2 mm, tube rotation time: 0.5–1 s. Reconstructions were applied to obtain axial images with a section thickness of 2–5 mm and coronal and sagittal images with a section thickness of 3 mm. Multiphasic CT images were obtained using the same CT acquisition parameters as well as an unenhanced phase, and contrast-enhanced images were obtained at arterial and venous phases.

Computed tomography data collection and image analysis

All the evaluated abdominal CT scans were performed within 15 days of confirmation of COVID-19 and were interpreted by radiologists experienced in abdominal radiology. Initially, the dates of the CT scans and information about the IV contrast administration as well as the CT study phases were recorded. Abdominal CT scans were reviewed to detect the presence and frequency of positive ischemic and non-ischemic findings. Positive findings for an ischemic abdominal process were defined as follows: acute mesenteric artery embolism, acute thrombosis of the superior mesenteric vein, non-occlusive mesenteric ischemia (NOMI), perivascular infiltration, bowel wall thickening (single-wall thickness >3 mm in distended loops and >5 mm in collapsed loops), pneumatosis intestinalis, bowel wall necrosis, gas in the portal venous system, hollow viscus perforation, and renal ischemia.

Non-ischemic abdominal CT findings included small and large bowel inflammation, acute pyelonephritis, acute cholecystitis, acute pancreatitis, acute diverticulitis, acute appendicitis, bowel obstruction, and intra-abdominal malignancy.

To investigate the relationship between the severity of atherosclerotic changes in the abdominal aorta and abdominal CT findings, the atherosclerosis score of the abdominal aorta was determined through a quantitative assessment of calcific atheroma plaques in the abdominal aorta. The final scores were designated as the abdominal aortic calcific
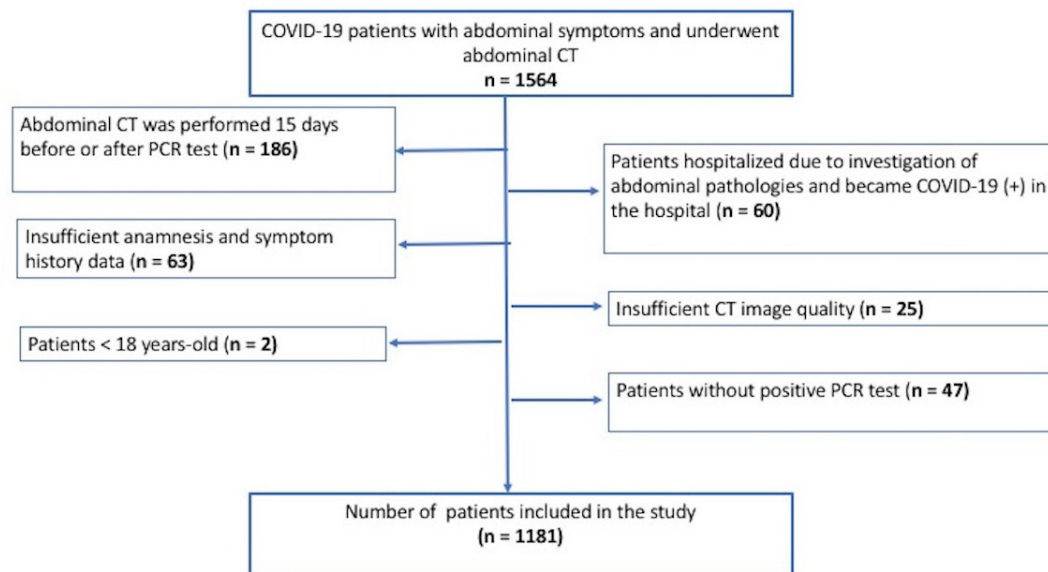

Figure 1. Flowchart of patient selection for the study cohorts. CT, computed tomography; COVID-19, coronavirus disease-2019; PCR, polymerase chain-reaction.

atherosclerosis score (AA-CAS). The AA-CAS was calculated according to a method described in previous reports (Figure 2).[12] The measurements were taken from the aortic wall at a level between the L1 and L4 vertebral bodies. On the sagittal CT images, the affected abdominal aorta length with reciprocal vertebra was scored between 0 and 3 as 0 (no calcification), 1 (1/3 of vertebral length affected), 2 (2/3 of vertebral length affected), and 3 (whole vertebral length affected). An axial CT image of the abdominal aorta at each vertebral level was divided into four quadrants. The total area of the abdominal aorta circle affected by calcific plaques was classified as 1, 2, 3, and 4. For each level, a single-level score was determined by multiplying the scores measured in axial and sagittal image planes. The AA-CAS for each vertebral level ranged from 0 to 12, with a minimum of 0 and a maximum score of 48. The final AA-CAS was concluded as the sum of the AA-CAS from each lumbar vertebral level.

Statistical analysis

All study data were collected from the contributing centers and combined into a single data sheet. Categorical data were presented as numbers (percentages), with continuous variables with normal distribution expressed as mean ± standard deviation and continuous variables with non-normal distribution as median and 95% confidence interval (95% CI). Categorical data were compared using Pearson's chi-square test or Fisher's exact test, and continuous variables were compared using the Student's t-test or Mann–Whitney U test, depending on the distribution of data. A two-tailed P value <0.05 was considered statistically significant. The significance level was established as $\alpha = 0.05$. All statistical analyses were performed using SPSS v22.0 software.

Results

Patient characteristics

The study included 1.181 patients (male/female: 632/549) with a mean age of 61.6 ± 17.4 years, ranging from 18 to 97 years. Of all the patients, 274 (23.2%) were smokers, and 597 (50.5%) were non-smokers. Smoking history was obtained from 310 (26.3%) patients. The most common comorbidities of patients were as follows: HT (n = 483, 40.89%), DM (n = 338, 28.6%), HF (n = 129, 10.92%), CRF (n = 78, 6.6%), a combination of comorbidities including DM, HT, HF, and CRF (n = 306, 25.91%), and intra-abdominal malignancy (n = 147, 12.4%). The most frequent symptoms were as follows: epigastric pain (33.3%), nausea (31.2%), vomiting (23.8%), diarrhea (11.9%), and upper GI bleeding (2.6%). The median duration of hospital stay was 8 days (0–142 days). The median and 95% CI of the median for AST, ALT, D-dimer, and the direct and indirect bilirubin levels of the cohort was 30 U/L (29–31), 24 U/L (22–25), 1.03 (0.96–1.10), 0.21 mg/dL (0.20–0.23), and 0.38 mg/dl (0.36–0.40), respectively. A total of 874 patients (74%) were discharged following recovery, whereas 268 patients (22.7%) died secondary to COVID-19 infection. The disease outcome could not be determined from electronic medical charts in 39 (3.3%) patients.

Computed tomography findings

The ischemic and non-ischemic abdominal CT findings detected after a review of CT scans are summarized in Table 1 (Figure 3). The frequency of overall ischemic and non-ischemic CT findings was 20.3% (n = 240) and 27.7% (n = 328), respectively. The most frequent ischemic abdominal CT findings were bowel wall thickening (n = 120, 10.2%) (Figure 4) and perivascular infiltration (n = 40, 3.4%) (Figure 5), whereas the most frequent non-ischemic abdominal CT findings were large bowel inflammation, with a frequency of 7.7% (n = 91), and small bowel inflammation, with a frequency of 6.2% (n =
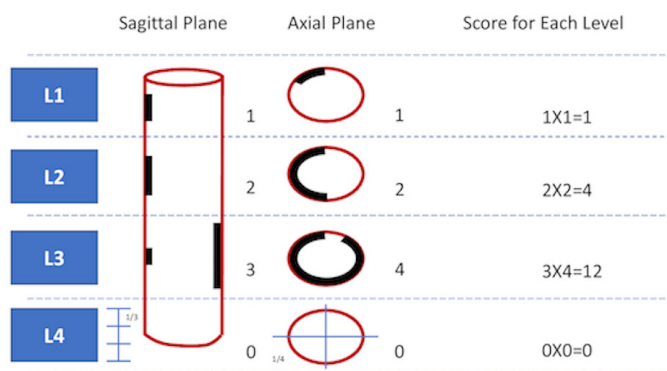

Figure 2. Abdominal aorta calcification score measurement method in the abdominal aorta.

Table 1. Ischemic and non-ischemic abdominal computed tomography findings in patients with COVID-19

Ischemic abdominal CT findings	n (%)	Non-ischemic abdominal CT findings	n (%)
Acute superior mesenteric artery embolism	10 (0.8)	Small bowel inflammation	73 (6.2)
Acute mesenteric vein thrombosis	6 (0.5)	Large bowel inflammation	91 (7.7)
NOMI	8 (0.7)	Intestinal obstruction	42 (3.5)
Bowel wall thickening	120 (10.2)	Acute cholecystitis	36 (3.04)
Perivascular infiltration	40 (3.4)	Acute pancreatitis	38 (3.21)
Pneumatosis intestinalis	12 (1)	Acute diverticulitis	8 (0.67)
Portal venous gas	9 (0.8)	Acute appendicitis	18 (1.5)
Intestinal necrosis	8 (0.7)	Acute pyelonephritis	22 (1.9)
Hollow viscus perforation	17 (1.4)	Intra-abdominal malignancy	147 (12.4)
Renal ischemia	10 (0.8)	-	-
Total	240	-	475

NOMI, non-occlusive mesenteric ischemia; CT, computed tomography; COVID-19, coronavirus disease-2019.

73). The mean AA-CAS was calculated as 10.6 ± 12.1 (ranging from 0 to 48).

No significant difference in sex distribution was detected in relation to the presence of abdominal CT findings and AA-CAS.

Overall abdominal CT findings was not significantly different between smokers and non-smokers ($P = 0.49$). The most common underlying comorbidity related to positive abdominal CT findings was HT (40.89%), and a significant association was found between the presenting symptoms of diarrhea, anorexia, nausea, vomiting, epigastric pain, and upper GI bleeding and the presence of abdominal CT findings. The associations between each abdominal symptom and the presence of abdominal CT findings are summarized in Table 2. A significant association was identified between all the presenting symptoms and the presence of abdominal CT findings. The investigation into the relationship between abdominal symptoms and ischemic CT findings revealed that patients with diarrhea ($P = 0.001$) and nausea ($P = 0.027$) had significantly greater bowel wall thickening than patients without these symptoms. Mesenteric vein thrombosis $P = 0.031$) (Figure 6), perivascular infiltration ($P = 0.008$), bowel wall thickening ($P < 0.001$), pneumatosis intestinalis ($P = 0.002$), and portal venous gas ($P < 0.001$) were found to be significantly more frequent in patients with anorexia, and patients with vomiting were significantly more prone to present with the ischemic findings of bowel wall thickening ($P = 0.010$), portal venous gas ($P = 0.025$), and renal ischemia ($P = 0.008$)

Figure 3. Axial unenhanced computed tomography image demonstrating a diffusely swollen pancreas and peripancreatic fat inflammation (arrows) consistent with edematous pancreatitis in a 65-year-old male patient with coronavirus disease-2019 who presented with abdominal pain.
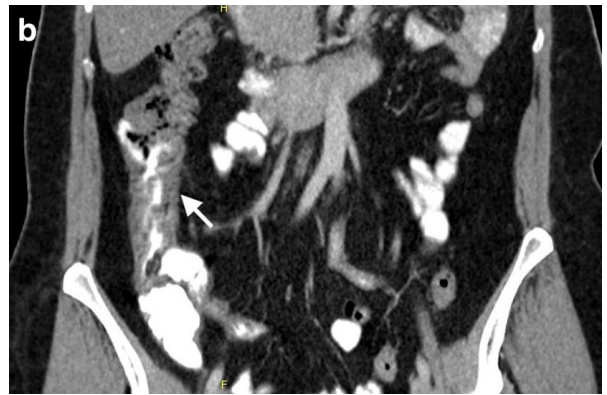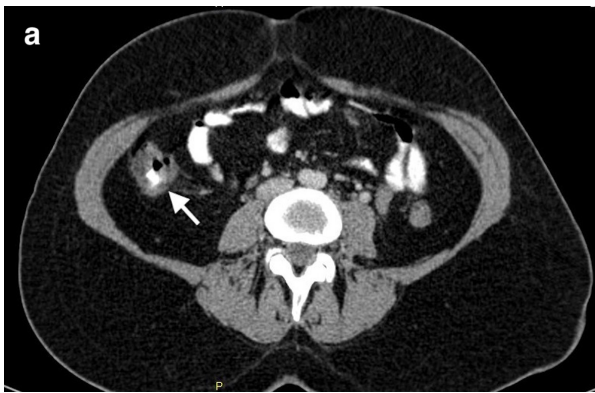
Figure 4. A 39-year-old woman with coronavirus disease-2019 presented with abdominal pain. Axial (a) and coronal (b) computed tomography images demonstrating the thickening of the ascending colon wall (arrows).
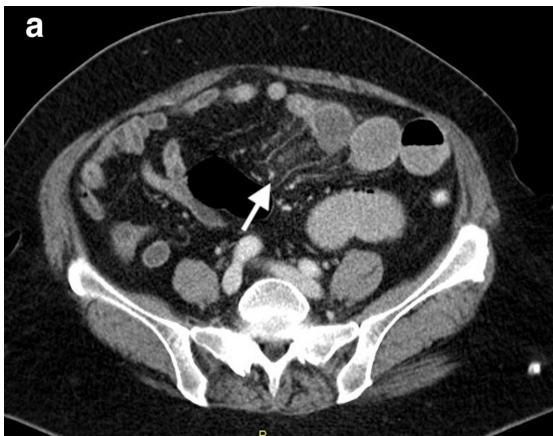

Figure 5. Axial (a) and coronal (b) contrast-enhanced computed tomography images of a 70-year-old female patient with coronavirus disease-2019 revealing perivascular infiltration, mesenteric stranding (arrows), and bowel dilatation, which indicates bowel ischemia. The patient underwent segmental bowel resection surgery because of the progressive deterioration in her clinical status.

Table 2. Association between abdominal symptoms and abdominal computed tomography findings of patients

Symptoms	Presence of abdominal CT finding n (%)	P
Diarrhea		
(+)	54/131 (41.2)	0.005
(−)	306/1.050 (29.1)	
Anorexia		
(+)	96/192 (50)	<0.001
(−)	264/989 (26.7)	
Nausea		
(+)	145/368 (39.4)	<0.001
(−)	215/813 (26.4)	
Vomiting		
(+)	120/281 (42.7)	<0.001
(−)	240/900 (26.7)	
Epigastric pain		
(+)	174/393 (44.3)	<0.001
(−)	186/788 (23.6)	
Upper GI bleeding		
(+)	17/31 (54.8)	0.003
(−)	343/1.150 (29.8)	

CT, computed tomography; GI, gastrointestinal.
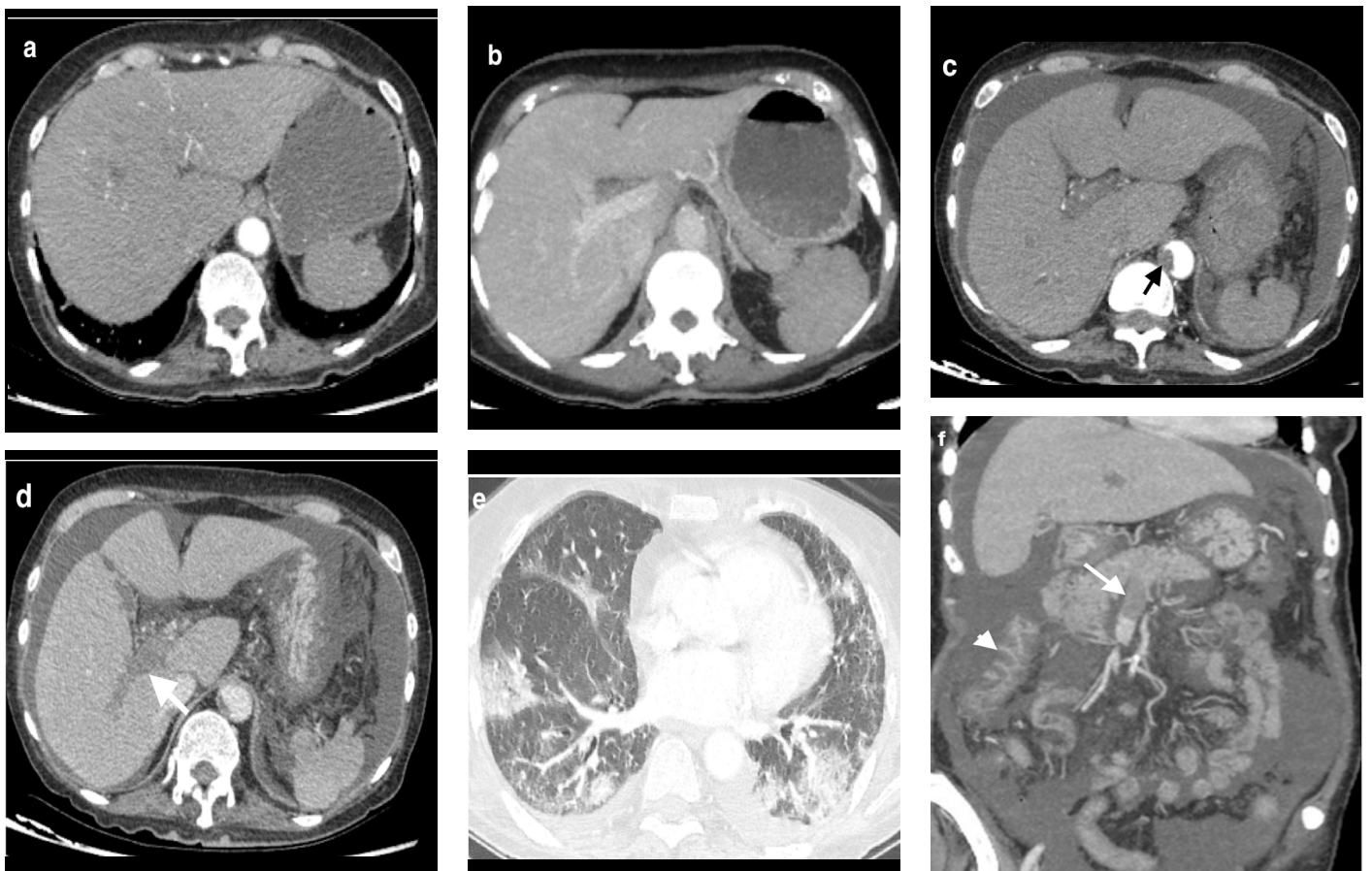
Figure 6. Acute superior mesenteric vein thrombosis. A 74-year-old woman with acute myeloid leukemia who presented with shortness of breath, abdominal pain, and diarrhea was diagnosed with coronavirus disease-2019. Axial contrast-enhanced abdominal computed tomography (CT) images **(a, b)** obtained 1 month before hospital admission reveal patent abdominal aorta and right portal vein. Axial arterial phase contrast-enhanced CT image obtained on hospital admission **(c)** demonstrating an acute thrombus in the abdominal aorta (arrow). Axial portal venous phase contrast-enhanced CT image **(d)** reveals an acute thrombus in the right portal vein (arrow). Axial chest CT image **(e)** demonstrating bilateral ground-glass opacities in both lungs. Coronal-reformatted abdominal CT image **(f)** showing an acute thrombus in the superior mesenteric vein (arrow). Note the bowel wall thickening of the ascending colon (arrowhead) and ascites.
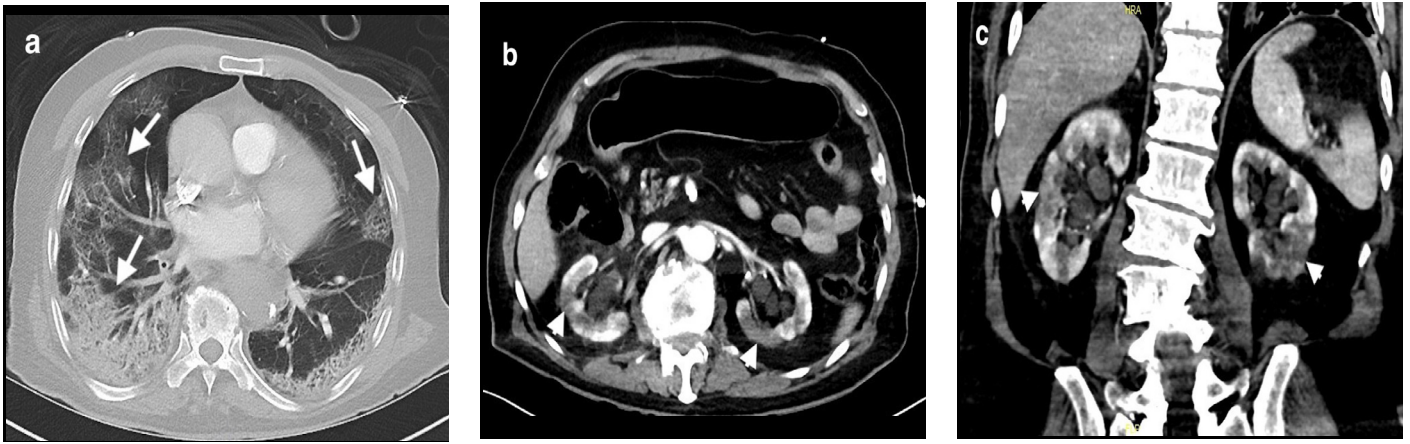
Figure 7. Renal infarct. (a) Axial chest computed tomography (CT) image showing bilateral ground-glass density and consolidations (arrows) in the peripheral portions of the lungs. Axial (b) and coronal (c) CT images reveal focal unenhanced areas (arrowheads) in the renal parenchyma, representing renal infarcts.
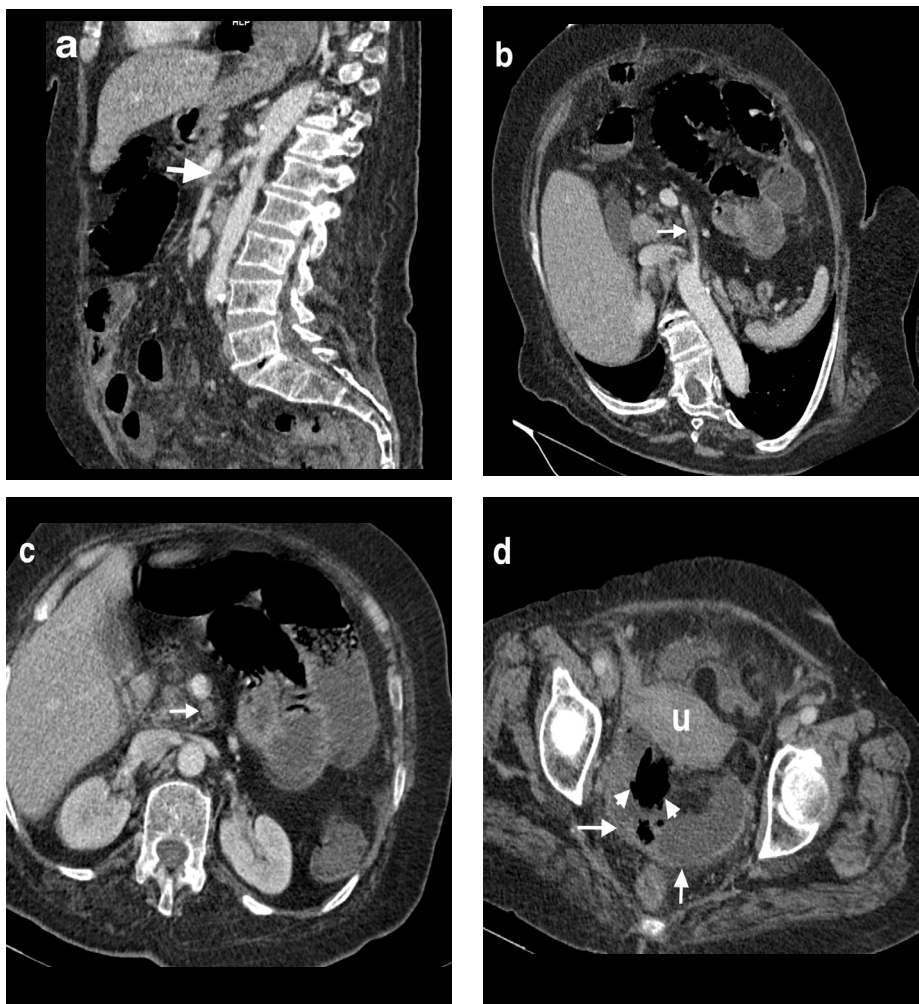
Figure 8. Acute superior mesenteric artery embolism. Sagittal **(a)**, oblique reformatted **(b)**, and axial **(c)** computed tomography (CT) images of a 61-year-old woman with sudden onset abdominal pain 6 days after the diagnosis of coronavirus disease-2019, revealing a hypodense filling defect (arrows) in the superior mesenteric artery lumen. Axial CT image **(d)** of the same patient at the pelvic level revealing hypo-enhancing segments of the ileum wall (arrows) and free intra-abdominal gas (arrowheads) behind the uterus (u), suggesting bowel wall ischemia and resultant perforation.

(Figure 7). Epigastric pain was significantly related to perivascular infiltration ($P = 0.001$), bowel wall thickening ($P < 0.001$), pneumatosis intestinalis ($P = 0.012$), portal venous gas ($P < 0.001$), hollow viscus perforation ($P = 0.024$), and renal ischemia ($P = 0.005$). Upper GI bleeding was found to be significantly related to perivascular infiltration ($P = 0.003$).

The association between the laboratory test results and abdominal CT findings is summarized in Supplementary Table 1. Liver function tests and D-dimer values were increased synchronously only in patients with acute mesenteric artery embolism (Figure 8), and D-dimer values were significantly increased in patients with the ischemic CT findings of perivascular infiltration, pneumatosis intestinalis, and bowel wall necrosis and non-ischemic CT findings of acute pancreatitis, diverticulitis, and appendicitis. No specific laboratory test parameters changed significantly with the ischemic CT findings.

The median and 95% CI of the median AA-CAS values in all patients was 5,[4-6] and AA-CAS were not significantly different between sexes ($P = 0.399$). However, not surprisingly, smokers had a significantly higher AA-CAS than non-smokers [11 (1-22) vs. 4 (0-15), $P < 0.001$]. The AA-CAS was significantly higher in patients with ischemic abdominal CT findings (n = 143) than in those with non-ischemic abdominal CT findings (n = 218) [6 (0–26) vs. 4 (0–16), $P = 0.011$]. The association between the AA-CAS and ischemic abdominal CT findings is summarized in Table 3. The AA-CAS were significantly higher in patients with pneumatosis intestinalis, bowel wall necrosis, portal venous gas, acute cholecystitis, and acute appendicitis. However, the reliability of the statistical tests investigating the association between the AA-CAS and these subgroups was not high because of the low

number of patients in the subgroups, with the exception of intra-abdominal malignancy.

An association was detected between the presence of abdominal CT findings and COVID-19 outcomes. The duration of hospital stay was higher in patients with abdominal CT findings than in those without any positive findings (13.8 ± 13 vs. 10.4 ± 12.8 days, $P < 0.001$). The frequency of abdominal CT findings was significantly higher in patients who could not survive the infection than in patients discharged after recovery (41.7% vs. 27.4%, $P < 0.001$). Patients with NOMI, perivascular infiltration, bowel wall thickening, pneumatosis intestinalis, bowel wall necrosis, portal venous gas, renal ischemia, small bowel inflammation, colitis, acute appendicitis, and intra-abdominal malignancy had a significantly higher death rate than those without these findings (Table 4).

Discussion

This multicenter study revealed that a wide range of abdominal CT findings, including ischemic and non-ischemic abnormalities, may be encountered in patients with COVID-19. The most common underlying comorbidity related to positive abdominal CT findings was HT. Patients with COVID-19 with diarrhea, anorexia, nausea, vomiting, epigastric pain, and upper GI bleeding had high positive abdominal CT finding rates. The presence of abdominal CT findings was related to poor patient outcomes with an increased duration of hospital stay and higher mortality rate. Patients with a high AA-CAS had significantly greater ischemic abdominal CT findings than patients with a low AA-CAS.

The involvement of abdominal viscera in COVID-19 has been reported previously. The presence of abdominal symptoms in COVID-19 is not unexpected because SARS-CoV-2 ribonucleic acid has been isolated in the duodenal wall and feces of patients as well as in wastewater.[13] The fecal positivity rate in COVID-19 infection is reported to be between 40% and 48%, whereas meta-analyses have demonstrated a prevalence of GI symptoms of 4%–12%.[14,15] In addition to intestines, abdominal viscera also seem to be affected by COVID-19 because of the high surface expression of the ACE-2 receptor in vasculature. Besides GI findings, biliary tract, abdominal vasculature, and pancreas involvement with related radiological abnormalities have been reported.[8,16-18]

In our study, we evaluated the abdominal CT findings as ischemic and non-ischemic CT findings. The high frequency of ischemic abdominal findings (20.3%) in this study was attributed to the abdominal vascular involvement of COVID-19. Perivascular infiltration on CT represents the previously reported perivascular inflammation and perivascular infiltration of T-cells that contribute to endothelial damage.[9,19] In our study, the most common ischemic abdominal CT findings in patients with COVID-19 were bowel wall thickening (10.2%) and perivascular infiltration (3.4%), representing well-known non-specific CT findings in ischemic bowel disease. Bowel wall thickening has been highlighted as the most common CT finding in patients with COVID-19 with acute abdominal pain.[20] Perivascular infiltration, the second most commonly detected abdominal CT finding in our study, may represent endothelial damage in COVID-19 resulting from direct viral effects as well as perivascular inflammation.[21] Due to its common presence in patients with COVID-19 and abdominal symptoms in our study, perivascular infiltration should alert radiologists to ischemic bowel disease when reviewing abdominal CT scans in these patients. In the non-ischemic group, large bowel inflammation (7.7%) and small bowel inflammation (6.2%) constituted the most frequent imaging finding except intra-abdominal malignancy. These results are consistent with previous reports that noted bowel wall thickening as the most common CT feature in patients with COVID-19 presenting with abdominal pain.[1,2] Kidneys are the second most commonly targeted abdominal organ regarding ischemic events in COVID-19. Endothelial damage and the resulting occlusion in the microvasculature of the renal parenchyma have been demonstrated in the postmortem renal histopathologic analysis of patients who died from COVID-19.[22] Renal parenchymal perfusion defects have also been identified in dual-energy CT scans.[23] For all these reasons, we paid special attention to kidneys when evaluating ischemic abdominal abnormalities. In addition to other examinations, we investigated the association between comorbidities and abdominal CT findings. Although it was impossible to verify a direct association between comorbidity subgroups and the overall CT findings, we noticed that HT was the comorbidity most commonly associated with abdominal CT findings. This finding may be related to HT being the most frequently observed comorbid disease since the beginning of the pandemic.

The most frequent respiratory symptoms in patients with COVID-19 are sore throat, shortness of breath, and cough. However, medical practitioners must also be vigilant to check for symptoms related to other organs. The presence of these symptoms in patients with COVID-19 should alert clinicians to the potential involvement of abdominal organs. Each abdominal symptom included in our study was found to be significantly associated with the presence of abdominal CT findings, which emphasizes the importance of increased vigilance toward the abdominal symptoms of COVID-19.

In our study, we also investigated the association between each abdominal symptom and the CT findings. The results revealed that abdominal symptoms may be associated with a wide range of CT findings, limiting the prediction of specific abdominal abnormalities to abdominal symptoms only. Although an association between abdominal symptoms and the presence of abdominal CT findings was found in our study, previous reports noted that fluid-filled colon and bowel wall thickening might be detected on CT in two-thirds of patients with COVID-19 who reported no abdominal symptoms.[7] Other reports have highlighted the absence of any CT findings in patients with COVID-19 with acute abdominal pain.[24] The discrepancy between our results and those of some other reports may be due to a lack of standardization in the severity of symptoms.

When reviewing the CT images of patients, laboratory test results should be considered. Therefore, in our study, we investigated the laboratory test results of patients and their potential association with the abdominal CT findings. Elevated liver function tests are a common finding in the course of COVID-19.[8,25,26] In this study, no specific laboratory test was found to predict ischemic abdominal CT findings. Acute mesenteric artery embolism was the only clinical entity in patients with COVID-19 that was synchronously elevated by liver enzymes. The D-dimer value, which was identified in previous reports as a helpful indicator for ischemic and thromboembolic changes in patients with COVID-19, was not detected as a specific laboratory test for ischemic abdominal changes in our study because a significant increase in D-dimer values was detected in both ischemic (perivascular infiltration, pneumatosis intestinalis, and bowel wall necrosis) and non-ischemic CT findings, including acute pancreatitis, diverticulitis, and appendicitis.[7]

Table 3. Association between abdominal aorta calcification score and abdominal computed tomography finding subgroups

Abdominal CT findings	Median AA-CAS (95% CI for median)	P
Acute mesenteric artery embolism (+) (−)	22 (0–41.7) 5 (4–6)	0.153
Acute mesenteric vein thrombosis (+) (−)	0 (0–29.4) 5 (4–6)	0.109
Non-occlusive mesenteric ischemia (+) (−)	6.5 (3–11.5) 4 (4–6)	0.505
Perivascular infiltration (+) (−)	4.5 (2.3–10) 5 (4–6)	0.858
Bowel wall thickening (+) (−)	5 (3–10) 5 (4–6)	0.506
Pneumatosis intestinalis (+) (−)	32 (9.3–44.4) 5 (4–6)	<0.001
Bowel wall necrosis (+) (−)	20 (4–45.5) 5 (4–6)	0.013
Portal venous gas (+) (−)	31 (13.3–45.8) 5 (4–6)	<0.001
Perforation (+) (−)	3 (0–19.8) 5 (4–7)	0.629
Renal ischemia (+) (−)	14.5 (0.95–45.1) 4 (4–6)	0.099
Small bowel inflammation (+) (−)	4 (2–8.3) 5 (5–6.1)	0.568
Colitis (+) (−)	6 (3–10) 5 (4–6)	0.726
Acute pyelonephritis (+) (−)	16.5 (0–32.1) 5 (4–6)	0.160
Acute cholecystitis (+) (−)	13 (8.6–19.3) 5 (3–6)	0.013
Acute pancreatitis (+) (−)	8.5 (1-14) 5 (4–6)	0.869
Acute diverticulitis (+) (−)	9 (0–23.9) 5 (4–6)	0.941
Acute appendicitis (+) (−)	0 (0–1) 5 (5–7)	<0.001
Bowel obstruction (+) (−)	5 (3–10) 5 (4–6)	0.756
Intra-abdominal malignancy (+) (−)	4 (2.1–6) 5 (4–7)	0.079

AA-CAS, abdominal aorta calcification score; CT, computed tomography; CI, confidence interval.

Table 4. Association between abdominal computed tomography findings and outcomes of patients with COVID-19

Abdominal CT finding	Incidence of death n (%)	P
Acute mesenteric artery embolism		
(+)	4/10 (40)	0.305**
(−)	221/985 (22.4)	
Acute mesenteric vein thrombosis		
(+)	1/6 (16.7)	1**
(−)	223/1.014 (22)	
Non-occlusive mesenteric ischemia		
(+)	16/38 (42.1)	0.030*
(−)	233/1.063 (21.9)	
Perivascular infiltration		
(+)	19/40 (47.5)	0.007*
(−)	242/1.087 (22.3)	
Bowel wall thickening		
(+)	48/120 (40)	<0.001*
(−)	219/1.059 (20.7)	
Pneumatosis intestinalis		
(+)	11/12 (91.7)	<0.001*
(−)	255/1.165 (21.9)	
Intestinal necrosis		
(+)	8/8 (100)	<0.001*
(−)	256/1.159 (22.1)	
Portal venous gas		
(+)	7/9 (77.8)	0.008*
(−)	260/1.171 (22.2)	
Perforation		
(+)	6/17 (35.3)	0.345*
(−)	262/1.164 (22.5)	
Renal ischemia		
(+)	6/10 (60)	0.042*
(−)	236/1.087 (21.7)	
Small bowel inflammation		
(+)	26/73 (35.6)	0.039*
(−)	242/1.108 (21.8)	
Colitis		
(+)	39/91 (42.9)	<0.001*
(−)	229/1.089 (21)	
Pyelonephritis		
(+)	6/22 (27.3)	0.674*
(−)	257/1.146 (22.4)	
Acute cholecystitis		
(+)	11/36 (30.6)	0.378*
(−)	257/1.145 (22.4)	
Acute pancreatitis		
(+)	13/38 (34.2)	0.191*
(−)	255/1.142 (22.3)	
Acute diverticulitis		
(+)	1/8 (12.5)	1**
(−)	267/1.173 (22.8)	
Acute appendicitis		
(+)	51/147 (34.7)	0.005*
(−)	217/1.034 (21)	
Intestinal obstruction		
(+)	13/42 (31)	0.316*
(−)	255/1.139 (22.4)	
Intra-abdominal malignancy		
(+)	51/147 (34.7)	0.005*
(−)	217/1.034 (21)	
Overall CT finding		
(+)	112/360 (31.1)	<0.001*
(−)	156/821 (19)	

Pearson's chi-square test* or Fisher's exact test ** were used. CT, computed tomography; COVID-19, coronavirus disease-2019.

In our study, we categorized CT findings into ischemic and non-ischemic subgroups because it has been established that thrombophilia is induced in COVID-19, with resulting micro and macrovascular complications.[27] The presence of abdominal CT findings in patients with COVID-19 was found to be associated with poorer disease outcomes. We found that NOMI, perivascular infiltration, bowel wall thickening, pneumatosis intestinalis, bowel wall necrosis, portal venous gas, renal ischemia, small and large bowel inflammation, acute appendicitis, and intra-abdominal malignancy were significantly associated with mortality in patients with COVID-19. Our results indicate that ischemic CT findings in patients with COVID-19 are related to unfavorable clinical outcomes. Intestinal pneumatosis suggests severe intestinal ischemia, which may be because COVID-19 is associated with coagulopathy.[7] Pneumatosis intestinalis has also been reported in patients with viral enteritis.[28]

Since the beginning of the pandemic, vascular involvement and subsequent vascular abnormalities have been attributed to the tropism of SARS-CoV-2 to the vascular system.[9] In this study, we also investigated whether patients with chronic vascular disease might be more vulnerable to vessel involvement during COVID-19. To test this hypothesis, we used the AA-CAS, which represents calcific atherosclerotic changes in the abdominal aorta, as a parameter. We assumed that the AA-CAS may also reflect the atherosclerotic disease burden in the abdominal visceral vessels. The AA-CAS measurement in this multicenter study was performed using a previously defined method, and the positive correlation between AA-CAS, age, and smoking suggested that the AA-CAS measurement in different centers in this multicenter study was conducted using the same approach, yielding similar results in patients with the same atherosclerotic changes in the abdominal aorta. A significantly higher AA-CAS in the ischemic abdominal CT finding group than in the non-ischemic group in our study suggests that patients with COVID-19 with a high AA-CAS are more likely to have a greater number of ischemic complications related to the disease.

The presence of abdominal CT findings in patients with COVID-19 was found to be related to poor outcomes and a significantly increased duration of hospital stay and mortality rate. The ischemic and non-ischemic abdominal CT findings revealed in this study represent serious clinical entities such as bowel ischemia, hollow viscus perforation,

inflammation, and renal ischemia, which can potentially extend a patient's hospital stay and increase the risk of death. The absence of a significant association with severe abdominal CT findings such as mesenteric artery embolism (n = 4) and mesenteric vein thrombosis (n = 1) in our study was attributed to the low number of patients in these groups, which limited the predictability of statistical tests. Investigations into the effect of abdominal involvement on COVID-19 outcomes indicated that patients with COVID-19 with GI symptoms tended to have a relatively long course between symptom onset and viral clearance. They also required longer medical care and hospital stay than patients with respiratory symptoms only.[29,30]

Our study has several limitations. First, it is a retrospective multicenter study, and extracted medical records of patients from different centers, including clinical information, which may vary in terms of institutional treatment approaches. Despite this limitation, our study's multicenter design may be more representative of the general patient population than that of single-center studies. Second, the majority of CT findings were not verified using traditional gold standards such as surgical or pathological correlation. The relationship between abdominal CT findings and COVID-19 should be assessed with caution because GI involvement in the virus, in particular, depends on a theory suggesting that the virus enters the GI walls through the ACE-2 receptors. An assessment of abdominal CT images in 26 different medical centers increases heterogeneity in the evaluation of CT findings because of radiologists' different opinions on the same findings. To overcome this limitation, the CT assessment criteria in the abdominal CT findings, such as intestinal wall thickening and perivascular infiltration, were well defined and were relayed to the contributors at the initial phase of the study. Third, most studies have investigated the presence of ground-glass opacities at the base of the lungs as an ancillary finding in patients with COVID-19.[7] In our study, we did not assess this finding. Finally, although fecal COVID-19 testing to confirm GI involvement is not a standard clinical approach, the absence of fecal COVID-19 testing in our cohort may be another limitation that is worth mentioning.

In conclusion, ischemic and non-ischemic abdominal CT findings may be encountered in patients with COVID-19. The presence of abdominal CT findings is related to a long hospital stay and unfavorable clinical outcomes. Moreover, infected patients with a

high AA-CAS are more likely to have ischemic abdominal findings.

Conflict of interest disclosure

The authors declared no conflicts of interest.

References

1. Kapoor MC. Respiratory and cardiovascular effects of COVID-19 infection and their management. *J Anaesthesiol Clin Pharmacol.* 2020;36(Suppl 1):S21-S28. [CrossRef]

2. Leng L, Cao R, Ma J, et al. Pathological features of COVID-19-associated lung injury: a preliminary proteomics report based on clinical samples. *Signal Transduct Target Ther.* 2020;5(1):240. [CrossRef]

3. Kanne JP, Bai H, Bernheim A, et al. COVID-19 imaging: what we know now and what remains unknown. *Radiology.* 2021;299(3):E262-E279. [CrossRef]

4. Poyiadji N, Shahin G, Noujaim D, Stone M, Patel S, Griffith B. COVID-19-associated acute hemorrhagic necrotizing encephalopathy: imaging features. *Radiology.* 2020;296(2):E119-E120. [CrossRef]

5. Catapano F, Marchitelli L, Cundari G, et al. Role of advanced imaging in COVID-19 cardiovascular complications. *Insights Imaging.* 2021;12(1):28. [CrossRef]

6. Ramani SL, Samet J, Franz CK, et al. Musculoskeletal involvement of COVID-19: review of imaging. *Skeletal Radiol.* 2021;50(9):1763-1773. [CrossRef]

7. Tirumani SH, Rahnemai-Azar AA, Pierce JD, et al. Are asymptomatic gastrointestinal findings on imaging more common in COVID-19 infection? Study to determine frequency of abdominal findings of COVID-19 infection in patients with and without abdominal symptoms and in patients with chest-only CT scans. *Abdom Radiol (NY).* 2021;46(6):2407-2414. [CrossRef]

8. Bhayana R, Som A, Li MD, et al. Abdominal imaging findings in COVID-19: preliminary observations. *Radiology.* 2020;297(1):E207-E215. [CrossRef]

9. Boraschi P, Giugliano L, Mercogliano G, Donati F, Romano S, Neri E. Abdominal and gastrointestinal manifestations in COVID-19 patients: is imaging useful? *World J Gastroenterol.* 2021;27(26):4143-4159. [CrossRef]

10. Lui K, Wilson MP, Low G. Abdominal imaging findings in patients with SARS-CoV-2 infection: a scoping review. *Abdom Radiol (NY).* 2021;46(3):1249-1255. [CrossRef]

11. Barkmeier DT, Stein EB, Bojicic K, et al. Abdominal CT in COVID-19 patients: incidence, indications, and findings. *Abdom Radiol (NY).* 2021;46(3):1256-1262. [CrossRef]

12. Ozturk C, Gungor O, Kaplanoglu V, Kasikci M, Ramadan SU. Relationship between abdominal aortic calcification, abdominal adiposity, and liver density. *J Coll Physicians Surg Pak.* 2020;30(12):1245-1250. [CrossRef]

13. Safari S, Keyvani H, Malekpour Alamdari N, et al. Abdominal surgery in patients with COVID-19: detection of SARS-CoV-2 in abdominal and adipose tissues. *Ann Surg.* 2020;272(3):e253-e256. [CrossRef]

14. Cheung KS, Hung IFN, Chan PPY, et al. Gastrointestinal Manifestations of SARS-CoV-2 infection and virus load in fecal samples from a Hong Kong cohort: systematic review and meta-analysis. *Gastroenterology.* 2020;159(1):81-95. [CrossRef]

15. Parasa S, Desai M, Thoguluva Chandrasekar V, et al. Prevalence of gastrointestinal symptoms and fecal viral shedding in patients with coronavirus disease 2019: a systematic review and meta-analysis. *JAMA Netw Open.* 2020;3(6):e2011335. [CrossRef]

16. Shiralkar K, Chinapuvvula N, Ocazionez D. Cross-sectional abdominal imaging findings in patients with COVID-19. *Cureus.* 2020;12(8):e9538. [CrossRef]

17. Dane B, Smereka P, Wain R, Kim D, S Katz D. Hypercoagulability in patients with coronavirus disease (COVID-19): identification of arterial and venous thromboembolism in the abdomen, pelvis, and lower extremities. *AJR Am J Roentgenol.* 2021;216(1):104-105. [CrossRef]

18. Mazrouei SSA, Saeed GA, Al Helali AA. COVID-19-associated acute pancreatitis: a rare cause of acute abdomen. *Radiol Case Rep.* 2020;15(9):1601-1603. [CrossRef]

19. Ackermann M, Verleden SE, Kuehnel M, et al. Pulmonary vascular endothelialitis, thrombosis, and angiogenesis in Covid-19. *N Engl J Med.* 2020;383(2):120-128. [CrossRef]

20. Goldberg-Stein S, Fink A, Paroder V, Kobi M, Yee J, Chernyak V. Abdominopelvic CT findings in patients with novel coronavirus disease 2019 (COVID-19). *Abdom Radiol (NY).* 2020;45(9):2613-2623. [CrossRef]

21. Varga Z, Flammer AJ, Steiger P, et al. Endothelial cell infection and endotheliitis in COVID-19. *Lancet.* 2020;395(10234):1417-1418. [CrossRef]

22. Su H, Yang M, Wan C, et al. Renal histopathological analysis of 26 postmortem findings of patients with COVID-19 in China. *Kidney Int.* 2020;98(1):219-227. [CrossRef]

23. Idilman IS, Telli Dizman G, Ardali Duzgun S, et al. Lung and kidney perfusion deficits diagnosed by dual-energy computed tomography in patients with COVID-19-related systemic microangiopathy. *Eur Radiol.* 2021;31(2):1090-1099. [CrossRef]

24. Gahide G, Frandon J, Vendrell JF. COVID-19 patients presenting with afebrile acute abdominal pain. *Clin Med (Lond).* 2020;20(3):e4-e6. [CrossRef]

25. Taya M, Paroder V, Redelman-Sidi G, et al. Abdominal imaging findings on computed tomography in patients acutely infected with SARS-CoV-2: what are the findings? *Emerg Radiol.* 2021;28(6):1087-1096. [CrossRef]

26. Xiao F, Tang M, Zheng X, Liu Y, Li X, Shan H. Evidence for gastrointestinal infection of SARS-CoV-2. *Gastroenterology.* 2020;158(6):1831-1833.e3. [CrossRef]

27. Keshavarz P, Rafiee F, Kavandi H, Goudarzi S, Heidari F, Gholamrezanezhad A. Ischemic gastrointestinal complications of COVID-19: a systematic review on imaging presentation. *Clin Imaging.* 2021;73:86-95. [CrossRef]

28. Ho LM, Paulson EK, Thompson WM. Pneumatosis intestinalis in the adult: benign to life-threatening causes. *AJR Am J Roentgenol.* 2007;188(6):1604-1613. [CrossRef]

29. Han C, Duan C, Zhang S, et al. Digestive symptoms in COVID-19 patients with mild disease severity: clinical presentation, stool viral RNA testing, and outcomes. *Am J Gastroenterol.* 2020;115(6):916-923. [CrossRef]

30. Pan L, Mu M, Yang P, et al. Clinical characteristics of COVID-19 patients with digestive symptoms in Hubei, China: a descriptive, cross-sectional, multicenter study. *Am J Gastroenterol.* 2020;115(5):766-773. [CrossRef]

Supplementary Table 1. Table showing differences in age and laboratory tests according to specific CT findings in study cohort

	Age ± SD	Median AST (95% CI for median)	Median ALT (95% CI for median)	D. bilirubin 95% CI for median)	I. bilirubin (95% CI for median)	D-dimer (95% CI for median)
Acute mesenteric artery embolism						
Present (n = 10)	61.60 ± 24.09	67.5 (21.9–183.6)	94 (25.5–163.9)	1.67 (0.3–8.67)	1.55 (0.46–3.59)	33.5 (6.9–3491.9)
Absent (n = 1009)	61.20 ± 17.46	30 (29–32)	24 (22–25.1)	0.21 (0.20–0.23)	0.39 (0.36–0.40)	159.5 (99.3–254.3)
P	0.739	0.045*	0.004*	0.001*	0.002*	0,505
Acute mesenteric vein thrombus						
Present (n = 6)	57.83 ± 15.51	93 (15.4–247.1)	39.5 (18.3–240.6)	1 (1-1)	0.24 (0.16–0.30)	444.0 (7–1231.9)
Absent (n = 1014)	61.21 ± 17.55	30 (29–32)	24 (23–26)	0.21 (0.20–0.23)	0.39 (0.36–0.40)	156.5 (89.3–250.3)
P	0.563	0.079	0.091	0.007*	<0.001*	0.557
Non-occlusive mesenteric ischemia						
Present (n = 8)	70.50 ± 15.82	32 (27–48.7)	30 (20.3–36.8)	0.30 (0.22–0.60)	0.60 (0.42–0.85)	420 (19.9–1253.1)
Absent (n = 1093)	61.39 ± 17.54	30 (29–31)	24 (22–25)	0.20 (0.20–0.23)	0.38 (0.35–0.40)	170.5 (115.3–290.4)
P	0.114	0.222	0.455	0.035*	<0.001*	0.148
Perivascular infiltration						
Present (n = 40)	59.52 ± 18.25	34 (28.3–52.7)	27 (17.9–35.7)	0.30 (0.22–0.57)	0.62 (0.40–1)	793 (94.5–1429.1)
Absent (n = 1087)	61.59 ± 17.55	30 (29–31)	24 (22.4–25)	0.21 (0.20–0.23)	0.38 (0.36–0.40)	168.3 (112.3–277.7)
P	0.451	0.102	0.976	0.057	<0.001*	0.023*
Bowel wall thickening						
Present (n = 120)	60.53 ± 18.76	31 (28.3–37.6)	24 (19–30)	0.25 (0.19–0.37)	0.48 (0.42–0.54)	243.5 (22.7–604.5)
Absent (n = 1059)	61.68 ± 17.29	30 (28–31)	24 (22–25)	0.21 (0.20–0.23)	0.36 (0.34–0.39)	254 (167–379)
P	0.649	0.370	0.518	0.032*	<0.001*	0.378
Pneumatosis intestinalis						
Present (n = 12)	71.83 ± 11.77	105 (50.3–205.7)	52.5 (27.2–227.6)	0.66 (0.30–1.49)	0.70 (0.28–1.84)	1469 (24.1–5002.3)
Absent (n = 1165)	61.52 ± 17.43	30 (28–31)	24 (22–25)	0.21 (0.20–0.23)	0.38 (0.35–0.40)	254 (166.3–370.7)
P	0.043*	<0.001*	0.021*	0.001*	0.056	0.043*
Bowel wall necrosis						
Present (n = 8)	69.37 ± 11.62	165.5 (44.9–450.5)	54.5 (23.3–403.4)	0.43 (0.19–13.5)	0.65 (0.22–6.47)	1577.5 (165.2–7677.8)
Absent (n = 1159)	61.57 ± 1.49	30 (28–31)	24 (22–25)	0.21 (0.20–0.23)	0.37 (0.35–0.39)	245.5 (157.8–350)
P	0.234	0.002*	0.034*	0.034*	0.267	0.025*
Air in the portal venous system						
Present (n = 9)	76.77 ± 12.86	99 (34.4–206)	45 (27.3–231.7)	0.66 (0.20–8.75)	0.77 (0.28–10.1)	200 (16.5–6688.1)
Absent (n = 1171)	61.46 ± 17.43	30 (28–31)	24 (22–25)	0.21 (0.20–0.23)	0.38 (0.36–0.40)	254 (167–370)
P	0.007*	0.003*	0.033*	0.022*	0.051	0.253
Perforation						
Present (n = 17)	60.17 ± 17.62	40 (29–63.7)	34 (21.5–49.6)	0.19 (0.11–0.57)	0.35 (0.17–0.63)	7 (2.5–1397.4)
Absent (n = 1164)	61.61 ± 17.44	30 (28–31)	24 (22–25)	0.21 (0.20–0.23)	0.38 (0.36–0.40)	254 (167–300)
P	0.576	0.211	0.224	0.924	0.921	0.892
Renal ischemia						
Present (n = 10)	69.9 ± 15.3	55 (23.5–786.8)	74 (21.6–447.8)	0.30 (0.13–1.57)	0.54 (0.32–2.21)	502.5 (8.4–3186.5)
Absent (n = 1087)	61.4 ± 17.5	30 (28–31)	24 (22–25)	0.22 (0.20–0.23)	0.38 (0.36–0.40)	240 (150.3–350.4)
P	0.156	0.085	0.006*	0.312	0.102	0.233
Small bowel inflammation						
Present (n = 73)	56.94 ± 18.86	31 (24–37)	21 (15.4–30.6)	0.30 (0.20–0.51)	0.44 (0.37–0.56)	24 (9–452.9)
Absent (n = 1108)	61.90 ± 17.31	30 (28–31)	24 (22.2–25)	0.21 (0.20–0.23)	0.37 (0.35–0.40)	282.5 (175.3–389.9)
P	0.018*	0.964	0.284	0.010*	0.008*	0.857
Colitis						
Present (n = 91)	59.59 ± 17.33	30 (25.3–35.7)	24.8 (19.3–31)	0.24 (0.17–0.37)	0.47 (0.38–0.55)	55.3 (13.6–467.3)
Absent (n = 1089)	61.76 ± 17.45	30 (28–31)	24 (22–25)	0.21 (0.20–0.23)	0.37 (0.35–0.40)	269.5 (170.2–387.9)
P	0.229	0.577	0.966	0.133	0.002*	0.695
Acute pyelonephritis						
Present (n = 22)	62.36 ± 20.50	28 (16.8–38.8)	22 (16.7–44.6)	0.19 (0.11–0.45)	0.36 (0.19–0.46)	494.5 (5.8–1331.1)
Absent (n = 1146)	61.48 ± 17.42	30 (28–31)	24 (22–25)	0.21 (0.20–0.23)	0.38 (0.35–0.40)	257.5 (170.3–386.8)
P	0.622	0.487	0.516	0.547	0.369	0.568
Acute cholecystitis						
Present (n = 36)	70.27 ± 15.39	39 (32.4–65.7)	29.5 (14–58.3)	0.37 (0.25–0.57)	0.51 (0.37–0.79)	560.2 (8.6–1320.4)
Absent (n = 1145)	61.32 ± 17.44	30 (28–31)	24 (22–25)	0.21 (0.20–0.22)	0.37 (0.35–0.40)	250 (165.2–350)
P	0.001*	0.045*	0.578	0.001*	0.003*	0.576

	Age ± SD	Median AST (95% CI for median)	Median ALT (95% CI for median)	D. bilirubin 95% CI for median)	I. bilirubin (95% CI for median)	D-dimer (95% CI for median)
Acute pancreatitis						
Present (n = 38)	62.94 ± 16.80	48 (33.7–74.3)	46.5 (27.7–84.7)	0.34 (0.26–0.51)	0.41 (0.29–0.67)	1231.3 (376.5–2541.1)
Absent (n = 1142)	61.56 ± 17.47	29 (28–31)	24 (22–25)	0.21 (0.20–0.22)	0.38 (0.35–0.40)	235 (155.1–346.8)
P	0.667	0.001*	0.001*	0.017*	0.183	0.006*
Acute diverticulitis						
Present (n = 8)	65.87 ± 23.04	30 (15–419.5)	21.5 (13.5–281.3)	0.13 (0.10–0.25)	0.34 (0.16–1.01)	2092.8 (212.2–11243.5)
Absent (n = 1173)	61.56±17.40	30 (28–31)	24 (22–25)	0.21 (0.20–0.23)	0.38 (0.35–0.40)	250 (165.3–350)
P	0.370	0.781	0.889	0.153	0.762	0.032*
Acute appendicitis						
Present (n = 18)	40.94 ± 19.98	22 (19–35.6)	21 (17.3–24.7)	0.19 (0.11–0.45)	0.44 (0.26–0.54)	1.5 (0.6–82.1)
Absent (n = 1160)	61.90 ± 17.23	30 (29–31)	24 (22–25)	0.21 (0.20–0.23)	0.38 (0.35–0.40)	284 (173.3–390)
P	<0.001*	0.129	0.380	0.546	0.951	0.011*
Bowel obstruction						
Present (n = 42)	59.19 ± 15.34	32 (27.4–46.8)	25 (19.5–33.5)	0.28 (0.15–0.43)	0.49 (0.40–0.77)	370 (28.7–376.5)
Absent (n = 1139)	61.68 ± 17.51	30 (28–31)	24 (22–25)	0.21 (0.20–0.23)	0.37 (0.35–0.40)	250 (161.6–351.4)
P	0.257	0.107	0.905	0.212	<0.001*	0.124
Intraabdominal malignancy						
Present (n = 147)	59.99 ± 14.61	32 (28–39)	25 (20–32)	0.30 (0.22–0.41)	0.45 (0.40–0.51)	134 (10.5–501.6)
Absent (n = 1034)	61.82 ± 17.80	29 (28–31)	24 (22–25)	0.20 (0.19–0.22)	0.36 (0.35–0.39)	266 (170–390)
P	0.257	0.362	0.884	<0.001*	<0.001*	0.600

*Represents statistical significance. Data were summarized as mean ± SD for normal distributed variables and, median (95% CI for median) for non-normal distributed variables. ALT, alanine aminotransferase; AST, aspartate aminotransferase; SD, standard deviation; CI, confidence interval.