Diagnostic and Therapeutic Radiology of the GI Tract, Liver, and Pancreas in Patients with COVID

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PII: S0889-8553(22)00085-1

DOI: https://doi.org/10.1016/j.gtc.2022.10.006

Reference: GTC 1245

To appear in: *GASTROENTEROLOGY CLINICS OF NORTH AMERICA*

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Disclosure Statement:

The Authors have nothing to disclose.

Key Words:

Gastrointestinal findings; Hepato-biliary findings; Pancreatic findings; COVID-19; SARS-CoV-2; Computed tomography; Ultrasound; Diagnostic Imaging; Interventional radiology.

Key Points:

1. Imaging findings have been recently investigated regarding gastrointestinal, hepatobiliary, and pancreatic involvement with COVID-19 infection.
2. Radiological findings of gastrointestinal, hepatic, and pancreatic involvement in patients with COVID-19 are generally nonspecific.
3. Ultrasound and particularly computed tomography with multiphasic acquisition are the primary diagnostic methods utilized in COVID-19 patients to evaluate the significance of gastrointestinal, hepatobiliary, and pancreatic clinical symptoms and signs.
4. Imaging should be performed if abdominal or gastrointestinal disease is suspected in COVID-19 patients.
5. Diagnostic imaging modalities, particularly computed tomography, are helpful to evaluate and manage COVID-19 patients with gastrointestinal, hepatic, and pancreatic involvement.

Synopsis:

COVID-19 pulmonary involvement has been extensively reported in the literature. Current data highlight how COVID-19 is a systemic disease, affecting many other organs, including the gastrointestinal, hepatobiliary, and pancreatic organs. Recently these organs have been investigated using imaging modalities of ultrasound and, particularly, computed tomography. Radiological findings of the gastrointestinal, hepatic, and pancreatic involvement in patients with COVID-19 are generally nonspecific but are nonetheless helpful to evaluate and manage COVID-19 patients with organ involvement of these organs.

Synopsis

COVID-19 pulmonary involvement has been extensively described in the literature. However, COVID-19 is a systemic disease that affects many other organs. Gastrointestinal, hepatobiliary. and pancreatic clinical manifestations in COVID-19 have been recently investigated using imaging modalities, including ultrasound and, particularly, computed tomography. Even if radiological findings of the gastrointestinal, liver, and pancreatic involvement in patients with COVID-19 are often nonspecific, imaging should be performed to evaluate suspected abdominal and gastrointestinal disease in these patients. The radiologist must be familiar with imaging features of involvement of these organs with COVID-19 infection in order to properly diagnose and manage these patients. In conclusion, diagnostic imaging, particularly CT are helpful to evaluate and manage COVID-19 patients with gastrointestinal, hepatic, and pancreatic disease.

Introduction

The lungs are the primarily involved organs in coronavirus disease 2019 (COVID-19), but COVID-19 infection is a systemic disease, with tropism for the vascular system, that can cause variable and widespread clinical manifestations that frequently involve the gastrointestinal tract and hepatobiliary system and infrequently involve the pancreas[1,2] Accordingly, imaging modalities play a pivotal role in patients with abdominal and gastrointestinal symptoms and signs to investigate possible abdominal features of SARS-CoV-2 infection [3]. Abdominal ultrasound (US) is frequently the first imaging exam clinicians request to evaluate patients with abdominal discomfort, especially in ICU (intensive care unit) patients [4]. However, US has a limited role in evaluating gastrointestinal involvement, and it is primarily requested to evaluate the hepatobiliary system and portal vein patency [4,5]. In a study of 30 ICU COVID-19 patients, the most frequent findings on abdominal ultrasound included: hepatomegaly in 23/41 (56%) which is often associated with elevated liver function tests and a bright echo pattern of the liver parenchyma; and biliary system disease in 17/41 (41.5%) such as gallbladder distention, biliary sludge, gallbladder wall thickening, and common bile duct dilatation. Nephropathy was the third most common ultrasound abnormality which occurred in 7/41 (17%) [4]. Nonetheless, ultrasound can show life-threatening conditions. For example, Bayana et al. reported on an ICU patient who had portal venous gas incidentally detected at abdominal ultrasound and subsequently confirmed by computed tomography (CT) [1].

Abdominal magnetic resonance (MR) is rarely performed in patients with COVID-19 infection because it is time-consuming and difficult to perform in patients with respiratory disease [6]. Moreover, MR rarely leads to a change in diagnosis or management related to COVID-19 [7], as demonstrated by Anderson et al. in a study of 1107 COVID-19 patients. Main MRI indications were unrelated to SARS-CoV-2 infection in 75%, and MRI was performed for workup of acute liver dysfunction in 25% [7].

Abdominal CT plays a crucial role in identifying abdominal involvement due to COVID-19 infection, particularly for the gastrointestinal tract. CT should routinely include the baseline and post-contrast infusions in the arterial, portal-venous, and delayed phases.

Radiology also plays an important role in the management of COVID-19-related complications using interventional radiology (IR) procedures. Lee et al.8 described the most common interventional procedures in a series of 724 COVID-19 patients: central venous catheter placement for haemodialysis in 31.5% in patients with renal failure; inferior vena cava filter placement in 9.7% in selected patient with venous thromboembolism;

angiography/embolization in 4.8% in patients with bleeding complications; gastrostomy tube placement in 9.7%; image-guided biopsy in 10.5%; abscess drainage in 9.7%; and cholecystostomy tube placement in 6.5%.

Gastrointestinal Tract

The gastrointestinal tract is a well-known route of COVID-19 infection as demonstrated by the finding of the SARS-CoV-2 viral ribonucleic acid in stool [3]. The gastrointestinal tract is the most common site of extrapulmonary involvement of COVID-19 disease (11.4-61.1%) [9], with manifestations of variable severity. As summarised by Zhang et al. subgroups of COVID-19 patients can be identified by: 1) the presence of gastrointestinal symptoms without respiratory symptoms; 2) the concurrent presence of gastrointestinal and respiratory symptoms; and 3) gastrointestinal involvement before the occurrence of respiratory symptoms [3]. Gastrointestinal symptoms during SARS-CoV-2 infection are generally nonspecific and usually mild and self-limiting (diarrhoea, vomiting, abdominal distension). However, patients can occasionally present with acute abdominal pain due to intestinal obstruction, bowel ischemia, acute appendicitis, hemoperitoneum or disorders involving other abdominal organs [9].

As gastrointestinal signs are frequently observed in COVID-19 patients, a correct abdominal diagnosis and correlation with SARS-CoV-2 infections has become more important. Various studies report that abdominal symptoms at the onset of the infection may not be appreciated promptly as related to COVID-19, thus delaying the diagnosis and therapy with a consequent higher risk of complications [10]. Moreover, gastrointestinal involvement in COVID-19 has been associated with a worse disease outcome, expressed by longer hospital stay, and the need for mechanical ventilation [9,11].

Bayhana et al. reported that COVID-19 patients in the ICU are more likely to have gastrointestinal involvement than other in-patients (65% vs 23%, p=0.04) [1]. Horvat et al. in a multicentre study of 81 COVID-19 patients, correlated the abdominal radiological features with clinical outcome; they reported that abnormal abdominal imaging findings were associated with an increased risk of bad outcomes (death/invasive mechanical ventilation) (RR=2.6, p=0.04), invasive mechanical ventilation (RR=6.2, p=0.05), longer hospital stay (adjusted difference: +6.2 days, p=0.1) and longer ICU stay (adjusted difference: +7.1, p=0.07) [12].

Abdominal CT is the main imaging modality in the diagnosis of COVID-19 patients with non-specific abdominal symptoms (including abdominal pain, diarrhoea, nausea, and vomiting) and suspicion of complications (intestinal ischemia and sporadic gastrointestinal bleeding) [12,5,6]. Abdominal CT may also be useful in suggesting the diagnosis of SARS-CoV-2 infection in patients with abdominal features and ground glass opacities at lung bases [6]. The most common CT findings in symptomatic and asymptomatic patients are bowel wall abnormalities: bowel wall inflammation (gastritis, enterocolitis), and bowel wall ischemia[12]. Thrombosis of great abdominal vessels can be detected as a filling defect on CT angiography [1,5,6]. However, abdominal imaging findings can be absent in some patients complaining of abdominal symptoms due to the complex pathogenesis of enterocyte damage which is still not clear, with possible factors causing direct viral mucosal injury, increased intraluminal pressure, gut microbiota impairment, lymphoid atrophy, and vessel thrombosis (arterial macro/micro thrombosis and venous occlusion)[13]. The most common CT features of gastritis and enterocolitis are fluid-filled and distended bowel lumen (43%), and mural thickening of large and small intestine due to submucosal oedema and mucosal hyperenhancement (Figure 1). Enterocolitis can be segmental in early stages and worsen to become pancolitis [2]. Perivisceral fat stranding, abdominal free fluid and isolated mesenteric nodal enlargement are common associated findings because of COVID-19-induced inflammatory responses[2,5]. Moreover, thrombosis of the arterioles can cause mesenteric congestion, as demonstrated by autopsy studies[12].

COVID-19-related bowel ischemia is a life-threatening emergency [10]. CT findings range from a contracted gas-less bowel loop appearance (early stage) to dilated gas-filled bowel loops with a paper-thin bowel wall (intermediate stage), and to a late ischemic stage characterised by intestinal wall pneumatosis with or without porto-mesenteric gas, lack of mucosal enhancement, and luminal dilatation which could cause intestinal perforation (Figure 2). Pneumatosis intestinalis with intramural bowel gas is a rare sign of intestinal ischemia (Figure 3), but it is nonspecific as this finding can also occur with other conditions such as mechanical ventilation or pneumomediastinum [14]. Bowel perforation is not always visible on CT, but may be suspected when associated features such as fat stranding, perivisceral fluid/abscess or pneumoperitoneum are present.

Gastrointestinal bleeding is rare and occurs in about 3% of COVID-19 patients [1,2]. It presents as a hyperdense fluid within gastric or bowel lumen detected on CT images (Figure 1, Figure 4). Martin et al. [15] in a matched (1:2) case-control study of 41 cases of COVID-19 related gastrointestinal bleeding (31 upper and 10 lower) found that the most common etiologies of gastrointestinal bleeding were gastric or duodenal peptic ulcers (80%) in upper gastrointestinal bleeding, and rectal ulceration (50%) in lower gastrointestinal bleeding.

However, aetiology is multifactorial and still not completely known [15]; it could be secondary to factors related to treatment (anticoagulation) and critical illness, more than direct viral damage on enterocytes [15]. GI bleeding in COVID-19 infected patients is reviewed in an accompanying chapter in this monograph by Cappell and Friedel. Endoscopy is the standard for the diagnosis and treatment of gastrointestinal bleeding [16].

Trans-arterial endovascular embolization (TAE) is a viable alternative treatment in patients with COVID-19. In a multicenter retrospective observational study, TAE had a minor risk of aerosol COVID-19 transmission to angiography staff and of respiratory exacerbation in patients undergoing the angiography[15]. TAE is a safe and effective alternative in this patient population with technical and clinical success rates of embolization of 88.2% and 94.1%, respectively [15]. Moreover, another international multicenter retrospective observational study[17] showed that TAE had technical and clinical success in 100% and 90.9% of patients, respectively[17]. Rebleeding occurred in 1 patient (9%) who then needed a complementary therapeutic endoscopy. Mortality within 30 days after embolization was 0%. Minor complications occurred in 18.2%, including a groin hematoma and an ischemic rectal ulcer, both of which were managed conservatively [17].

Liver and Biliary Tract

Liver involvement occurs in up to 45% of patients with COVID-19, particularly in patients with severe viral infection[18,19]. Several mechanisms contribute to the liver injury: systemic inflammatory process, drugs, hypoxia, and the direct effect of SARS-CoV-2. The virus directly enters and injures cholangiocytes, which contain the angiotensin converting enzyme-2 (ACE2) receptor in the same proportion as the alveolar cells of the lungs [10,20], while this receptor is less represented in hepatocytes [20]. The simultaneous presence of multiple pathogenic factors causes a generalised coagulopathy with consequent microthrombosis within the sinusoids and consequent necrosis, lymphocytic infiltration of the sinusoids, and hepatic fibrosis or crrhosis[20,10].

The most frequent radiological features are hepatic steatosis, and the formation of gallbladder sludge and gallstones, often complicated by cholecystitis, and sometimes complicated by secondary sclerosing cholangitis [21]. There is an increased frequency of hepatic steatosis on CT scans in COVID-19 patients compared with uninfected controls, although some patients may have had abnormal liver function prior to SARS-CoV-2 infection, from disorders such as non-alcoholic fatty liver disease (NAFLD) or chronic hepatitis B [22]. Moreover, the higher prevalence of hepatic steatosis is probably due to the known association between COVID-19 infection and obesity[22], and the known association between pre-existing liver disease and COVID-19 infection. Steatosis is common in COVID-19 patients. It occurs because the virus affects mitochondrial activity, inhibits autophagy, and promotes lipogenesis[23]. The classic signs of steatosis on ultrasound are: a luminous hepatic pattern (presence of numerous fine, intense and dense parenchymal echoes, which give the hepatic parenchyma an echogenicity higher than that of the cortex of the right kidney), and the sign of attenuation (deep attenuation of ultrasonic echoes, associated with poor visibility of the diaphragm and echogenic portal and suprahepatic vascular walls) [24] [25] . The evaluation of hepatic steatosis with CT is performed by calculating hepatic hypoattenuation; if the liver density is less than 10 Hounsfield units (HU) compared to the spleen density, the steatosis is mild, whereas if the density is greater than 40 HU, the steatosis is moderate/severe[25].

MRI is the primary imaging modality for both qualitative and quantitative evaluation of hepatic steatosis. Fatty liver has a high signal intensity on T1-weighted images; in addition, several MRI sequences, including fat suppression sequences and chemical shift imaging with dual-echo sequences, facilitate fat detection. Specifically, chemical displacement imaging determines whether lipid and water protons are present within the same small voxel space (three-dimensional pixel). In the case of fatty liver disease, there is a signal drop in opposed-phase sequences [25] (Figure 5).

Gallbladder sludge and gallstones are common in COVID-19 patients. They develop in 54% of infected patients compared to the incidence of 10% to 20% in the general population[26,27]. The causes are hypoxia, bile duct ischemia, and an altered bile composition, resulting in necrosis of cholangiocytes and gallstone formation [27].

US is currently the reference technique for evaluating pathology of the gallbladder, macro- and micro- lithiasis, gallbladder sludge, and cholesterol deposits. Cholesterol deposition appears as hyperechoic spots with the typical "comet sign", biliary sludge as sediment in the sloping portion of the gallbladder lumen, and gallstones appearing as hyperechogenic with a posterior shadow cone, if calcified [28,29]. CT usually plays a marginal role, although, it can be helpful in uncooperative COVID-19 patients; calcium stones appear hyperdense, whereas cholesterol stones appear hypodense[10]. Even if MRI is the method of choice to detect choledochal stones, it is rarely utilised in COVID-19 patients as aforementioned. However, gallbladder sludge and biliary sediments are hyperintense on T1-weighted images and iso-hypointense on T2-weighted sequences [30]. Furthermore, gallstones are usually represented on MRI by the characteristic signal void as opposed to the elevated signal intensity of surrounding bile [31]. Biliary stasis and the formation of gallstones can lead to cholecystitis and cholangitis. Some authors[32] have hypothesised that the cytotoxic effect of the virus can cause ischemia with consequent necrosis of the biliary tract. Furthermore, the virus aggravates cholestasis, by altering the cholangiocyte barrier, and the transport of bile acids[32].

US is the imaging of choice, but CT can be used to evaluate patients with acute abdominal pain or inconclusive US. Findings indicative of acute cholecystitis include gallbladder over distension, gallbladder wall thickening (>3 mm), mural oedematous stratification and hypervascularization, and pericholecystic and perihepatic fluid [33 34](Figure 6).

A small proportion of patients affected by COVID-19 in critical conditions may develop progressive cholestatic damage from consequent secondary sclerosing cholangitis (SSC). In a series of 34 COVID-19 ICU patients, 9 of them developed severe cholestasis and 4 of them exhibited signs of SSC on magnetic resonance cholangiopancreatography (MRCP) [35]. The MR appearance of SCC is usually similar to that of primary sclerosing cholangitis (Figure 7). The main characteristics of SSC on MRCP are narrowing of the intrahepatic biliary tract with monolobar, bilobar or segmental distribution, possibly associated with dilation, assuming the appearance of “beads” or a "pruned tree". Involvement of the extrahepatic biliary tree is rare because the intrahepatic bile ducts are vascularized via the hepatic artery, while the extrahepatic biliary tree receives a double arterial supply via the hepatic artery and the gastroduodenal artery [36]. Other abnormalities can be represented by high signal intensity of the hepatic parenchyma in the T2-weighted sequences and in diffusion weighted imaging, and by impaired contrast enhancement due to reduced bile flow, and areas of cholangitis and fibrosis. Periportal lymphadenopathies are rare, unlike the situation in primary sclerosing cholangitis [37].

Pancreas

Pancreatic involvement in COVID-19 infection is less frequent compared to bowel and hepatobiliary involvement, but more cases are emerging in the literature, albeit mostly in the form of case reports or single-centre studies. Furthermore, only a few studies have focused on abdominal imaging of pancreatic involvement in COVID-19 patients. The first case-series exploring pancreatic pathology in patients with COVID-19 pneumonia reported an incidence of 17% of pancreatic injury [38], although the radiological findings or the abdominal pain were not described [39].

The predominant pancreatic gland abnormality is represented by acute pancreatitis (AP), especially in the form of oedematous-interstitial pancreatitis referred as pancreatic enlargement, peripancreatic inflammatory changes, and peripancreatic fluid collection [40,41]. According to the revised Atlanta classification, AP is diagnosed if at least two of the following three criteria are present: (1) abdominal pain, (2) elevation of pancreatic enzymes (>three times the upper limit of normal), and (3) typical radiological findings[42]. Nevertheless, COVID-19-related AP requires exclusion of other aetiologies for the diagnosis, including gallstones, alcoholism, medications, and other infections[40]. If clinical and biochemical data are inconsistent, contrast-enhanced CT (CECT) should be performed. CECT should include a baseline scan of the abdomen and pelvis followed by arterial and portal-venous phases after administration of an iodinated contrast medium at 40 and 65-70 seconds, respectively [43]. On CECT, the most typical pattern is either a diffusely enlarged pancreas with homogeneous/slightly heterogeneous enhancement and blurred margins or a combination of an enlarged pancreas with signs of inflammatory changes in peripancreatic fat represented by haziness and mild stranding. Non-encapsulated peripancreatic fluid may also be present [44] (Figure 8). Hinosa et al. reported a case of a 72-years old man who eight days after hospitalisation for COVID-19 pneumonia underwent chest CT scan to exclude pulmonary embolism; the CT scan extended to the upper abdomen and revealed pancreatic pseudocysts at the pancreatic head and tail, findings that were not present at the initial CT performed on admission. No other findings of peripancreatic inflammation or ductal dilatation or pancreatic enzyme alteration were present [45].

Pancreatic pseudocyst is a late phase collection typically occurring 4 weeks after the onset of AP. It consists of an encapsulated fluid collection with an enhancing wall. The fluid is homogeneous and hypoattenuating at CECT [46]. Schepis et al. reported a patient with a pancreatic pseudocyst undergoing percutaneous ultrasound-guided transgastric drainage because of partial gastric obstruction. Moreover, analysis of the drained fluid revealed the presence of 3 genes of SARS-CoV-2 [47].

Pancreatic involvement has also been described in children with COVID-19 infection or multisystem inflammatory syndrome in children (MIS-C) [48]. Stevens et al. presented the first case of AP in MIS-C; it occurred in a 10-year-old female with previous COVID-19 infection who presented to the emergency department with abdominal pain, pyrexia, fatigue, and hyperlipasemia; CT scan revealed pancreatomegaly and peripancreatic fatty change, from AP [49] (Figure 9).

A few cases of necrotizing pancreatitis and its complications in COVID-19 infection have also been described. Parenchymal necrosis has to be considered when in the pancreatic phase there is low attenuation/no homogeneous enhancement of any part of the gland. Small necrotic areas could be mistaken for heterogeneous parenchyma in interstitial oedematous AP [46]. A young man with positive nasal swab for SARS-CoV-2, underwent chest and abdomen CT scans for pulmonary symptoms and abdominal pain; CT depicted multifocal bilateral ground-glass opacities consistent with COVID-19 infection and revealed non-enhancing head and body of the pancreas with fat stranding [50]. A necrotizing pancreatitis infected by Clostridium perfringens has been reported, expressed by gas within the peripancreatic fluid collection [51]. Among complications of necrotizing pancreatitis, haemorrhage has to be appreciated on CT scan. It can result from parietal erosion of peripancreatic arteries and is usually treated via vascular embolization (Figure 10). Although a few patients with necrotizing-emphysematous pancreatitis have been described, attention must be paid to this complication in severe COVID-19 infection. AP in COVID-19 patients is rare with a low prevalence of pancreatitis in hospitalised COVID-19 patients, a worse prognosis in patients with COVID-19, and a higher mortality[52,40]. In this setting imaging plays a crucial role in the early diagnosis, in particular when clinical and biochemical findings are inconclusive, but especially to monitor the patient with complications and to guide clinicians in the work-up of AP, and to reduce morbidity and mortality in COVID-19 patients [10].

Conclusions

Gastrointestinal, hepatobiliary, and pancreatic clinical manifestations in COVID-19 patients have been recently investigated using imaging modalities, including US and particularly CT. The radiologist must be familiar with imaging features of potential gastrointestinal, hepato-biliary, and pancreatic COVID-19 involvement to promptly diagnosis and manage these patients [7]. Even if radiological findings of gastrointestinal, hepatic, and pancreatic involvement in patients with COVID-19 are non-specific, imaging should be performed if abdominal or gastrointestinal disease is suspected in these patients. Furthermore, diagnostic imaging, particularly CT, is helpful to evaluate and manage gastrointestinal, hepatic, and pancreatic disease in COVID-19 patients.

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Figure legends

Figure 1. A 72-year-old man with COVID-19-infection was referred for abdominal CT after presentation with abdominal pain and tenderness and a hemoglobin decline.

(a) An axial non-contrast CT image showed distended duodenum from hyperdense hematic content in the lumen.

(b) Arterial phase of contrast-enhanced CT shows a contrast blush in the lumen of the horizontal duodenum that persists in the venous phase (c), indicating active arterial bleeding. Peritoneal free-fluid (peri-splenic in the image) was present as an associated finding.

(d) Sagittal reconstruction shows an active arterial blush into the lumen of the horizontal duodenum.

Active bleeding from a duodenal ulcer was stopped by endoscopic therapy.

Due to worsening anaemia, an abdominal CT was performed (d, e, f,).

Non-enhanced sagittal reconstruction (e) shows persistence of duodenal distension due to high density content, extending to the proximal jejunal loop, and increased density of diffuse peritoneal fluid, suggesting hemoperitoneum. Note distension of other bowel loops and peritoneal fluid as signs of gastrointestinal involvement (e).

Post-contrast CT image did not show signs of active bleeding; however, angiography was still performed.

Angiographic study showed arterial blush coming from tiny branches in the duodenum. Super selective embolization of gastroduodenal branches was performed using coils. Angiographic study of the SMA and IMA (e) showed no other bleeding source.

Figure 2. A 75-year-old male was admitted from the emergency department because of abdominal pain. Despite an absence of respiratory symptoms or signs, a COVID-19 PCR test was positive. Abdominal CT was performed. Post-contrast acquisitions (a-c arterial phase; d-f venous phase) show a distended and atonic caecum, reduced enhancement of the bowel wall, and signs of pneumatosis, suggesting intestinal ischemia. A distended, air-filled, and atonic transverse colon were also present.

Figure 3. A 76-year-old female with COVID-19 infection underwent a thorax CT scan for suspicion of interstitial pneumonia. CT scan was extended to the abdomen due to findings on the transverse colon. CT post-contrast acquisitions (a,b) confirmed transverse colon distention with wall thickening, air-fluid levels, and lack of wall enhancement in the arterial

phase (a). Windowing showed the presence of pneumatosis intestinalis through the wall layers, indicating intestinal ischemia. No obstruction of the major vessels was seen. The patient underwent laparoscopic surgery and resection of the necrotic colon with ileostomy.

Figure 4. A 66-year-old patient with COVID-19-infection and slight pulmonary symptoms was admitted from the emergency department because of rectal bleeding. Laboratory tests showed a lowered hemoglobin; rectal examination seemed to exclude hemorrhoidal bleeding. An abdominal CT scan was performed.
(a) Axial non-contrast CT image shows distention of sigmoid colon and rectum due to hyperdense intraluminal fluid, suspicious for hematic content.
(b) Arterial phase of contrast-enhanced CT shows medium contrast blush at left side of rectal-sigmoid junction, that persists in the venous phase (c), indicating active arterial bleeding. Moreover, in the venous phase a bleeding focus is better appreciated in the proximal sigmoid colon.
Patient underwent an endoscopic procedure to stop the bleeding and 5 days later another CT scan was performed.
(d-e) Sagittal reconstruction shows active arterial blush of medium contrast at rectosigmoid junction (d) and proximal sigmoid colon (e).
(f-g-h) Unenhanced CT images show persistence of hyperdense fluid in rectal ampulla (d) without signs of active bleeding in sigmoid colon or rectum, on the arterial (e) and venous phases (f).

Figure 5. A 64-year-old man, three months after COVID-19 infection, underwent routine MRI for follow-up of pancreatic intraductal papillary mucinous neoplasm (IPMN). Axial T1-weighted "in phase" image (a) shows a diffuse liver hyperintensity, while axial T1-weighted "opposite phase" (b) demonstrates a loss of signal in the hepatic parenchyma, suggesting hepatic steatosis. On the previous MRI, performed about 6 months earlier, no appreciable differences were found in signal intensity between the axial T1-weighted image "in phase" (c) and "opposite phase" (d) images at the level of the liver parenchyma, strongly suggesting that the hepatic steatosis increased after the COVID-19 infection.

Figure 6. A 72-year-old man who presented to the emergency department for cholecystitis two weeks after severe COVID-19 infection. (a, b) Axial CT with contrast on portal venous phase imaging shows an enlarged gallbladder with mural thickening and

hypervascularization, with hyperdense calcium stones in the infundibular region, with no biliary tree dilatation.

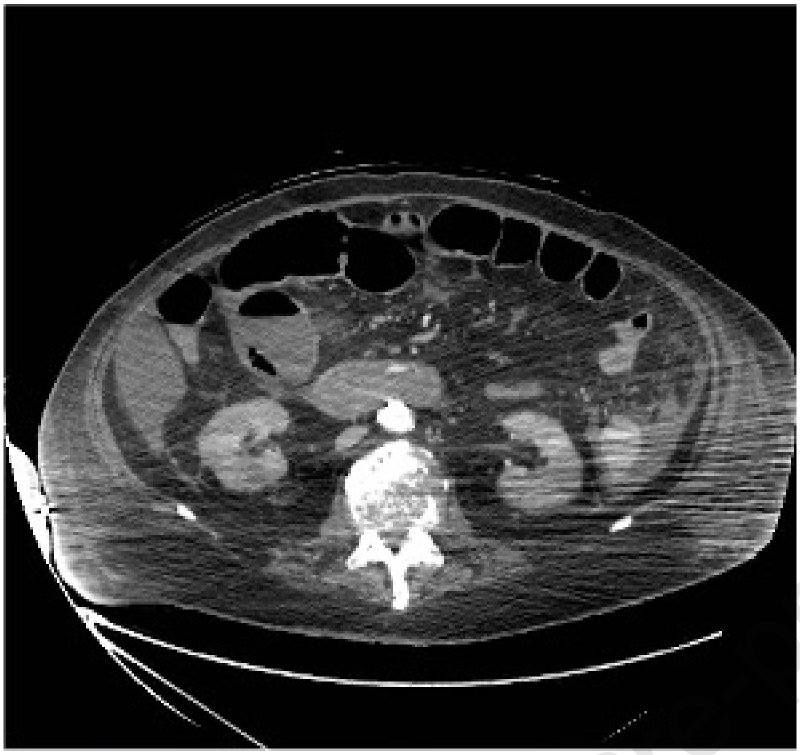
The patient underwent placement of a percutaneous cholecystostomy tube for gallbladder drainage. The procedure was performed with the combined ultrasonography and fluoroscopy. The gallbladder fundus was punctured under ultrasound guidance. (c) A pigtail catheter was inserted under fluoroscopic guidance to aspirate purulent bile from the gallbladder. The gallbladder was decompressed at the end of the procedure. (d, e) Axial contrast-enhanced CT scans at the portal venous phase show the gallbladder size was reduced after drainage.

Figure 7. A 69-year-old male patient with COVID-19 associated SSC after severe COVID-19 infection. (a) Axial fat suppressed propeller T2-weighted image shows hepatic contours are rounded, caudate lobe is enlarged, hyperintense signal changes in the liver parenchyma, particularly along the periportal-biliary spaces, and slight dilatation of the biliary tree. (b) High b-value diffusion-weighted image also demonstrates subcapsular and central-hepatic areas of signal changes with mild diffusion restriction. (c) Maximum intensity projection MRCP image shows irregularities of the intrahepatic bile ducts with multifocal strictures and dilatations, while the extrahepatic biliary tree appears dilated due to stenosis of the hypertrophied papilla. (d) Axial and (e) coronal post-contrast T1-weighted images in the hepatobiliary phase show patchy hypointense parenchymal areas of decreased contrast enhancement with lack of excretion within the corresponding bile ducts.

Figure 8. A 79-year-old man with COVID-19-related slight respiratory symptoms developed acute abdominal pain 10 days later. Patient presented to the emergency department and underwent an abdominal CT scan for a significantly increased serum amylase and lipase. (a-b) Axial contrast-enhanced CT images show loss of the normal pancreatic lobulation of the pancreatic head, and fluid collections in the peripancreatic space and in the anterior pararenal spaces. Axial magnetic resonance T2-weighted (c) and axial T2-weighted fat-sat-suppression image (d), obtained 10 days after the onset of AP, reveal peripancreatic fat stranding and the resolution of fluid collections. (e) Axial fat-suppressed T1-weighted image exhibits high signal intensity foci in the pancreas and peripancreatic fat tissue, consistent with necrotic/haemorrhagic components. (f) Thick-slab MR cholangiopancreatography (MRCP) demonstrates a normal calibre of the pancreatic and biliary ductal system.

Figure 9. A 17-year-old woman was hospitalised for the onset of conjunctivitis, joint pain, bilateral palmar erythema, cutaneous manifestations to the lower limb and abdominal pain 1 year after COVID-19 infection. (a) CECT scan shows an enlarged pancreas with loss of the normal pancreatic lobulation. Peri-splenic fluid collection is also present. (b-c) Axial MR T2-weighted fat-sat-suppression PROPELLER images demonstrate patchy inhomogeneous pancreatic parenchyma with areas of high signal intensity. The main pancreatic duct is not dilated. (d) Reduced FOV (Field-of-View) diffusion weighted image with a *b* value of 1000 sec/mm² well exhibits areas of proton diffusivity restriction in the pancreatic parenchyma. (e-f) An inhomogeneous contrast uptake after gadolinium injection was observed on T1-weighted LAVA (Liver Acquisition with Volume Acceleration) sequences.

Figure 10. A 78-year-old woman presented to the emergency room for abdominal pain, nausea and vomiting. Intestinal obstruction was suspected. (a) Axial CECT on portal-venous phase shows peripancreatic heterogeneous fluid collections, fat stranding and splenic vein thrombosis. (b) Coronal reconstruction of CECT image on portal-venous phase demonstrates hypoattenuating region in the head and body of the pancreas (consistent with parenchymal necrosis) along with ill-defined heterogeneous peripancreatic fluid collections, and mesenteric vein thrombosis. (c) Axial CECT image in the arterial phase, acquired 2 weeks later for worsening abdominal pain, reveals an extravasation of contrast material within the peripancreatic necrotic collection, a finding that is suggestive of haemorrhage. (d) Digital subtraction angiography (DSA) obtained after super-selective catheterization of a dorsal pancreatic artery branch confirms active bleeding. (e) Angiography post-embolization confirmed adequate vessel occlusion. (f) Axial CECT image obtained 5 weeks after the onset of AP demonstrates a well-defined walled-off-necrosis (WON) in the body of the pancreas measuring 9x6 cm. Note the naso-jejunal feeding tube in the stomach and jejunum, that was inserted to bypass the mass effect determined by the WON. (g) Transabdominal US image reveals a well-defined hypoechoic collection with internal echogenic spots consisting of solid necrotic/haemorrhagic debris.

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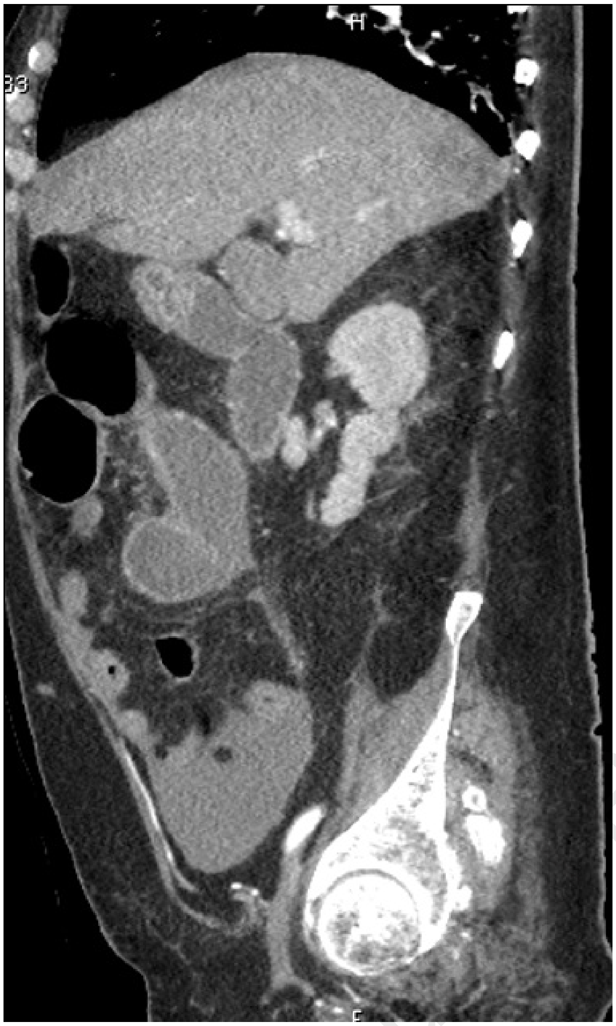

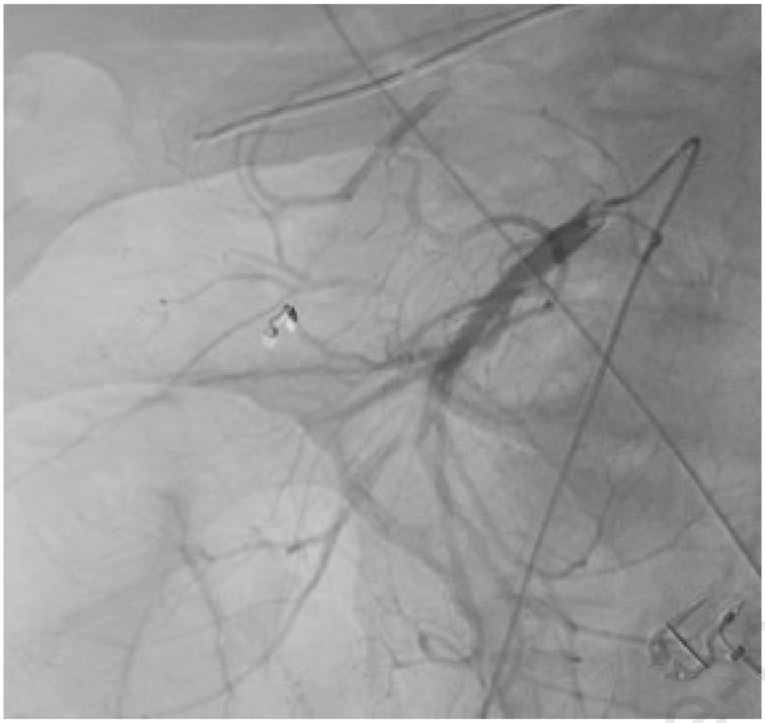

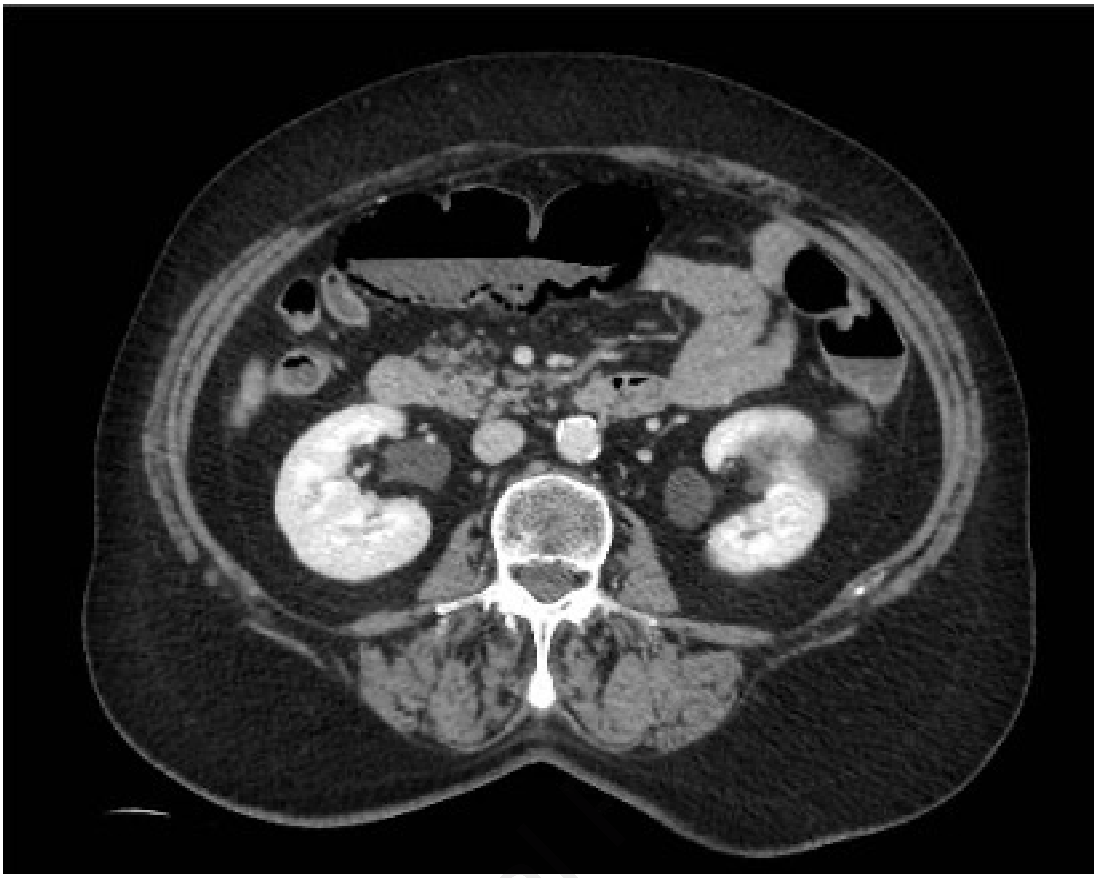

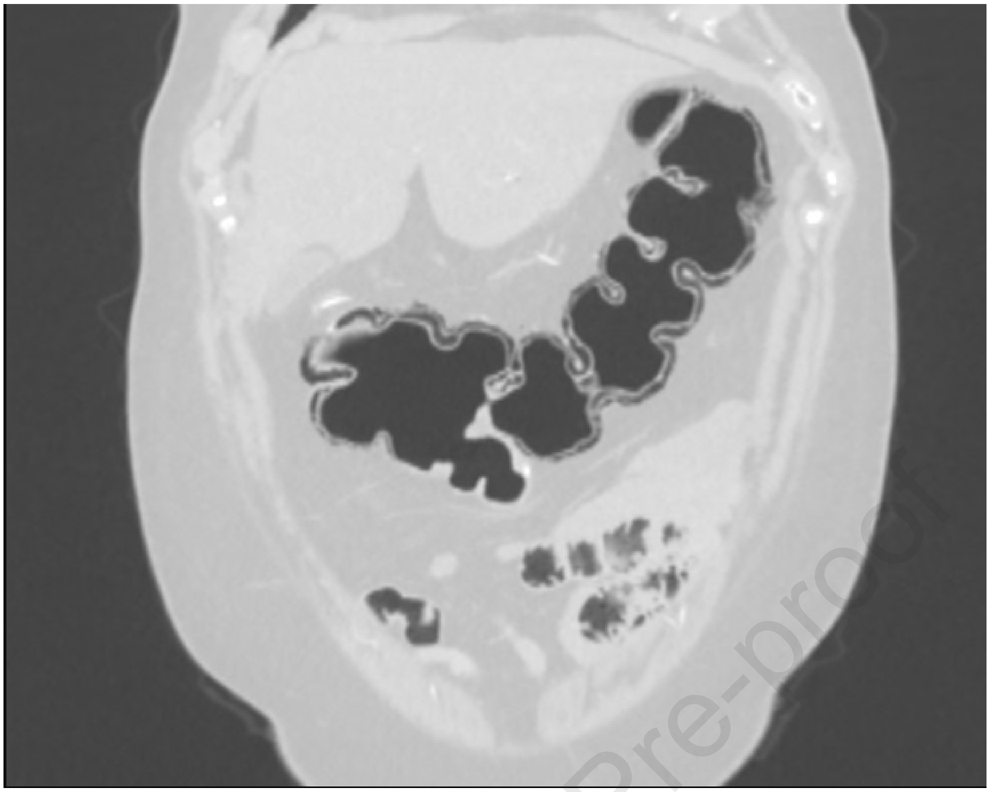

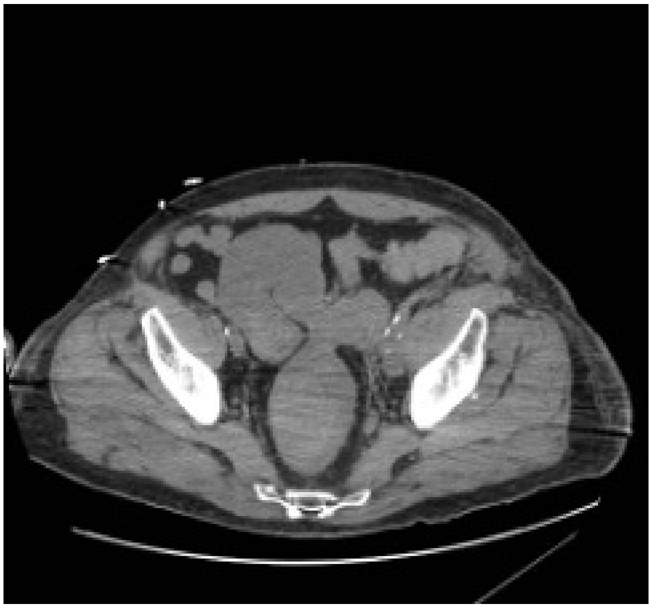

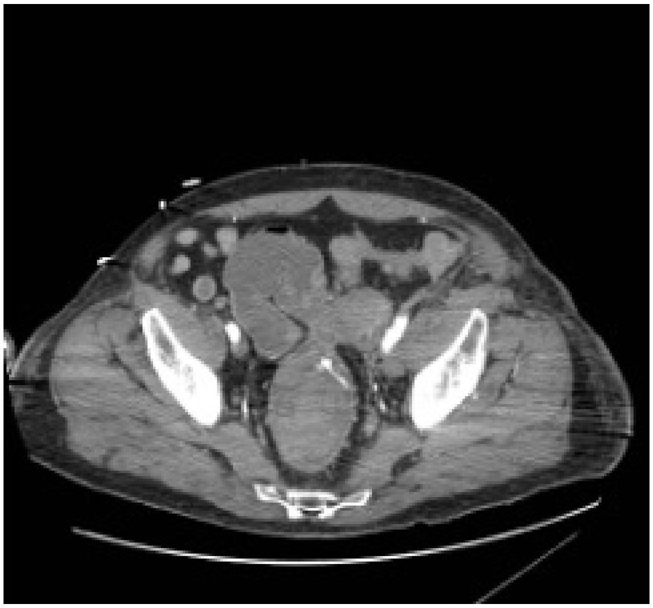

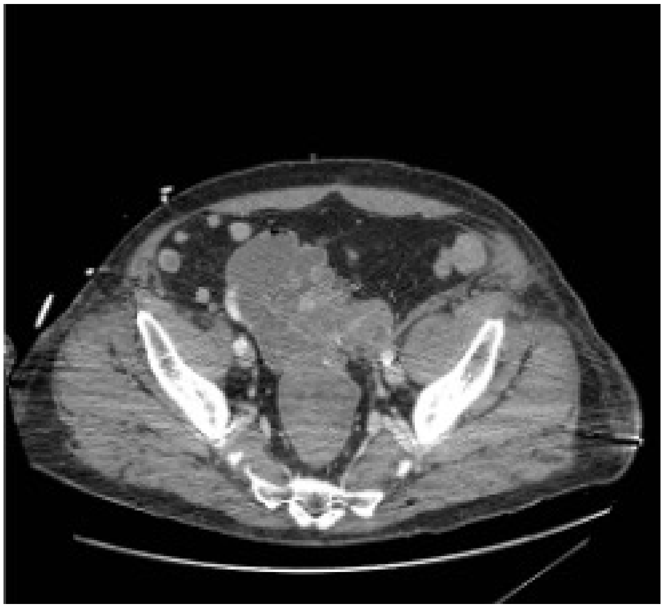


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