

Acute Mesenteric Ischemia and Ischemic Bowel Complications in Patients with COVID-19: A Six-Case Series

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ABSTRACT

Background: Coronavirus disease 2019 (COVID-19) is associated with systemic inflammation, endothelial dysfunction, and thromboembolic complications. Acute mesenteric ischemia is an uncommon but life-threatening abdominal manifestation that may rapidly progress to bowel infarction, gangrene, or perforation. **Materials and Methods:** We describe six reverse transcription-polymerase chain reaction-confirmed COVID-19 patients who developed acute mesenteric ischemia or related ischemic bowel complications during the first pandemic wave between March and October 2020. Clinical presentation, laboratory findings, chest and abdominal computed tomography (CT) findings, operative details, histopathology, anticoagulation, and short-term outcomes were reviewed. **Results:** The patients included three men and three women aged 50–73 years. All had acute abdominal symptoms and were subjected to emergency laparotomy and bowel resection. Three patients had superior mesenteric artery thrombosis, one of whom had splenic artery thrombosis and another had portal venous gas. One patient developed sigmoid-colon ischemia with suspected partial inferior mesenteric artery thrombosis, one had probable non-occlusive mesenteric ischemia, and one developed ischemic ileal perforation without major-vessel thrombosis. Four patients had pneumatosis intestinalis or coli. All six cases had transmural ischemic necrosis with fibrin thrombi in intraluminal or submucosal vessels on histopathological examination. Five patients received unfractionated heparin, and one patient with probable non-occlusive mesenteric ischemia did not receive anticoagulation. The early postoperative mortality rate was 66.7% (4 patients). At 3-month follow-up, the two survivors were asymptomatic. **Conclusion:** Intestinal ischemia associated with COVID-19 can be caused by large-vessel arterial thrombosis, non-occlusive ischemia, or microvascular thrombosis and can manifest as bowel gangrene or perforation. In patients with COVID-19, persistent or severe abdominal symptoms should be evaluated promptly with contrast-enhanced CT and early surgical evaluation. Even with emergency intervention, mortality is high after the development of transmural bowel necrosis.

Keywords: Acute mesenteric ischemia, Bowel gangrene, Bowel ischemia, Case series, Coronavirus disease 2019, Emergency laparotomy, Pneumatosis intestinalis, Portal venous gas, Superior mesenteric artery thrombosis

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INTRODUCTION

Coronavirus disease 2019 (COVID-19), caused by severe acute respiratory syndrome coronavirus 2, was initially recognized predominantly as a respiratory illness but was subsequently shown to involve multiple organ systems. The hypercoagulable state of COVID-19 is due to vascular endothelial injury, systemic inflammation, platelet activation, and abnormalities of coagulation and fibrinolysis.^[1,2] Early evidence for the occurrence of both macrovascular and microvascular thrombotic complications came from endothelial involvement in various vascular beds and from evidence of hypercoagulability on thromboelastographic studies in critically ill patients.^[1,2] Acute mesenteric ischemia is a rare but life-threatening abdominal emergency caused by decreased blood supply to the intestine. It can be caused by arterial embolism or thrombosis, mesenteric venous thrombosis, non-occlusive hypoperfusion, or microvascular thrombosis. Possible mechanisms proposed in COVID-19 patients include systemic hypercoagulability, endothelial dysfunction, inflammation-mediated thrombosis, hypoxia, hemodynamic compromise, and potential direct injury to the intestine due to angiotensin-converting enzyme 2 expression in enterocytes.^[3-5] Thus, the ischemic spectrum can be more than just occlusion of a large mesenteric vessel and may involve non-occlusive ischemia, small vessel thrombosis, bowel infarction, and perforation. The clinical diagnosis may be challenging due to the possibility of abdominal pain, vomiting, diarrhea, and abdominal distention being misdiagnosed as non-specific gastrointestinal symptoms of COVID-19. Contrast-enhanced computed tomography (CECT) or

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CT angiography is therefore essential for early diagnosis and may show arterial or venous filling defects, decreased enhancement of the bowel wall, bowel wall thickening, mesenteric edema, pneumatosis intestinalis, portal venous gas, solid-organ infarction, or pneumoperitoneum.^[4,6] Pneumatosis and portal venous gas are especially worrisome if mural enhancement is diminished or there are peritoneal signs, which can be signs of advanced ischemia and bowel necrosis. Imaging-pathology correlations published in COVID-19 have also shown ischemic enteritis, transmural necrosis, and fibrin thrombi in submucosal arterioles, suggesting a role for microvascular thrombosis in patients without obvious large-vessel occlusion.^[4] Acute mesenteric ischemia is a rare but serious complication of COVID-19, with significant morbidity

and mortality reported in those who develop it, especially if it is delayed in diagnosis and emergency bowel resection is required.^[5-7] Gastrointestinal issues such as mesenteric ischemia have also been reported to be more common in critically ill COVID-19 patients than in similar patients with non-COVID-19 acute respiratory distress syndrome.^[7] We report six COVID-19 patients with acute mesenteric ischemia or ischemic bowel complications confirmed by reverse transcription-polymerase chain reaction (RT-PCR) during the first wave of the pandemic. The series outlines the clinical presentation, radiological spectrum, operative findings, histopathological correlation, management, and short-term outcome of patients who require emergency surgical intervention.

MATERIALS AND METHODS

Study Design and Case Selection

This retrospective descriptive case series included six patients with RT-PCR-confirmed COVID-19 who developed acute mesenteric ischemia or related ischemic bowel complications during the first pandemic wave, between March and October 2020. All patients presented with an acute abdomen and underwent emergency surgical exploration.

Patients were included when they fulfilled the following criteria: Confirmed severe acute respiratory syndrome coronavirus 2 infection by RT-PCR; clinical and radiological suspicion of intestinal ischemia, bowel infarction, or ischemic perforation; and operative confirmation of ischemic or gangrenous bowel requiring resection. The series included patients with large-vessel mesenteric arterial thrombosis, probable non-occlusive mesenteric ischemia, and microvascular ischemic injury without demonstrable major-vessel occlusion.

Data Collection

Clinical data were gathered from hospital records, operative notes, radiological reports, histopathology reports, and follow-up documentation. The variables collected included age, sex, presenting symptoms, comorbidities, blood pressure, pulse rate, oxygen saturation, abdominal examination findings, total leukocyte count (TLC), platelet count, D-dimer, C-reactive protein, international normalized ratio (INR), and chest CT severity score.

Abdominal contrast-enhanced CT was reviewed for the presence of mesenteric arterial thrombosis, decreased bowel-wall enhancement, bowel-wall thickening, mesenteric edema, pneumatosis intestinalis or coli, portal venous gas, solid-organ infarction, pneumoperitoneum, and associated intra-abdominal abnormalities. In some instances, the exact numerical values of D-dimer and C-reactive protein were not available and were therefore recorded qualitatively.

Treatment and Outcome Assessment

Initial treatment consisted of intravenous (IV) fluid resuscitation, nasogastric decompression, urinary catheterization, IV antibiotics, analgesics, antipyretics, antiemetics, oxygen supplementation as needed, and correction of electrolyte abnormalities. In selected patients, unfractionated heparin (UFH) was used as per the treating team's assessment.

Emergency laparotomy was performed on all six patients. Operative details included location and severity of bowel ischemia, presence of gangrene or perforation, length of bowel resected, thrombectomy performed, type of anastomosis or stoma, and intraoperative evaluation of bowel viability. Histopathological examination of resected specimens was performed for transmural ischemic necrosis, hemorrhage, perforation, and fibrin thrombi in intraluminal or submucosal vessels.

The outcome of the surgery was evaluated in terms of survival, early postoperative mortality, discharge status, and follow-up at 3 months if available.

Ethical Considerations

The study was conducted in accordance with institutional ethical standards. Ethical approval was obtained, and consent for publication of de-identified clinical information and images was obtained from the patients or their legally authorized representatives.

RESULTS

Baseline Clinical and Laboratory Characteristics

Six patients with RT-PCR-confirmed COVID-19 developed acute mesenteric ischemia or related ischemic bowel complications requiring emergency surgery between March and October 2020. The cohort included three men and three women, with ages ranging from 50 to 73 years. Abdominal pain was present in all patients and was accompanied by varying combinations of abdominal distension, bilious vomiting, constipation or obstipation, loose stools, and fever. Dyspnea and productive cough were prominent in one patient.

Systemic hypertension was present in two patients, one of whom also had a previous cerebrovascular accident (CVA) and was receiving antihypertensive and antiplatelet therapy. The remaining patients had no recorded major comorbidities, although one patient had a history of alcohol use.

All patients were tachycardic at presentation, with pulse rates ranging from 100 to 120 beats/min. Oxygen saturation on room air ranged from 88% to 98%. Abdominal examination showed distension and diffuse tenderness in all cases. Guarding was present in five patients, rigidity in one, and bowel sounds were absent or sluggish in all six.

Leukocytosis was present in every patient, with TLC s ranging from 16,000 to 22,196/ μ L. D-dimer and C-reactive protein were elevated in five patients and normal in one patient with probable non-occlusive mesenteric ischemia. Platelet counts were normal in four patients and were 1 lakh/ μ L and 1.1 lakh/ μ L in two patients. INR values ranged from 0.9 to 1.1. Baseline clinical and laboratory characteristics are summarized in Table 1.

Thoracic and Abdominal Imaging Findings

Chest CT demonstrated bilateral ground-glass opacities in four patients, multifocal and multisegmental bilateral ground-glass opacities in one, and patchy right upper-lobe fibrotic changes consistent with resolving post-infective sequelae in one. CT severity scores ranged from 2/25 to 15/25.

Abdominal CECT confirmed superior mesenteric artery (SMA) thrombosis in three patients. Case 1 showed SMA

Table 1: Baseline clinical characteristics

Case	Age/sex	Main presenting symptoms	Comorbidities/Relevant history	SpO ₂ on room air (%)	TLC (/μL)
1	64/F	Abdominal pain, bilious vomiting, loose stools, and high-grade fever	Systemic hypertension for 10 years	94	16,000
2	50/F	Dyspnea, productive cough, abdominal pain, and high-grade fever	None recorded	88	19,500
3	60/M	Abdominal pain and distension, obstipation, bilious vomiting, and fever	Systemic hypertension; previous cerebrovascular accident; on antihypertensive and antiplatelet therapy	95	17,000
4	52/M	Constipation, abdominal pain, and high-grade fever	No major comorbidity; alcohol use for 5 years	98	20,100
5	73/M	Intermittent abdominal pain, worsening over 2 days, bilious vomiting, and high-grade fever	None recorded	92	22,196
6	53/F	Abdominal pain and distension, constipation, bilious vomiting, and high-grade fever	None recorded	95	18,230

SpO₂: Peripheral oxygen saturation, TLC: Total leukocyte count, F: Female, M: Male

thrombosis with pneumatosis intestinalis involving the jejunal and ileal loops. Case 2 showed SMA thrombosis with jejunal pneumatosis intestinalis and associated splenic artery thrombosis with multiple splenic infarcts. Case 5 showed SMA thrombosis, reduced small-bowel mural enhancement, pneumatosis intestinalis, and portal venous gas involving the main portal vein and its branches.

Case 3 showed dilated jejunal and proximal ileal loops with multiple air-fluid levels, decreased mural enhancement of the distal ileum, bowel-wall thickening, and mesenteric edema, without demonstrable SMA, inferior mesenteric artery (IMA), or mesenteric thrombosis. These findings supported probable non-occlusive mesenteric ischemia. Case 4 showed pneumatosis coli and ischemic changes involving the sigmoid colon, with suspected partial IMA thrombosis. Case 6 showed pneumoperitoneum, distal ileal wall thickening, decreased mural enhancement, and possible ischemic changes, without evidence of SMA or IMA thrombosis.

The radiological findings therefore demonstrated a spectrum ranging from confirmed large-vessel arterial occlusion to probable non-occlusive and microvascular ischemic injury. Representative radiological findings for all six cases are shown in Figure 1a-f. The principal abdominal imaging findings are summarized in Table 2.

Operative Findings and Surgical Management

All six patients underwent emergency laparotomy and bowel resection.

In Case 1, SMA thrombectomy was performed with vascular surgical assistance, followed by resection of a 25-cm gangrenous ileal segment located approximately 50 cm proximal to the ileocecal junction and end-to-end anastomosis.

In Case 2, approximately 50 cm of gangrenous distal jejunum was resected. The proximal end of the ischemic segment was located approximately 200 cm distal to the duodenojejunal flexure, and an end-to-end jejunal anastomosis was performed.

Case 3 had approximately 70 cm of gangrenous ileum, with the distal end located approximately 50 cm proximal to the ileocecal junction. No adhesive band or other mechanical cause of obstruction was identified. The affected bowel was resected, followed by ileoileal anastomosis.

Case 4 had ischemic and gangrenous sigmoid colon and underwent sigmoid resection with Hartmann's procedure,

including a proximal descending colostomy and closure of the distal rectal stump.

Case 5 had approximately 180 cm of gangrenous small bowel extending from around 80 cm distal to the duodenojejunal flexure to around 150 cm proximal to the ileocecal junction. The ischemic segment was resected, and a proximal jejunostomy with distal ileostomy was created.

In Case 6, approximately 500 mL of seropurulent intraperitoneal fluid with fibrinous flakes was encountered. A 1.5 × 1.5-cm perforation was present along the mesenteric border of the ileum, approximately 20 cm proximal to the ileocecal junction. Around 5 cm of bowel on either side appeared dusky but regained only partial viability following warm-pad compression and administration of 100% oxygen. An approximately 15-cm perforated ileal segment was resected, followed by end-to-end ileoileal anastomosis.

The corresponding operative findings are shown in Figure 2a-f. The corresponding operative findings and surgical procedures are also summarized in Table 2.

Histopathological Findings

Histopathological examination confirmed transmural ischemic necrosis in all six patients. Intraluminal fibrin thrombi were identified in Cases 1 and 2, both of whom had confirmed SMA thrombosis. Fibrin thrombi within submucosal vessels were demonstrated in Cases 3, 4, 5, and 6.

Case 3 showed transmural ischemic necrosis with mucosal hemorrhage and fibrin thrombi in the submucosal vessels despite the absence of major mesenteric arterial occlusion on CECT. Case 6 showed transmural ischemic necrosis with focal perforation and fibrin thrombi in the submucosal vessels. These findings supported both macrovascular and microvascular thrombotic mechanisms across the series. Histopathological findings are summarized in Table 3.

Anticoagulation and Supportive Treatment

All patients received IV fluid resuscitation, nasogastric decompression, urinary catheterization, IV antibiotics, analgesics, antipyretics, and antiemetics. Oxygen supplementation was administered when required.

UFH at a dose of 5000 IU intravenously every 6 h was started preoperatively and continued postoperatively in Cases

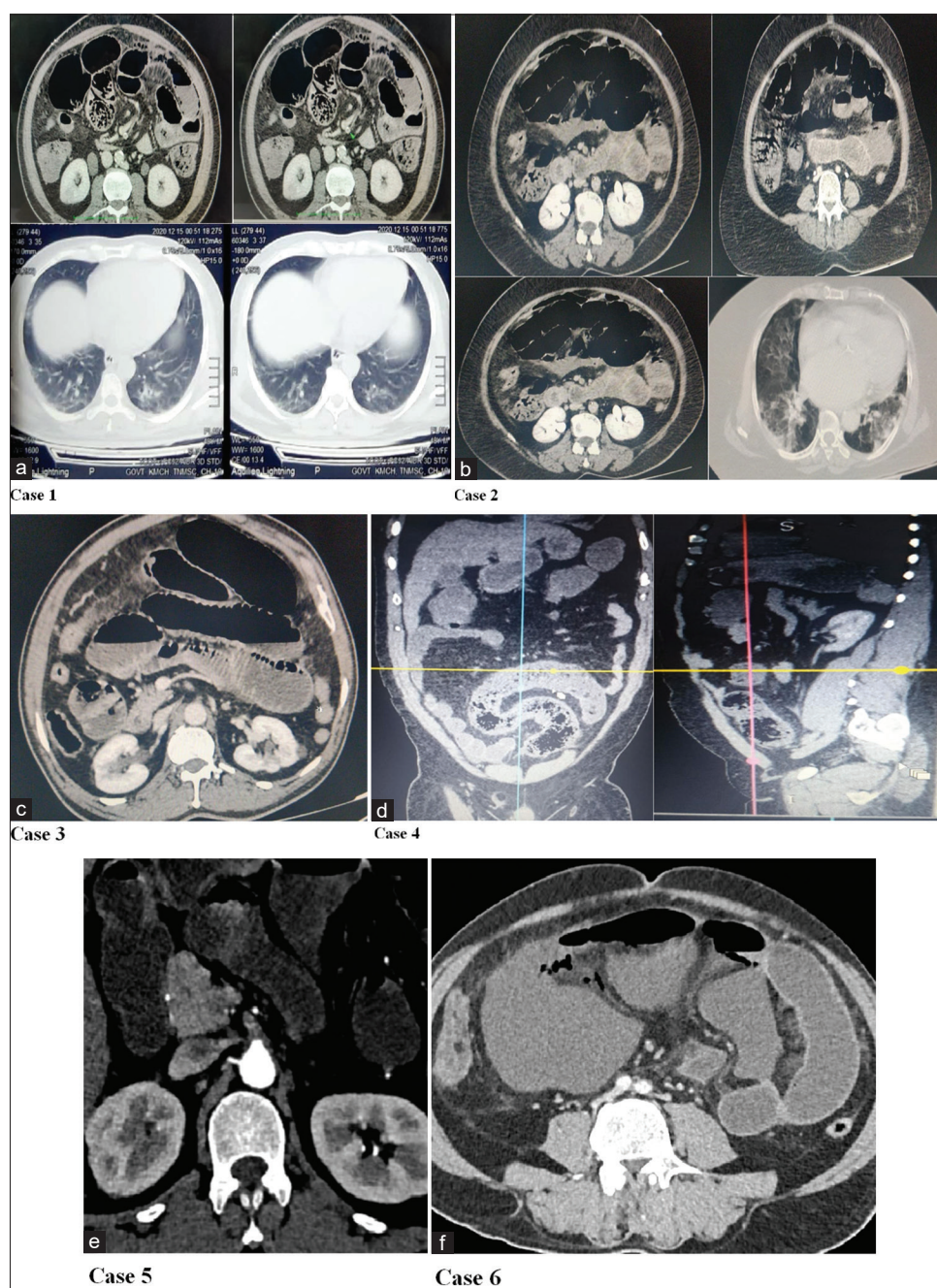


Figure 1: Radiological findings in Cases 1–6. (a) Case 1: Contrast-enhanced computed tomography (CT) abdomen showing superior mesenteric artery (SMA) thrombosis with pneumatosis intestinalis involving the jejunal and ileal loops. (b) Case 2: Contrast-enhanced CT abdomen showing SMA thrombosis with jejunal pneumatosis and associated splenic infarction due to splenic artery thrombosis. (c) Case 3: Contrast-enhanced CT abdomen showing dilated jejunal and proximal ileal loops, reduced distal ileal mural enhancement, bowel-wall thickening and mesenteric edema, without demonstrable major mesenteric arterial thrombosis. (d) Case 4: Contrast-enhanced CT abdomen showing pneumatosis coli and ischemic changes involving the sigmoid colon, with suspected partial inferior mesenteric artery thrombosis. (e) Case 5: Contrast-enhanced CT abdomen showing SMA thrombosis, reduced small-bowel mural enhancement, pneumatosis intestinalis, and portal venous gas. (f) Case 6: CT abdomen showing free intraperitoneal air consistent with pneumoperitoneum, with distal ileal ischemic changes and no demonstrable major mesenteric arterial thrombosis

1, 2, 4, and 5. Case 3 did not receive anticoagulation. In Case 6, postoperative UFH was administered, subsequently tapered, and discontinued.

COVID-19-directed treatment during the first pandemic wave included ivermectin, azithromycin, Vitamin C, and zinc in all patients, with methylprednisolone additionally

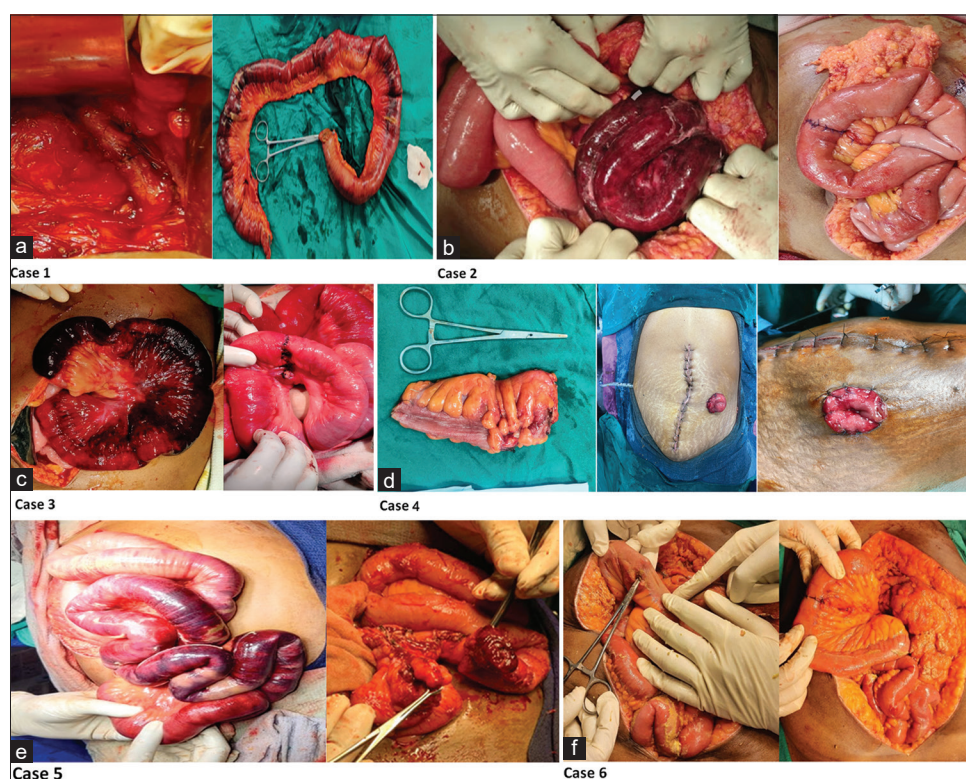


Figure 2: Operative findings in Cases 1–6. (a) Case 1: Intraoperative image showing a gangrenous ileal segment; superior mesenteric artery thrombectomy and ileal resection and end-to-end anastomosis were performed. (b) Case 2: Intraoperative image showing gangrenous distal jejunum requiring resection and end-to-end jejunal anastomosis. (c) Case 3: Intraoperative image showing a gangrenous ileal segment in the absence of an adhesive band or other mechanical obstructive cause, requiring resection and ileoileal anastomosis. (d) Case 4: Intraoperative image showing ischemic and gangrenous sigmoid colon requiring resection and Hartmann's procedure. (e) Case 5: Intraoperative image showing extensive small-bowel gangrene requiring resection and formation of a proximal jejunostomy and distal ileostomy. (f) Case 6: Intraoperative image showing an ileal perforation along the mesenteric border with adjacent ischemic bowel requiring resection and ileoileal anastomosis

Table 2: Radiological and operative findings

Case	Abdominal CECT findings	Operative findings	Surgical procedure
1	SMA thrombosis; pneumatosis intestinalis involving jejunal and ileal loops	25-cm gangrenous ileal segment approximately 50 cm proximal to the ileocecal junction	SMA thrombectomy, ileal resection, and end-to-end anastomosis
2	SMA thrombosis; jejunal pneumatosis; splenic artery thrombosis with multiple splenic infarcts	50-cm gangrenous distal jejunum, beginning approximately 200 cm distal to the duodenojejunal flexure	Jejunal resection and end-to-end jejunal anastomosis
3	Dilated jejunal and proximal ileal loops; reduced distal ileal enhancement; bowel-wall thickening and mesenteric edema; no major mesenteric arterial thrombosis	70-cm gangrenous ileum; no adhesive band or mechanical obstructive cause	Ileal resection and ileoileal anastomosis
4	Pneumatosis coli and sigmoid-colon ischemia; suspected partial IMA thrombosis	Ischemic/gangrenous sigmoid colon	Sigmoid resection and Hartmann's procedure
5	SMA thrombosis; pneumatosis intestinalis; reduced small-bowel enhancement; portal venous gas	180-cm gangrenous small bowel extending from about 80 cm distal to the duodenojejunal flexure to about 150 cm proximal to the ileocecal junction	Small-bowel resection, proximal jejunostomy, and distal ileostomy
6	Pneumoperitoneum; distal ileal wall thickening and reduced mural enhancement; no major-vessel thrombosis	1.5×1.5-cm ileal perforation, 20 cm proximal to the ileocecal junction, with adjacent dusky bowel	Resection of approximately 15 cm of ileum and end-to-end ileoileal anastomosis

CECT: Contrast-enhanced computed tomography, IMA: Inferior mesenteric artery, SMA: Superior mesenteric artery

Table 3: Histopathology, anticoagulation, and outcomes

Case	Histopathology	Anticoagulation	Postoperative outcome
1	Transmural necrosis with intraluminal fibrin thrombus	UFH 5000 IU IV every 6 h, started preoperatively and continued postoperatively	Died on postoperative day 2 following cardiac arrest
2	Transmural necrosis with intraluminal fibrin thrombi	UFH 5000 IU IV every 6 h, started preoperatively and continued postoperatively	Died on postoperative day 1 following cardiopulmonary arrest
3	Transmural ischemic necrosis with mucosal hemorrhage and fibrin thrombi in submucosal vessels	Not given	Survived; asymptomatic at 3 months with normal bowel and bladder habits
4	Transmural bowel-wall necrosis with fibrin thrombi in submucosal vessels	UFH 5000 IU IV every 6 h, started preoperatively and continued postoperatively	Died on postoperative day 2 following cardiac arrest
5	Transmural bowel-wall necrosis with fibrin thrombi in submucosal vessels	UFH 5000 IU IV every 6 h, started preoperatively and continued postoperatively	Died on postoperative day 2 following cardiopulmonary arrest
6	Transmural ischemic necrosis with focal perforation and fibrin thrombi in submucosal vessels	Postoperative UFH, subsequently tapered and discontinued	Survived; uneventful recovery and asymptomatic at 3 months

IV: Intravenous, UFH: Unfractionated heparin

administered in Case 2. Anticoagulation details are presented in Table 3.

Outcomes

Four of the six patients died during the early postoperative period, corresponding to an overall mortality rate of 66.7%. Case 1 died of cardiac arrest on postoperative day 2, Case 2 died of cardiopulmonary arrest on postoperative day 1, Case 4 died of cardiac arrest on postoperative day 2, and Case 5 died of cardiopulmonary arrest on postoperative day 2.

Cases 3 and 6 survived to discharge. Both had uneventful postoperative recovery and remained asymptomatic at 3-month follow-up. Case 3 had normal bowel and bladder habits, while no subsequent postoperative complications were reported in Case 6.

Postoperative outcomes and follow-up are summarized in Table 3.

Individual Case Summaries

Case 1

A 64-year-old female patient with systemic hypertension presented with abdominal pain, bilious vomiting, loose stools, and high-grade fever for 3 days. She was tachycardic, with a pulse rate of 110/min, and had an oxygen saturation of 94% on room air. Abdominal examination showed distention, diffuse tenderness, guarding, and no bowel sounds. Laboratory examination revealed leukocytosis (WBC 16,000/ μ L) and high levels of D-dimer and C-reactive protein. Chest CT revealed bilateral ground-glass opacities and a CT severity score of 8/25. Abdominal CECT demonstrated SMA thrombosis with pneumatosis intestinalis involving the jejunal and ileal loops. After resuscitation and starting UFH, the patient was taken to the operating room for emergency laparotomy and SMA thrombectomy with vascular surgical support. About 25 cm of ileum was resected, and end-to-end anastomosis was performed, about 50 cm proximal to the ileocecal junction. Histopathology showed transmural necrosis with an intraluminal fibrin thrombus. The patient died of cardiac arrest on postoperative day 2.

Case 2

A 50-year-old woman presented with dyspnea at rest, productive cough for 1 week, abdominal pain, and high-grade fever for 1 day. She was hypotensive and tachycardic, with a blood pressure of 90/60 mmHg, pulse rate of 120/min, and oxygen saturation of 88% on room air. Abdominal distention, guarding, rigidity, and sluggish bowel sounds were present. The TLC was 19,500/ μ L, and D-dimer and C-reactive protein were significantly elevated. Chest CT showed multifocal, multiseptal bilateral ground-glass opacities, with a CT severity score of 15/25. Abdominal CECT revealed pneumatosis intestinalis, SMA thrombosis, and multiple splenic infarcts due to splenic artery thrombosis. After resuscitation and preoperative UFH, emergency laparotomy was performed. The distal 50 cm of the jejunum was resected, and the proximal margin was about 200 cm distal to the duodenojejunal flexure. An end-to-end jejunal anastomosis was performed. Histopathology showed transmural necrosis with intraluminal fibrin thrombi. The patient died of cardiopulmonary arrest on postoperative day 1.

Case 3

A 60-year-old male patient with a history of systemic hypertension and previous CVA came with complaints of diffuse abdominal pain and distention, obstipation, and bilious vomiting for 4 days and high-grade fever for 2 days. He was on antihypertensive and antiplatelet drugs. Abdominal examination revealed diffuse tenderness, guarding, and no bowel sounds. The TLC was 17,000/ μ L, and D-dimer, C-reactive protein, platelet count, and INR were normal. Chest CT revealed patchy fibrotic changes in the right upper lobe, which were compatible with resolving post-infective sequelae, and a CT severity score of 2/25.

Abdominal CECT revealed dilated jejunal and proximal ileal loops with multiple air-fluid levels, decreased mural enhancement of the distal ileum, bowel wall thickening, and mesenteric edema, but no SMA, IMA, or mesenteric thrombosis. At laparotomy, about 70 cm of gangrenous ileum was found, but no adhesive band or other mechanical cause was identified. Resection and ileoileal anastomosis were done. Transmural ischemic necrosis, mucosal hemorrhage, and fibrin thrombi in submucosal vessels were identified on histopathology, supporting probable non-occlusive

mesenteric ischemia. The postoperative period was uneventful, and the patient was asymptomatic at 3-month follow-up with normal bowel and bladder habits.

Case 4

A 52-year-old man with no significant comorbidities and a history of alcohol use for 5 years presented with constipation for 4 days and abdominal pain with high-grade fever for 1 day. He was tachycardic, with a pulse rate of 108/min, and had an oxygen saturation of 98% on room air. Abdominal examination revealed distention, diffuse tenderness, guarding in the left iliac region, and no bowel sounds. The TLC was 20,100/ μ L, and the D-dimer and C-reactive protein were elevated. Chest CT showed bilateral basal ground-glass opacities with a CT severity score of 6/25.

Abdominal CECT showed pneumatosis coli and ischemic changes in the sigmoid colon with suspected partial thrombosis of IMA. Post-resuscitation and UFH, emergency laparotomy was performed, which showed ischemic and gangrenous sigmoid colon. Sigmoid resection with Hartmann's procedure was performed, including proximal descending colostomy and closure of the distal rectal stump. Histopathology revealed transmural necrosis of the bowel wall with fibrin thrombi in the submucosal vessels. The patient died of cardiac arrest on postoperative day 2.

Case 5

A 73-year-old man presented with intermittent abdominal pain for about 1 month, worsening in the past 2 days, with high-grade fever and bilious vomiting for 2 days. His blood pressure was 96/66 mmHg, pulse rate 106/min, and oxygen saturation 92% on room air. The abdomen was distended, with diffuse tenderness, guarding, and absent bowel sounds. The TLC was 22,196/ μ L, platelet count was 1.1 lakh/ μ L, and D-dimer and C-reactive protein were significantly raised. Chest CT revealed diffuse bilateral ground-glass opacities and a CT severity score of 12/25.

Abdominal CECT showed SMA thrombosis, pneumatosis intestinalis, poor mural enhancement of the small bowel, and gas in the main portal vein and its branches. Emergency laparotomy showed about 180 cm of gangrenous small bowel from about 80 cm distal to the duodenojejunal flexure to about 150 cm proximal to the ileocecal junction. Ischemic bowel was resected, and a proximal jejunostomy and distal ileostomy were performed. Histopathology revealed transmural necrosis of the bowel wall with fibrin thrombi in the submucosal vessels. On postoperative day 2, the patient suffered from cardiopulmonary arrest and died.

Case 6

A 53-year-old female presented with abdominal pain, distention, and constipation for 3 days, followed by bilious vomiting and high-grade fever for 2 days. Her heart rate was 118/min, and her oxygen saturation was 95% on room air. Abdominal examination showed distention, diffuse tenderness, guarding, and no bowel sounds. The TLC was 18,230/ μ L, and the levels of D-dimer and C-reactive protein were slightly elevated. Chest CT showed bilateral basal ground-glass opacities with a CT severity score of 3/25.

Abdominal CECT revealed pneumoperitoneum, thickening of the distal ileal wall, decreased mural enhancement, and potential ischemic changes, but no evidence of SMA or IMA thrombosis. Emergency laparotomy showed about 500 mL of seropurulent

fluid containing fibrinous flakes and a perforation in the ileum, 1.5 $\times$ 1.5 cm in diameter, located along the mesenteric border, 20 cm from the ileocecal junction. Around 5 cm of bowel on either side appeared dusky but regained only partial viability after warm-pad compression and administration of 100% oxygen. The ileum was resected about 15 cm and then end-to-end ileoileal anastomosis was performed. Histopathology revealed transmural ischemic necrosis, focal perforation, and fibrin thrombi in submucosal vessels. UFH was given, weaned, and discontinued after surgery. The patient made a full recovery and was asymptomatic at 3-month follow-up.

DISCUSSION

This six-patient series demonstrates the broad spectrum of intestinal ischemic complications associated with COVID-19, ranging from major-vessel arterial thrombosis to probable non-occlusive ischemia and microvascular thrombotic injury. Three patients had radiologically confirmed SMA thrombosis, including one with associated splenic artery thrombosis and another with portal venous gas. One patient had sigmoid-colon ischemia with suspected partial IMA thrombosis, while two patients developed severe ischemic bowel injury without demonstrable major-vessel occlusion. All six required emergency laparotomy and bowel resection, and histopathology showed transmural ischemic necrosis with fibrin thrombi in intraluminal or submucosal vessels. Four patients died during the early postoperative period, giving an overall mortality of 66.7%.

The pathogenesis of intestinal ischemia in COVID-19 is likely multifactorial. Systemic inflammation, endothelial injury, platelet activation, hypoxia, and coagulation abnormalities can contribute to macrovascular and microvascular thrombosis. This combined mechanism is supported by the present series. Cases 1, 2, and 5 had obvious SMA thrombosis, whereas Cases 3 and 6 had no obvious major mesenteric arterial occlusion but had fibrin thrombi in submucosal vessels. Sarkardeh *et al.* reported 24 patients with COVID-19-associated intestinal ischemia, with a median age of 61.5 years; 87.5% had no macrovascular mesenteric occlusion, and the overall mortality was 62.5%.^[8] The predominance of non-macrovascular disease in their series is different from our series, in which half of the patients had confirmed SMA thrombosis, but both studies show that severe bowel ischemia can occur via either large-vessel or tissue-level thrombotic pathways.

The clinical presentation was variable but abdominal pain was present in every patient, accompanied by vomiting, distension, constipation or obstipation, loose stools, and fever. These symptoms can be similar to non-specific gastrointestinal symptoms of COVID-19, making early recognition challenging. Beccara *et al.* reported a case of SMA branch thrombosis following a previous normal CT scan, which necessitated repeat imaging and bowel resection.^[9] This observation is clinically important because mesenteric ischemia can develop during the course of infection; persistent or worsening abdominal symptoms should therefore not be attributed solely to viral gastroenteritis or ileus. In the present series, all patients had clinical features of an acute abdomen by the time of surgical assessment.

CECT played a key role in the diagnosis of vascular occlusion and secondary bowel damage. Significant findings were SMA thrombosis, decreased mural enhancement, bowel-wall thickening, mesenteric edema, pneumatosis intestinalis or coli, portal venous gas, splenic infarction, and pneumoperitoneum.

Four patients had pneumatosis, and Case 5 had portal venous gas, which was complicated by extensive small-bowel gangrene. In Case 6, pneumoperitoneum was associated with an ischemic perforation of the ileum with submucosal fibrin thrombi. In a scoping review of 61 patients from 35 reports, Gebran *et al.* reported that the most common imaging patterns were mesenteric arterial or venous thromboembolism and radiological signs of bowel ischemia, with 67% of patients undergoing exploratory laparotomy and bowel resection, and the most common necrotic bowel segment was the terminal ileum.^[10] Our series also demonstrated a predominant small-bowel involvement, especially of the ileum, and also jejunal and sigmoid-colon ischemia.

The operative findings reflected advanced disease. All six patients had gangrene, transmural ischemia, or perforation necessitating resection. Case 1 underwent SMA thrombectomy, while the remaining patients underwent bowel resection without documented mesenteric revascularization. Four patients underwent primary anastomosis, one had Hartmann's procedure, and one patient with extensive small-bowel gangrene underwent proximal jejunostomy with distal ileostomy. Balani *et al.* reported successful early catheter-directed treatment of SMA thrombosis in a patient with COVID-19, avoiding extensive bowel resection and highlighting the potential value of diagnosis before irreversible intestinal necrosis develops.^[11] Ignat *et al.* described three cases of small-bowel ischemia in patients with COVID-19 and emphasized the possibility of under-recognition of intestinal ischemia, especially when major-vessel occlusion is not immediately apparent.^[12] This applies to Cases 3 and 6, in which CECT did not show large-vessel thrombosis, although transmural ischemic necrosis was found at surgery.

Histopathological correlation was an important strength of this case series. Transmural ischemic necrosis was found in all patients and fibrin thrombi in the vascular lumen or in the submucosal vessels in all six patients. The results of Cases 3 and 6 are especially significant as they illustrate microvascular thrombosis without SMA or IMA occlusion on imaging. This reinforces the observation that radiologically patent major mesenteric vessels do not exclude severe thrombotic bowel injury. In Case 2, the multivessel thrombosis of the SMA and splenic artery, along with the splenic infarction, also points to a systemic thrombotic process. De Barry *et al.* also reported on a patient with COVID-19 pneumonia who developed simultaneous arterial and venous abdominal thromboses, showing that multiple vascular territories in the abdomen can be involved at the same time.^[13]

There was a high mortality rate in our cohort. Four patients died within 2 postoperative days, and the two survivors were asymptomatic at 3-month follow-up. The mortality rate of 66.7% was comparable to that reported by Sarkardeh *et al.*^[8] (62.5%) but higher than the overall mortality rate reported in the scoping review by Gebran *et al.*^[10] (around 33%). This discrepancy could be due to the selection of only surgically advanced cases in the current series, universal transmural necrosis, delayed presentation, extensive bowel involvement, associated pulmonary disease, and the first wave treatment setting. Kaafarani *et al.* reported bowel ischemia requiring emergency surgery in four of 141 critically ill patients with

COVID-19, emphasizing that although this complication is relatively uncommon, it is associated with severe illness and major operative morbidity.^[14] In our group, the fatal cases were those with confirmed or suspected large vessel thrombosis, multivessel involvement, portal venous gas, hypotension, or extensive bowel gangrene.

Two clinically relevant exceptions are also emphasized in the series. Case 3 had normal levels of D-dimer and C-reactive protein, which did not rule out transmural ischemia or submucosal thrombosis. Second, Case 6 had no evidence of major-vessel thrombosis but developed ischemic perforation of the ileum, suggesting that microvascular injury can lead to perforation even when mesenteric arteries are patent. These findings support the importance of interpreting laboratory markers and imaging in conjunction with the clinical examination.

Overall, the present series offers radiological, operative, and histopathological evidence of macrovascular, non-occlusive, and microvascular forms of COVID-19-associated intestinal ischemia in a single surgical cohort. In patients with COVID-19, persistent or severe abdominal symptoms should raise the suspicion for urgent contrast-enhanced imaging and early surgical evaluation. The lack of large vessel thrombosis should not be a reason for delay in intervention if clinical and radiological signs indicate advanced ischemia, as mortality is high once transmural necrosis or perforation has occurred.

CONCLUSION

COVID-19-associated bowel ischemia may result from large-vessel thrombosis, non-occlusive ischemia, or microvascular thrombosis. Urgent contrast-enhanced imaging and early surgical assessment are essential, as mortality is high once gangrene, transmural necrosis, or perforation develops.

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