Acute mesenteric ischemia is a life-threatening condition, with a reported mortality rate of 50–90% [1–3], that requires early diagnosis and treatment. Angiography has been the reference standard imaging examination; however, the role of CT in this setting has expanded with the advent of helical CT scanners [3–9]. In particular, MDCT technology has dramatically improved the performance of CT by allowing rapid volumetric data acquisition to provide increased longitudinal spatial resolution over a large anatomic volume. From the volume data, retrospective thin or thick sections; sagittal, coronal, or curved multiplanar reformatted images; and CT angiograms with 2D or 3D visualization can be obtained. The rapid scanning capability of this technique coupled with IV bolus contrast injection substantially optimizes scan timing to allow both the arterial and venous phases to be imaged. These advantages are helpful in identifying the site, level, and cause of bowel ischemia by showing abnormalities in the bowel wall, mesentery, and mesenteric vessels. With these developments, the ability of CT for diagnosing mesenteric ischemia has recently been reported to have a sensitivity of approximately 90% [3, 10, 11]. It can also provide alternative diagnoses for patients in whom mesenteric ischemia is suspected.

Acute mesenteric ischemia can be caused by various conditions such as arterial occlusion, venous occlusion, strangulating obstruction, and hypoperfusion associated with nonocclusive vascular disease, and the CT findings vary widely depending on the cause and underlying pathophysiology. The aim of this article is to review the CT appearances of acute mesenteric ischemia in various conditions.

**CONCLUSION.** Recognition of characteristic CT appearances and the variations associated with each cause may help in the accurate interpretation of CT in the diagnosis of mesenteric ischemia.
Luminal contrast material may be useful in relatively stable patients, and neutral contrast material should be used for the correct assessment of bowel enhancement after IV contrast administration [3, 10, 12]. The use of neutral contrast material is also beneficial in the formation of multiplanar images and in CT angiography because neutral contrast material does not interfere with image quality [3].

Positive contrast material may be advantageous in assessing patients with ischemic colitis by showing thickened bowel wall and revealing the presence of bowel obstruction or in evaluating patients with a contraindication for IV contrast administration. When contrast material is applied, oral administration of 600–750 mL of luminal contrast material 30–120 minutes before scanning and rectal administration of 400–800 mL of luminal contrast material are used [1, 10].

CT technique
CT images are obtained from the dome of the liver to the level of the perineum to cover the entire course of the intestine. With MDCT scanners, a collimation of 0.5–2.5 mm and a detector pitch of 1.0–2.0 are used. Images with a 5- to 7-mm section thickness are usually constructed for image interpretation; however, thinner sections of contiguous 1–2 mm should also be constructed for multiplanar image reformations and CT angiography. Sagittal images are helpful in assessing the origin of the mesenteric arteries and their variations [10].

Acquisition of both unenhanced and contrast-enhanced CT scans is always necessary. The role of unenhanced CT is to identify vascular calcification, hyperattenuating intravascular clotting, and intramural hemorrhage; the role of contrast-enhanced CT is to identify thrombi in the mesenteric arteries and veins, abnormal enhancement of the bowel wall, and the presence of embolism or infarction of other organs [1]. For contrast-enhanced CT, 100–150 mL of iodinated contrast material is administered at a rate of 2–5 mL/s, and scanning starts with delay times of 30 and 60 seconds for dual acquisition and 40–60 seconds for single acquisition [1, 10, 13].

CT Findings in Acute Bowel Ischemia
Acute bowel ischemia provides various morphologic and attenuation abnormalities on CT images in the bowel wall, mesenteric vessels, and mesentery. The lumen of the bowel may dilate when filled with air or fluid. These variations depend on the pathogenesis of bowel ischemia as well as the acuteness, duration, site, and extent of the ischemic attack and the state of the collateral circulation. Superimposed bowel wall infection and the presence of perforation may also affect the CT appearances of acute bowel ischemia. In film interpretation, radiologists should assess the bowel wall, its thickness and attenuation; luminal dilatation; mesenteric vessels; mesentery; and other organs [1, 14, 15].

Bowel Wall

Bowel wall thickness—Normal bowel ranges from 3 to 5 mm thick depending on the degree of bowel distention [1, 14–16]. Bowel wall thickening is not a specific but is the most frequently observed CT finding in mesenteric ischemia and is caused by mural edema, hemorrhage, or superinfection of the ischemic bowel wall [1, 10, 17] (Fig. 1). The degree of thickening is usually less than 1.5 cm, typically 8–9 mm [10], and is often observed in mesenteric venous occlusion, strangulation, ischemic colitis, and mesenteric arterial occlusion after reperfusion [1, 4–6, 10].

In exclusively arterial occlusive mesenteric ischemia or infarction, however, the bowel wall becomes thinner rather than thicker because there is no arterial flow and neither mural edema nor hemorrhage occurs. Thinning of the bowel wall or “paper-thin wall” is caused by volume loss of tissue and vessels in the bowel wall and by loss of intestinal muscular tone [1, 4–6, 8, 10] (Fig. 2). Bowel wall thickening is not a consistent CT finding in mesenteric ischemia, and the degree of thickening does not correlate with severity [1].

Bowel wall attenuation—Bowel wall attenuation should always be assessed on both unenhanced and contrast-enhanced CT images to avoid misinterpretation of high density of the bowel wall as normal positive enhancement on contrast-enhanced CT in cases of intramural hemorrhage. On unenhanced CT images, low attenuation of the bowel wall indicates bowel wall edema, which typically occurs in mesenteric arterial occlusion after reperfusion, mesenteric venous occlusion, strangulation, and ischemic colitis [1, 14–16, 18]. High attenuation of the wall is caused by intramural hemorrhage
and hemorrhagic infarction [1, 14–16, 18] (Fig. 3).

On contrast-enhanced CT, a highly specific but not sensitive finding for acute mesenteric ischemia is absent or diminished contrast enhancement of the bowel wall [1, 6, 19]. A halo or target appearance is also indicative of mesenteric ischemia, representing hyperemia and hyperperfusion associated with surrounding mural edema, and can be seen in arterial occlusion after reperfusion, nonocclusive and venoocclusive bowel ischemia, strangulation, and ischemic colitis [1, 14–16, 20] (Fig. 4). Although it seems paradoxical, hyperenhancement of the bowel wall caused by hyperemia (mesenteric venous occlusion), hyperperfusion (reperfusion after arterial occlusive or nonocclusive bowel ischemia), or prolonged enhancement due to reduction of arterial perfusion and venous outflow (strangulating bowel obstruction, nonocclusive bowel ischemia, shock bowel) may be observed in cases of mesenteric ischemia [1, 10] (Fig. 5).

Pneumatosis intestinalis can be indicated when CT depicts air in the bowel wall (Fig. 6). In the setting of mesenteric ischemia, pneumatosis often indicates transmural infarction, particularly if it is associated with portomesenteric venous gas [1, 10, 21–23].

Dilatation of the Bowel Lumen

The bowel lumen is often dilated because of interruption of normal bowel peristalsis (adynamic ileus) [1, 10]. Fluid distention of the bowel loops occurs by increased intestinal secretions, typically in venoocclusive ischemia and strangulating bowel obstruction. In exclusive arterial occlusion, the bowel seldom contains a large amount of luminal fluid [5].

Mesenteric Vessels

In most cases, emboli or thrombi in the mesenteric arteries and veins are clearly shown on contrast-enhanced CT images (Figs. 7 and 8); CT angiography may be helpful in seeing them [11]. Engorgement of the mesenteric veins caused by congestion of venous outflow is typically seen in venoocclusive bowel ischemia or strangulating bowel obstruction [1, 4, 5] (Fig. 8).
exclusively present with transmural infarction, this finding can be helpful in estimating the severity of bowel ischemia [1, 4, 5].

Bowel Ischemia and Infarction in Various Conditions

Bowel ischemia and infarction can be caused by various conditions such as mesenteric arterial occlusion, mesenteric venous occlusion, strangulating bowel obstruction, and hypoperfusion associated with nonocclusive vascular disease. The clinical features and typical CT appearances of each condition are summarized in Table 1.

Acute Mesenteric Arterial Occlusion

Acute mesenteric arterial occlusion is typically caused by a thromboembolism associated with cardiovascular problems followed by arterial thrombosis, which accounts for 60–75% (arterial embolism, 40–50%; arterial thrombosis, 20–30%) of all acute bowel ischemia cases [1–3, 24–26]. Most emboli wedge at branching points around or distal to the middle colic artery, whereas thrombosis typically occurs at or near the origin of the mesenteric arteries [3]. Although the severity may vary, bowel ischemia is typically followed by infarction, perforation, and peritonitis unless reperfusion occurs.

On contrast-enhanced CT images, emboli and thrombi can be seen as defects in the superior mesenteric artery and its branches [2, 10] (Figs. 7 and 9). The diameter of the super Honor mesenteric artery is often larger than that of the superior mesenteric vein. The thickness of the bowel wall of the involved segments is the same as or thinner than that of the healthy segments unless reperfusion occurs [1, 4, 9]. The lumen of the bowel may be filled with fluid, gas, or both; however, the bowel seldom contains a large amount of fluid. Contrast enhancement of the involved bowel is absent or diminished [1–5, 9, 10] (Fig. 9). Pneumatisos can typically be observed in cases with transmural infarction with or without associated portomesenteric venous gas. In cases with reperfusion or rich collaterals, the involved bowel segments may thicken and show the halo or target pattern of contrast enhancement [1, 4, 9] (Fig. 10). Coexisting embolism of other organs may also be observed on contrast-enhanced CT, which supports the diagnosis of mesenteric ischemia (Fig. 11).

The diagnosis of acute mesenteric arterial occlusion is usually made based on a combination of the CT findings described earlier. The diagnostic performance of CT for mesenteric ischemia confined to mesenteric arterial occlusion has not been ascertained, to our knowledge; however, the diagnostic performance of CT for primary mesenteric ischemia, including arterial and venous occlusive and nonocclusive mesenteric ischemia, has been reported as 64–96% in sensitivity and 92–100% in specificity [6, 11]. In the case of each CT finding, a lack of focal bowel wall enhancement and the presence of pneumatosis intestinalis are relatively sensitive (sensitivity, 42%) and highly specific (specificity, 97–100%) [11]. Findings of defects or occlusion of the mesenteric arteries or veins and gas in the mesenteric or portal veins or in the mesenteric arteries are less sensitive (12–15%) but are highly specific (94–100%) [11]. Findings of bowel wall thickening and mesenteric stranding are relatively high in sensitivity (85–88%) but are less specific (61–72%) [11].
Venous Occlusion

Thrombosis of the mesenteric vein can be primary or secondary to portal hypertension or infection or can be associated with various hypercoagulopathy states [1, 2, 20, 27]. Mesenteric venous obstruction does not typically lead to severe bowel ischemia; however, thrombosis of the mesenteric vein, particularly at a distal level, may cause bowel infarction and accounts for 5–10% of acute bowel ischemia. Impairment of venous drainage causes elevation of the hydrostatic pressure, which leads to extravascular leakage of plasma, RBCs, or both into the bowel wall, mesentery, and peritoneal cavity. The bowel loops are typically prominently dilated [1, 3, 26]. Impairment of venous drainage may also compromise the arterial blood flow and cause bowel ischemia and infarction.

On contrast-enhanced CT, thrombus in the mesenteric and portal veins is usually visible, and mesenteric venous obstruction can be confirmed by CT in more than 90% of cases [28–30] (Fig. 12). Engorgement of the mesenteric veins is also observed. Fat stranding in the mesentery and ascites are common findings. The bowel wall is prominently thickened with absent or diminished enhancement, hyperenhancement, or a halo or target pattern of contrast enhancement [1–5, 7, 28]. Absent or diminished contrast enhancement of the bowel wall usually indicates transmural infarction, particularly when it is associated with pneumatosus and portomesenteric venous gas [28–30]. On the contrary, the degree of bowel wall thickening, mesenteric fat stranding, or ascites does not correlate with the severity of ischemic bowel damage [28].

<table>
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<th>TABLE 1: Clinical Features and Typical CT Findings of Mesenteric Ischemia in Various Conditions</th>
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<tr>
<td>Characteristic</td>
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Note—PMI = primary mesenteric ischemia (i.e., arterial or venous occlusive or nonocclusive bowel ischemia), SBO = small-bowel obstruction, SMA = superior mesenteric artery, SMV = superior mesenteric vein.

A risk factor for thrombosis.
CT Diagnosis of Acute Mesenteric Ischemia

Fig. 9—71-year-old woman with superior mesenteric artery embolism. 
A. Contrast-enhanced CT image obtained cephalad to B shows defect in superior mesenteric artery (arrowhead). 
B. Contrast-enhanced CT image shows that mural enhancement is absent at most intestinal loops.

Fig. 10—Contrast-enhanced CT image in 83-year-old woman with superior mesenteric artery embolism after reperfusion. Mural thickening of intestine (circle) is visible, showing target appearance.

Fig. 11—Contrast-enhanced CT image in 74-year-old man with superior mesenteric artery embolism shows defect (arrowhead) in superior mesenteric artery. In addition, contrast enhancement of right kidney (arrow) is absent, which indicates embolism of right renal artery.

Fig. 12—46-year-old man with superior mesenteric vein thrombosis. 
A. Contrast-enhanced CT image obtained cephalad to B shows thrombi in superior mesenteric vein (arrowhead) and splenic vein (arrow). 
B. Contrast-enhanced CT image shows engorgement of mesenteric veins (arrowhead) and mural thickening of intestine. Ascites is present.
Strangulating Obstruction: Closed-Loop Bowel Obstruction

Strangulating obstruction is a mechanical bowel obstruction associated with bowel ischemia that is seen in approximately 10% of patients with small-bowel obstruction [31, 32]. Strangulating obstruction is almost exclusively associated with a closed-loop obstruction (Figs. 13 and 14), which is caused most often by an adhesive band and occasionally by an internal or external hernia. A closed-loop obstruction tends to involve the mesentery and mesenteric vessels and is prone to produce a volvulus. Typically, strangulation in a closed-loop bowel obstruction is caused initially by impairment of venous outflow followed by arterial ischemia because the arterial pressure is higher than the venous pressure. Congestion or hemorrhage in the bowel wall and mesentery occurs, and the affected bowel loops are distended and filled with fluid.

On CT, a closed-loop obstruction is identified by a unique configuration of C- or U-
Hypoperfusion Associated with Nonocclusive Vascular Disease

Bowel ischemia and infarction can occur with a reduction of mesenteric blood supply without vascular occlusion, which is called nonocclusive mesenteric ischemia or infarction. This type of bowel ischemia accounts for 20–30% of all acute mesenteric ischemia or infarction cases, with mortality rates from 30% to 93% [3, 41, 42]. A reduction of the mesenteric blood supply is the result of mesenteric arterial vasoconstriction on reflex to hypotension or administration or abuse of digitalis, ergotamine, vasopressin or other vasoconstrictive agents, amphetamine, and cocaine [3, 7, 41, 42]. Ischemic injury may range from reversible superficial damage localized to the watershed areas to a more severe form that extends to the entire bowel. Hypoperfusion results in increased vascular permeability that leads to extravascular leakage of plasma, RBCs, or both into the bowel wall, mesentery, and peritoneal cavity.

Shock bowel is a variation of nonocclusive mesenteric ischemia caused by hypotensive shock induced by blunt abdominal trauma [3, 43]. Ischemic colitis and obstructive colitis are considered similar disease entities [1, 4, 5]. On CT, the bowel wall of the involved segments may be normal or thickened (Fig. 17). The pattern of enhancement is variable as absent or diminished enhancement, increased enhancement, or halo or target type of enhancement [1, 4, 5]. Fat stranding of the mesentery and ascites are visible. Among various conditions of mesenteric ischemia, nonocclusive mesenteric ischemia is the most difficult condition to diagnose on CT, and angiography is often required for correct and confident diagnosis [42].

Fig. 17—Contrast-enhanced CT image (A) of pelvis in 69-year-old man with nonocclusive mesenteric ischemia. Contrast enhancement is prominently diminished or absent at distal ileal loops (arrowheads). Bowel wall thickening is not present. After reperfusion, bowel loops show prominent wall thickening with appearance of target sign (B).

Conclusion

An accurate and early diagnosis is essential for the appropriate and successful treatment of patients with acute mesenteric ischemia to improve their prognoses. With the advances in CT technology, CT has realized a high diagnostic performance and become an essential diagnostic tool in this clinical setting. For a correct diagnosis, a technically appropriate CT examination and proper interpretation of images are mandatory. Because acute mesenteric ischemia can be caused by various conditions, the CT findings vary widely, depending on the cause and underlying pathophysiology and the presence of associated complications. Recognition of the characteristic CT appearances and variations of each cause may help in the accurate interpretation of CT in the diagnosis of mesenteric ischemia.

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