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■ REVIEW ■

CT Interpretation of Gastrointestinal Tract Diseases

Most inflammatory, neoplastic and vascular disorders manifest bowel wall thickening on computed tomography (CT). Therefore, it is very important to understand the patterns of bowel wall involvement (degree, length, symmetry and contrast enhancement patterns) in each category to make a correct diagnosis. Observing extraluminal changes also help to classify the primary causes of pathological conditions involving the gastrointestinal tract. Adequate CT examinations with optimal opacification of the gastrointestinal tract are essential not only to avoid false positive findings but also to detect subtle or minimal lesions. If findings for establishing a diagnosis are equivocal, the use of combined findings increases the diagnostic accuracy of CT.

Key Words: *Tomography Scanners, X-ray Computed; Diagnostic Imaging; Gastrointestinal Diseases; Inflammatory Bowel Disease; Gastrointestinal Neoplasms; Vascular Diseases*

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INTRODUCTION

Recently, computed tomography (CT) has been increasingly used for patients suspected of having a variety of gastrointestinal diseases. Such advances may result from the ability of CT to assess intraluminal, intramural and extraluminal pathological processes as well as the development of high-resolution scanners and technical refinements which provide better quality studies. However, it should be stressed that CT is not superior to conventional barium examinations for evaluating mucosal diseases. Therefore, both CT and barium examinations have complementary roles in the diagnosis of gastrointestinal diseases, although both studies are not always required.

Regardless of their primary causes, most inflammatory, neoplastic and vascular disorders are recognized on CT by bowel wall thickening. However, as our experience has increased in performing and interpreting CT scans, we have found that there is a considerable overlap of findings in various gastrointestinal diseases. Therefore, to increase the diagnostic accuracy of CT, it is necessary to further investigate bowel wall involvement patterns, such as the degree, length, symmetry and contrast enhancement patterns in each disease entity. Moreover, observing changes in the perienteric or pericolonic spaces, mesentery, omentum and peritoneal cavity can narrow the differential diagnosis as this information sometimes provides clues for making a specific diagnosis. In addition, CT is renowned for the common occurrence of false positive findings as unopacified or poorly distended bowel may simulate masses, tumors or infection. Therefore, adequate CT examination with optimal opacification of the gastrointestinal tract in an appropriate amount of contrast is essential before interpreting CT scans.

The purpose of this review is to stress the importance of analyzing the bowel wall and extraluminal involvement patterns in inflammatory, neoplastic and vascular diseases of the gastrointestinal tract on CT.

NORMAL CT FINDINGS OF THE GASTROINTESTINAL TRACT

The normal gastric wall measures 2-5 mm in thickness with 10 mm being the upper limit for normal (1); in an air-filled stomach, a 3-mm (2) or 5-mm (3) wall thickness is considered the upper normal limit. However, anatomic difficulty is most frequently encountered in the region of the gastroesophageal junction (4, 5). As the esophagus becomes an intraabdominal organ and joins the stomach, it can produce a focal thickening and simulate a mass projecting into the gastric wall. Whenever a soft tissue mass is noted in this region, its relationship to the fissure plane anterior to the caudate lobe should be studied. If the mass and fissure plane are in the same or adjoining sections, a pseudotumor should be suspected (5). In cases of suspected gastric wall thickening, additional studies with different patient positioning are important. When using air techniques, the right decubitus position is used for the proximal stomach and gastroesophageal junction, while the left decubitus position is best for the distal stomach and duodenum; this is the reversal of the patient's position when using high-density oral contrast agent (4).

The normal small-bowel wall thickness measures 2-3 mm; a wall thicker than 4 mm is considered abnormal except in the terminal ileum where 5 mm is considered the upper limit for normal (2, 3). When the intestine is collapsed or partially distended, the wall may appear to be 3-4 mm thick. If the wall seems to be concentrically and symmetrically thickened and is homogeneously enhanced, the clinical significance of a thickness greater than 4 mm should be interpreted cautiously and assessed in relation to the degree of distension of the gastrointestinal segment analyzed (3, 6). The wall of the colon is also barely perceptible when viewed using a high-density contrast agent or air. It usually measures 2-3 mm, and a width greater than 4 mm is considered abnormal (1, 7).

On CT, the fat in the mesentery has the same attenuation as fat elsewhere in the body. Major arteries and veins are identifiable as branching structures within mesenteric fat and do not exceed 3 mm in diameter (8, 9). Mesenteric lymph nodes are occasionally observed within mesenteric fat and also do not exceed 3 mm in diameter.

BOWEL WALL INVOLVEMENT PATTERNS

Inflammatory diseases

The hallmark of most inflammatory bowel diseases on CT is symmetric and circumferential bowel wall thickening, usually not exceeding 1.5 cm (8) (Fig. 1). However, an asymmetrical pattern of bowel wall thickening is also commonly seen in chronic forms of inflammatory bowel diseases, such as Crohn's disease or intestinal tuberculosis, as cicatrical and fibrotic changes do not occur circumferentially. Furthermore, typical cases of Crohn's disease show marginal linear ulcerations along the mesenteric border of the intestine; therefore, the bowel wall can be asymmetrically thickened on CT even in the acute stage. The degree of bowel wall thickening depends primarily on which intestinal layers, i.e. mucosa, submucosa, muscularis propria, or serosa, are predominantly affected by the inflammatory process. Inflammatory processes confined to the mucosa or to the superficial layers of the bowel wall may not be displayed reliably on CT unless the full thickness of the bowel wall is involved. Bowel wall thickening results from a variety of pathologic processes occurring in various layers of the intestinal wall: transmural granulomatous infiltration with edema, fibrosis, inflammation and lymphangiectasis in Crohn's disease; a combination of infiltration of the lamina propria by round cells, hypertrophy of the muscularis mucosa, and deposition of submucosal fat in ulcerative colitis (10); muscle hypertrophy, fibrosis, edema, intramural inflammation, or organized intramural inflammatory mass in diverticulitis (11); and edema and necrosis in neutropenic colitis (12). Except for certain cases in which the predominant pathological processes in the intestinal wall result from hematoma or fat accumulation, CT may not clearly determine their primary pathological process. The stages of the inflammatory process may also affect the degree of thickening which is more severe in the acute stage than in the chronic stage, as an acute process frequently accompanies the edematous components associated with mucosal ulcerations.

Although some differences are noted in the degree of bowel wall thickness in a variety of inflammatory bowel diseases, bowel wall thickness alone cannot be used as an absolute indicator to establish a specific diagnosis. In certain instances, contrast enhancement patterns of the involved bowel wall rather than bowel wall thickness are more helpful for determining the diagnosis. Abnormally thickened bowel wall may enhance homogeneously or show heterogeneous enhancement with a "double halo (two rings)" or "target sign (three rings)" (Fig. 2). The "double halo" or "target sign" are mainly caused by accumulation of edematous fluid, hemorrhage, lymph, or fat predominantly in the submucosa. If these signs are demonstrated, there is a greater chance of a chronic rather than an acute inflammatory process (6). Although these signs are helpful for detecting gastrointestinal tract ab-

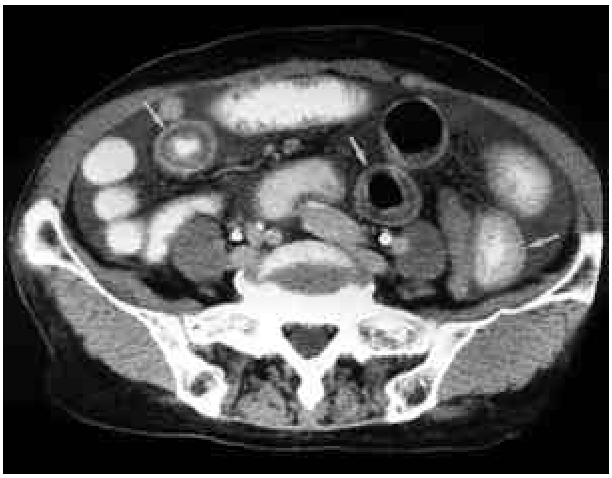

Fig. 1. Eosinophilic gastroenteritis. Contrast-enhanced CT scan shows nonsegmental distribution of bowel wall thickening (arrows) with target sign in the small intestine. Also noted is a large amount of ascites. The gastric wall is also diffusely thickened (not shown).

Fig. 2. Systemic lupus erythematosus. Contrast-enhanced CT shows diffuse, circumferential bowel wall thickening of the jejunum and ileum (asterisks) with target sign. Also noted is fluid collection along the mesentery (From [29], with permission).

normalities, they are unfortunately not specific for a particular type of disease process. Until recently, it has been generally agreed that the presence of these signs indicates non-neoplastic disease since these signs occur in various inflammatory and vascular disorders, such as Crohn's disease, ulcerative colitis, pseudomembranous colitis, radiation enterocolitis, esosinophilic gastroenteritis (Fig. 1), ischemic bowel diseases, amyloidosis and portal hypertensive colopathy. However, a recent series showed that these signs were seen in a neoplastic process in which abundant fibrosis accumulates in the submucosal layer of the gastrointestinal tract, especially in patients with metastasis to the gastrointestinal tract from gastric cancer (13) (Fig. 3). In addition, the thickness and enhancing degree of each layer in the double halo or target sign appear to differ from case to case or even in patients with the same disease entity. Further morphological investigation of the target appearance on CT scanning would help to discriminate inflammatory, ischemic and neoplastic diseases.

Another characteristic pattern of bowel wall thickening, i.e. the accordion sign, represents alternating edematous haustral folds separated by transverse mucosal ridges filled with oral contrast material (Fig. 4); it has been described in the literature as a highly suggestive finding for pseudomembranous colitis (14) and is demonstrated in 4-19% of patients with documented pseudomembranous colitis (15). However, recent reports suggest that this sign is also nonspecific and occurs in other conditions such as portal hypertensive colopathy (16), ischemic colitis and cytomegalovirus colitis (17). Therefore, it should be viewed as a sign indicative of severe colonic edema of uncertain cause.

In addition to bowel wall thickening patterns, observ-

Fig. 3. Metastatic linitis plastica involving the small intestine and descending colon in a patient who underwent subtotal gastrectomy for gastric cancer 33 months previously. Contrast-enhanced CT scan shows that the walls of the transverse (T) and descending (D) colon and ileum (arrows) are concentrically thickened with target sign. Also noted are retroperitoneal lymphadenopathy (arrowheads) and large amounts of ascites.

Fig. 4. Cytomegalovirus colitis. Contrast-enhanced CT scans shows bowel wall thickening (arrows) throughout the colon with "accordion sign" due to diffuse mural edema.

ing the length and multiplicity of the involved segment help in differentiating inflammatory from neoplastic and vascular diseases as well as in narrowing the range of differential diagnoses among inflammatory bowel diseases. Generally, in the acute stage of inflammatory bowel diseases, the length of the involved segment is longer than in neoplastic diseases (less than 10 cm) but it is shorter than in vascular diseases. However, in the chronic stage when strictures and fibrosis develop, the involved bowel length becomes much shorter than in the acute stage, thereby simulating neoplastic conditions. Multiplicity is also much commonly seen in inflammatory bowel diseases. However, multiplicity occurs in some

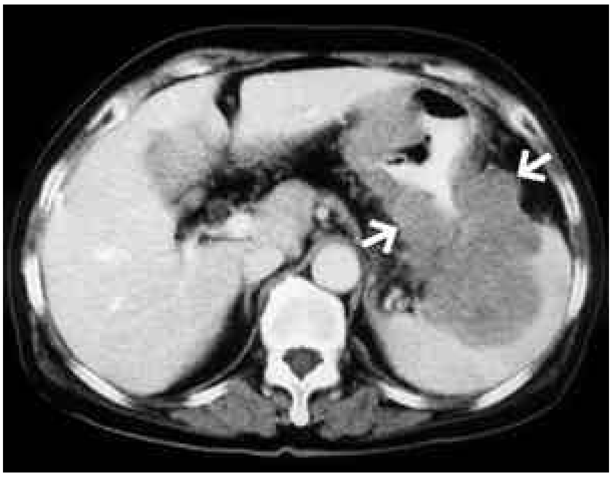

Fig. 5. Gastric lymphoma. Contrast-enhanced CT scan shows irregular, concentrical thickening (arrows) of the gastric wall along with poor contrast enhancement.

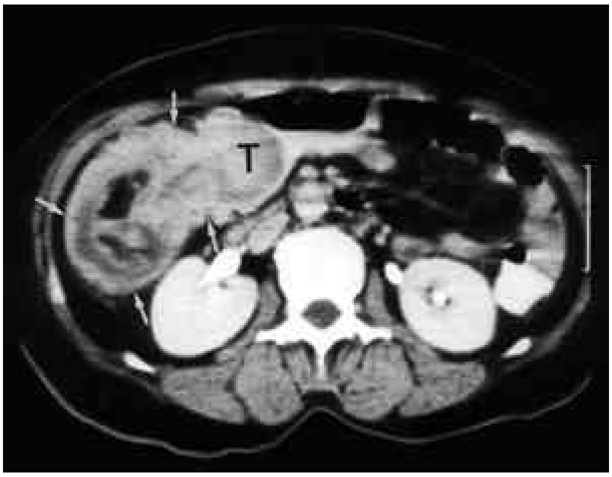

Fig. 6. Ileocolic intussusception due to an inflammatory fibroid tumor in the ileum. Contrast-enhanced CT shows a mass-like lesion (arrows) in the ascending and transverse colon with alternating hyperattenuated and hypoattenuated layers with interposition of the mesenteric fat, suggesting the presence of ileocolic intussusception. Also noted is a polypoid mass (T) at the leading point.

neoplastic diseases, such as lymphoma of the Mediterranean type involving the small intestine and metastatic neoplasm (Fig. 3) as well as in vascular diseases such as vasculitis (18) (Fig. 2).

It is well known that the appearance of a transition zone between the involved and normal segments is important in distinguishing inflammatory from neoplastic conditions on barium study. This finding can also apply to CT interpretation and is very useful in differentiating diverticulitis from colonic carcinoma. While abrupt transition is characteristic of neoplastic diseases, a tapered appearance is a common manifestation of inflammatory diseases.

Neoplastic diseases

Benign tumors of the small and large intestine include adenomas, lipomas, stromal tumors, harmatomas, fibromas and hemangiomas, while malignant tumors include adenocarcinomas, lymphomas, sarcomas and carcinoids. The hallmark of gastrointestinal neoplasm on CT is eccentric or asymmetric wall thickening or mass formation in the bowel; bowel wall thickening usually exceeds 1.5 cm (8). However, a circumferential pattern of bowel wall thickening can also be seen in neoplastic processes such as lymphoma (Fig. 5) as well as primary and metastatic neoplasms (Fig. 3). In certain instances, a mass with a large central cavitation is thought to be a lesion with circumferentially thickened bowel wall due to misinterpretation of large central cavitation as bowel lumen. The length of intestine involved in the neoplastic process is usually short (less than 10 cm), except for cases of infiltrative type of lymphoma, signet-ring cell colorectal carcinoma and linitis plastica type of metastatic neoplasm (13). Multifocal involvement of the bowel is a common manifestation of lymphoma, lipoma and metastatic neoplasm. As mentioned above, the transition zone to the normal segment is abrupt.

When neoplasms form a mass, the tumor margins are usually smooth in benign neoplasms and lobulated, irregular, or spiculated in a malignancy. Although masses with a diameter less than 2 cm may be missed on CT (19), most polypoid or pedunculated mucosal or submucosal masses are incidentally detected by intussusception with small bowel obstruction (Fig. 6). Exophytic tumor growth is favored by some gastrointestinal neoplasms, including gastrointestinal stromal tumors (Fig. 7), lymphomas and metastatic melanomas. However, gastric or colonic adenocarcinomas rarely show such behavior. In a series by Lee et al. (20), the presence of gastric wall thickening adjacent to an exophytic mass favors the diagnosis of exophytic adenocarcinoma rather than gastrointestinal stromal tumor.

Analyzing the internal constituents of a mass is helpful in establishing a specific diagnosis. The presence of fat within a mass on CT is a pathognomonic finding for lipoma (Fig. 8) or liposarcoma. When tumors show internal hemorrhage within a mass, which is easily detectable on unenhanced CT, differential diagnosis includes gastrointestinal stromal tumor and metastatic melanoma. CT is also very useful for detecting internal calcification of a mass. This is most commonly seen in mucinous adenocarcinoma (Fig. 9) and in gastrointestinal stromal tumor (21), but other possibilities include neurogenic tumor, carcinoid and adenocarcinoma or lymphoma treated with chemotherapy or radiation.

Fig. 7. Gastrointestinal stromal tumor of the ileum. Contrast-enhanced CT shows a large mass with irregular central ulceration (asterisk) exophytically growing from the proximal ileum. Also noted is minimal lymphadenopathy (arrows) in the regional mesentery.

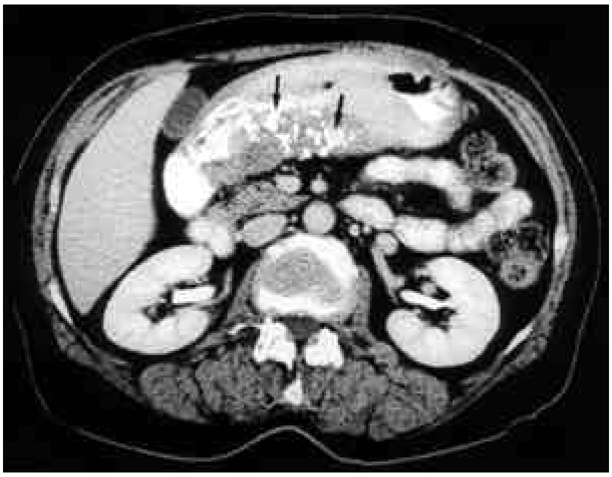

Fig. 9. Mucinous adenocarcinoma of the stomach. Contrast-enhanced CT scan shows circumferential thickening of the gastric wall, containing stippled and irregular calcifications (arrows).

Fig. 8. Gastric lipoma. Contrast-enhanced CT scan shows a polypoid mass (asterisk) with fatty component in the antrum of the stomach.

Fig. 10. Mucinous adenocarcinoma of the colon. Contrast-enhanced CT scan shows concentrical bowel wall thickening (asterisk) of the transverse colon with poor contrast enhancement. Also noted is minimal pericolonic infiltration.

The knowledge of a lesion site is also useful in the differential diagnosis when neoplasm is suspected on CT. In adenocarcinoma of the small intestine, 42% of the locations are in the duodenum, while more than 35% involve the proximal jejunum. Lymphomas primarily affect the ileocecal region in children and young adults, but those lymphomas complicating celiac disease usually involve the proximal jejunum. Ninety percent of carcinoid tumors are located in the ileum (22). The malignant form of gastrointestinal stromal tumors occurs with equal frequency in the jejunum or ileum, while the jejunum is more common in the benign form. The colon is a rare site for gastrointestinal stromal tumors, but when they develop in the colorectum, the most common site is the rectum (23). Most lipomas are located in the ileum or the ileocecal valve.

Contrast enhancement study helps not only to characterize the tumor but also to determine the extent of the tumor in the bowel wall. Contrast enhancement of the soft tissue mass may depend on the desmoplastic response, its vascularity and degree of tumor necrosis. One of the typical tumors eliciting a desmoplastic response is scirrhous gastric cancer (24) or metastatic linitis plastica to the colorectum (13) (Fig. 3). Because these tumors produce abundant fibrosis in the submucosal layer of the gastrointestinal tract, they are well enhanced after contrast infusion. In contrast, lymphomas which do not elicit a desmoplastic response, enhance poorly (25) (Fig. 5).

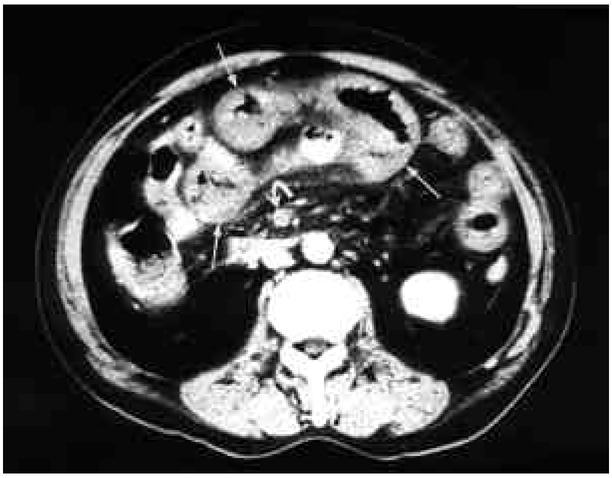

Fig. 11. Bowel infarct due to superior mesenteric venous thrombosis. Contrast-enhanced CT shows diffuse bowel wall thickening (straight arrows) of the jejunum along with a thrombus (curved arrow) in the superior mesenteric vein. Also noted are mesenteric vascular engorgement and haziness (From [27], with permission).

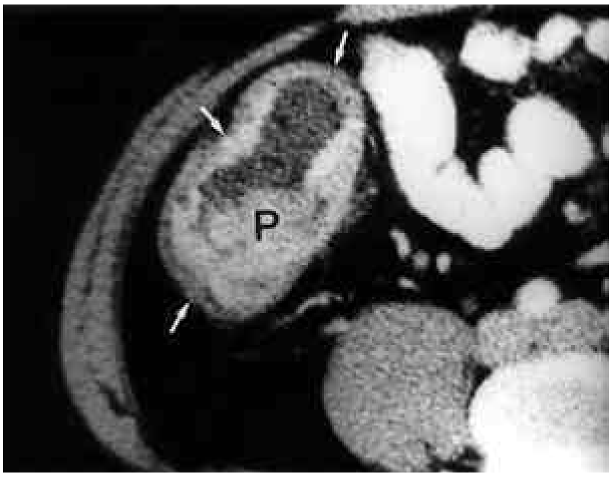

Fig. 12. Behcet syndrome involving the terminal ileum. Contrast-enhanced CT shows polypoid (P) and concentrical bowel wall thickening (arrows) of the terminal ileum along with marked contrast enhancement.

The accumulation of intra- or extracellular mucin also affects the degree of contrast enhancement. Thus, mucinous adenocarcinomas are also poorly enhanced (26) (Fig. 10).

Vascular diseases

Mesenteric ischemia occurs in a variety of conditions, incuding thromboembolism, bowel obstruction, neoplasm, vasculitis, inflammatory bowel diseases, trauma, and as a result of drug or radiation therapy (27). Hypoperfusion (low-flow state) of the blood flow is also one of the most common causes of bowel ischemia. The hallmark of a vascular disorder on CT is concentric bowel wall thickening; the thickness usually does not exceed 1.5 cm. The bowel wall becomes much more thicker in mesenteric ischemia caused by mesenteric venous occlusion (Fig. 11) than in ischemia of arterial origin. However, it should be remembered that intestinal ischemia is not always seen with bowel wall thickening. This is partially due to the inherent limitation of CT for detecting subtle bowel wall thickening. Moreover, bowel wall is thinned or occasionally invisible when the involved segments become gangrenous. A delayed diagnosis of intestinal ischemia is occasionally encountered in cases having normal-appearing or thinned bowel wall.

Thickened bowel wall is commonly associated with target or double halo signs due to the accumulation of edematous fluid or hemorrhage in the submucosal layer of the intestine. Although target or double halo signs are nonspecific, we have noted that close observation of these signs in patients with mesenteric ischemia may help in determining the presence or absence of irreversible changes in the gastrointestinal tract. Diffuse disruption of these signs or discontinuity of the outer (serosal) layer may suggest the presence of irreversible bowel changes. These target or double halo signs are also helpful in distinguishing whether bowel ischemia originates from thromboembolism or vasculitis (28). In our experience, the signs in patients with vasculitis are much more clearly layered (Fig. 2) than in those with thromboembolism (29). We assume that this is attributable to the fact that in vasculitis a larger amount of submucosal edematous fluid or hemorrhage is accumulated in the submucosal layer of the intestine than in thromboembolism. Intramural gas is also occasionally demonstrated in the ischemic segments. However, the presence of intramural gas does not always indicate mesenteric ischemia since it can be seen in patients with pulmonary disease, peptic ulcer disease, collagen vascular disease, steroid administration and intestinal obstruction (30, 31). In contrast to cases with mesenteric ischemia, Behcet's syndrome, which is a nonspecfic necrotizing vasculitis involving multiple organ systems, shows concentrical bowel wall thickening or polypoid mass formation on CT (32) (Fig. 12); the mass-like lesion develops due to marked thickening of the intestinal wall surrounding the large ulcerations.

When comparing cases with inflammatory or neoplastic bowel disease, one of the most characteristic CT features of intestinal ischemia caused by frequently encountered thromboembolism is the continuity and segmental distribution of involved segments; ischemic bowel is generally confined to the mesenteric vascular territory. In contrast, non-segmental distribution and multifocal involvement are characteristics of mesenteric ischemia

Fig. 13. Obstructed colonic ischemia proximal to colonic carcinoma. Contrast-enhanced CT shows diffuse dilatation and bowel wall thickening (straight arrows) of the ascending and transverse colon along with target sign and regional vascular engorgement (arrowheads), suggesting the presence of colonic ischemia. A short length of luminal narrowing is seen in the proximal descending colon, representing the site of colonic carcinoma (curved arrow).

Fig. 14. Strangulated small-bowel obstruction. Contrast-enhanced CT scan shows poor contrast enhancement of the strangulated intestinal segment (arrows) along with diffuse mesenteric haziness (From [36], with permission).

associated with multiple thromboemboli, vasculitis and drug or radiation therapy (27). In addition, ischemia proximal to obstructing colonic carcinoma also causes nonsegmental type of distribution, thus helping to detect small hidden malignancy on CT (Fig. 13). Although the length of the involved segment is usually long in mesenteric ischemia caused by thromboembolism, the length depends on the levels of vascular occlusion in the mesenteric vessels; it is very short when the vasa recta or intramural vessels are occluded and is very long when the proximal main branches are involved. The end results of mesenteric ischemia include normalization of the intestinal wall, bowel perforation, or stricture formation. In cases of intestinal stricture formation, the involved bowel is very short, simulating adenocarcinoma or stricture due to chronic inflammatory bowel disease such as Crohn's disease or intestinal tuberculosis.

There are preferential sites for certain types of intestinal ischemia. For example, the duodenum and rectum which are supplied by abundant blood flow, have a very low probability of developing ischemia caused by thromboembolism. However, these sites are interestingly a common sites of vasculitis; we presume that immune complex deposition occurs more commonly at sites of increased blood flow (28). In radiation enterocolitis, the involved site is confined to the radiation port. Posttraumatic stricture resulting from focal depriviation of mesenteric blood supply due to a tear in the mesenteric attachment, commonly occurs near the proximal or distal extreme of the small intestine where mesenteric mobility commences (33). Intestinal ischemia proximal to a colonic carcinoma develops at sites which are vulnerable to increased intraluminal pressure caused by bowel distention (34, 35); according to the application of Laplace's law, tension in the bowel wall increases both with increasing intraluminal pressure and with increasing diameter of the obstructed bowel.

Contrast enhancement patterns of vascular disorder (especially, mesenteric ischemia) are characteristic. The ischemic segments are not or poorly enhanced on the early phase (36) (Fig. 14), while these segments demonstrate prolonged enhancement during the late phase (37). These enhancement patterns result from perfusion problems associated with the ischemic segment, i.e. delayed return of the venous blood with subsequent slowing of the arterial supply in mesenteric venous occlusion and arteriospasm in arterial occlusion. This absence of or poor contrast enhancement is reported to be one of the most valuable findings in the differentiation of simple from strangulated intestinal obstruction, although its sensitivity is not high (34%) (36).

PERIGASTRIC, PERIENTERIC, OR PERICOLONIC CHANGES

Inflammatory diseases

CT is very useful for defining a variety of mesenteric and perienteric and pericolonic abnormalities that commonly occur in inflammatory diseases. Bowel separation is a common finding in Crohn's disease and is identical on barium study regardless of the primary cause. CT clearly determines the causes of bowel separation, such

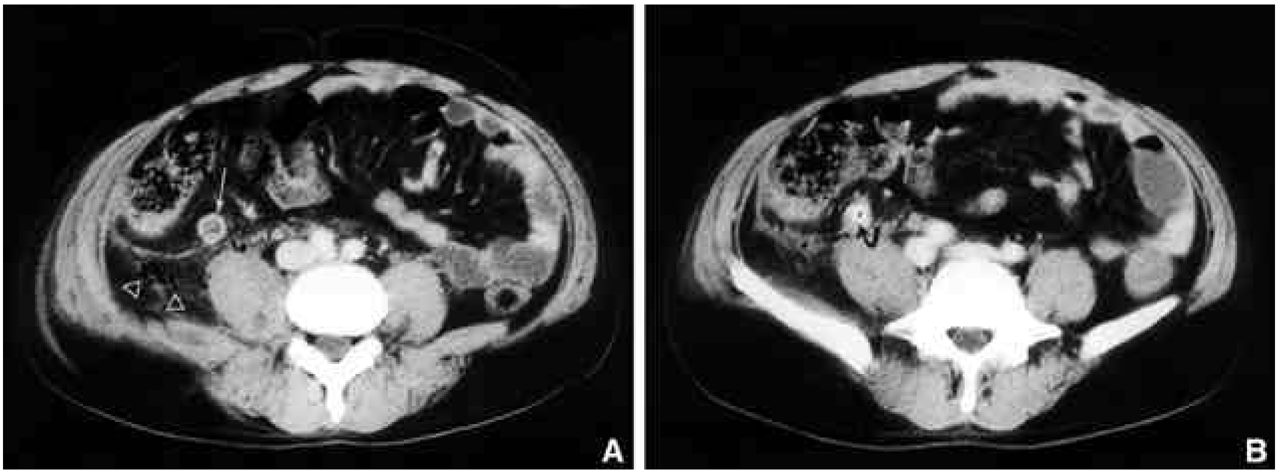

Fig. 15. Perforated appendicitis. A: Contrast-enhanced CT shows distended appendix (arrow) with thickened wall. Also noted are thickened adjacent parietal peritoneum, diffuse periappendiceal strandings, and extraluminal air collection (arrowheads). B: Contrast-enhanced CT caudad to the level (A) shows hyperattenuated appendicolith (arrow) in the tip of the distended appendix.

as fibrofatty proliferation, abscess formation, phlegmonous changes and lymphadenopathy. In patients with ulcerative colitis, CT helps to define the causes of widening of the presacral space whether it results from increased fat deposition, inflammatory infiltration of perirectal fat, or rectal wall thickening. Although observing mucosal changes is important in identifying gastrointestinal diseases, differentiating Crohn's disease from intestinal tuberculosis is not always easy with barium study which is the only reliable radiological tool for assessing mucosal detail. However, observing perienteric and/or peritoneal changes on CT may occasionally give the clues for solving the difficulty in distinguishing both conditions. The presence of partially calcified, enlarged lymph nodes with low-attenuation centers due to central caseation necrosis is the most diagnostic finding in intestinal tuberculosis. Other findings favoring a diagnosis of tuberculosis include diffuse infiltrations in the omentum and mesentery and multiple enlarged nodes larger than 1 cm; the latter finding is unusual in cases of Crohn's disease (usually 3-8 mm) if lymphoma or adenocarcinoma is not complicated (38). In contrast, the incidence of fibrofatty proliferation is much higher in Crohn's disease.

There are several gastrointestinal diseases in which the presence of inflammatory infiltrates in the perienteric or pericolonic fat adjacent to the bowel is crucial for making a specific diagnosis. The most typical cases in such circumstances include acute appendicitis, primary epiploic appendagitis and diverticulitis. The normal appendix appears on CT as a small tubular or ring-like structure with a pencil-thin wall. It can be filled with a small amount of fluid, air, or barium. The definite diagnosis of acute appendicitis is made on CT by identifying a combination of abnormal-appearing appendix (>6 mm in diameter or unopacified), periappendiceal inflammatory infiltrates and a calcified appendicolith (39) (Fig. 15). "Arrowhead sign", in which a high-density contrast medium is collected in the upper portion of the cecum, is also known as a highly specific finding for diagnosing appendicitis (40). In the absence of abnormal thickening of the appendiceal wall or periappendiceal inflammation, the presence of calcific appendicoliths or air is not clinically significant. Periappendiceal inflammatory changes without evidence of abnormal appendix or appendicolith is a suggestive but nonspecific finding as such conditions can occur in a variety of pathologies, like Crohn's disease, typhlitis, diverticulitis, pelvic inflammatory disease and perforated carcinoma. Primary epiploic appendagitis is a rare inflammatory intraabdominal process attributable to either torsion or spontaneous venous thrombosis of an epiploic appendage with subsequent ischemic infarction and inflammation (41). CT findings are virtually pathognomonic for establishing the diagnosis, and they include a pericolonic, oval-shaped lesion with fat attenuation, thickened visceral peritoneal lining and periappendageal fat stranding (42) (Fig. 16). Additional CT findings may include a central hyperattenuating dot and thickened nearby parietal peritoneum as well as mass effect, focal wall thickening of the adjacent colon or both (43). Diverticulitis results from diverticular perforation with resultant intramural, pericolic, or peritoneal inflammation. On CT, diagnostic findings include the presence of pericolic inflammation and edema, appearing as regions of linear stranding or hazy increased density in the pericolonic fat adjacent to the site of diverticular perforation (Fig. 17). In more severe cases, pericolonic phlegmon or abscess may be present. In the clinical setting, the differentiation of diverticulitis from colonic cancer is crucial for appropriate clinical management; Balthalzar et al. (11) reported that the imaging appear-

Fig. 16. Appendagitis. Contrast-enhanced CT shows a pericolonic, oval-shaped lesion (arrows) with fat attenuation anterior to the ascending colon, along with pericolonic fat stranding. The wall of the ascending colon is also mildly thickened with mural edema.

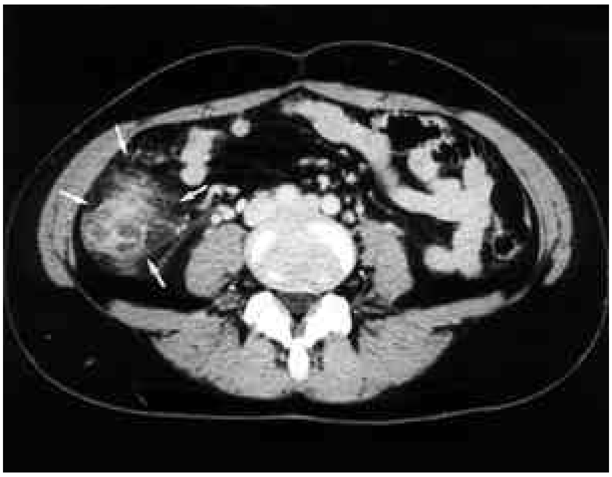

Fig. 17. Colonic diverticulitis. Contrast-enhanced CT shows thickening of the colonic wall with mural edema. Also noted is diffuse pericolonic infiltrates (arrows).

ances overlapped in about 10% of cases. Some researchers have stressed the importance of observing pericolonic or perienteric and mesenteric changes (44, 45). The incidence of pericolonic lymphadenopathy is much higher in patients with colonic cancer than in patients with diverticulitis, whereas CT findings of fluid at the root of the mesentery and vascular engorgement are much more common in patients with diverticulitis (46).

Neoplastic diseases

In neoplastic diseases, distinguishing the depth of tumor invasion in the bowel wall cannot be made on CT. Therefore, observing perigastric or pericolonic or perigastric changes may be essential for staging gastric or colorectal cancers; the margin of the strandings in neoplastic diseases generally appear to be sharper than those of inflammatory bowel diseases. Extension of tumor beyond the bowel wall is suggested when the outer borders of involved bowel wall are irregular along with soft tissue or linear strandings in the pericolonic or perigastric fat plane. However, using these CT signs in staging the tumors has been limited. It is because CT is not sensitive enough to detect microscopic invasion of the adjacent fat. Therefore, sharp outer border of the bowel wall without strands in the adjacent fat can not exclude the possibility of tumor extension beyond the bowel wall. Moreover, vascular or lymphatic congestion, coexisting inflammatory changes, acute and chronic radiation changes, or paucity of fat due to cachexia may produce extraluminal changes similar to those of tumor infiltration.

In addition, carcinoid tumor is one of the neoplastic diseases in which CT features provide a reliable and specific diagnosis by observing the mesenteric change. On CT, these tumors show linear or curvilinear soft tissue strands in the mesenteric fat, radiating from the primary mass to the displaced and angular bowel loops (47). There are several neoplastic diseases primarily involving both omentum and mesentery, which include peritoneal carcinomatosis, peritoneal lymphomatosis, pseudomyxoma peritoni and mesothelioma. However, except for cases of pseudomyxoma peritoni, in which CT commonly shows omental thickening, multiple septate cystic lesions in the peritoneal cavity, and scalloping in the hepatic and splenic surface (48) (Fig. 18), significant overlaps are present between the other conditions so that making a specific diagnosis may be difficult by CT findings alone. Furthermore, differentiating these neoplastic processes

Fig. 18. Pseudomyxoma peritoni of unknown origin. Contrast-enhanced CT shows multiple cystic masses (arrows) scattered through the greater and lesser omentum and peritoneal cavity, along with a large amount of ascites. The hepatic and splenic surfaces are slightly lobulated in the margin.

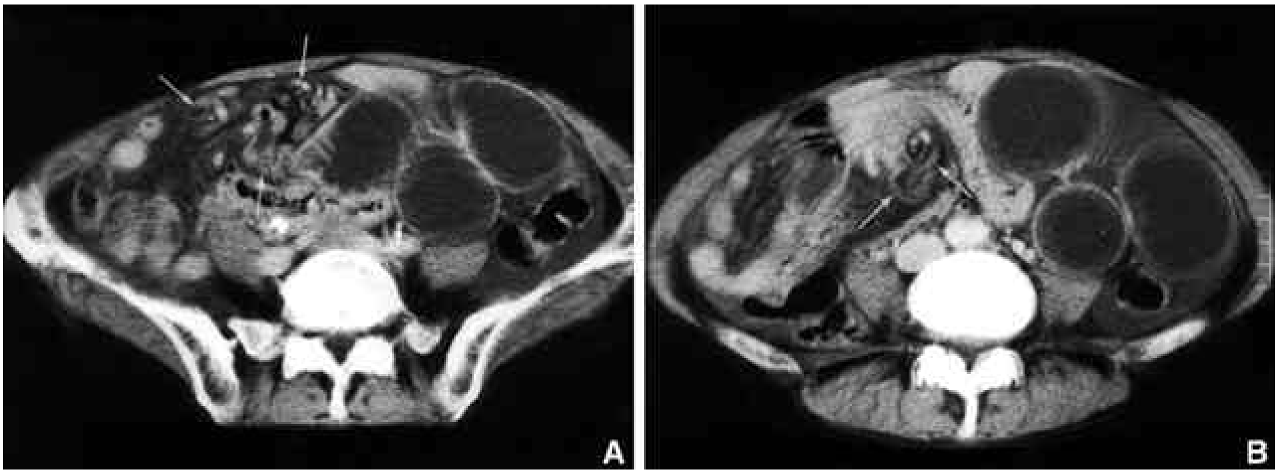

Fig. 19. Strangulated small-bowel obstruction. A: Contrast-enhanced CT shows diffuse jejunal dilatation due to bowel obstruction. Also noted are severe mesenteric vascular engorgement (arrows) and ascites. B: Contrast-enhanced CT scan cephalad to (A) shows twisting (whirl sign) of mesenteric vessels (arrows) adjacent to the obstructed site.

from tuberculous peritonitis may also be difficult or impossible although Ha et al. (49) reported a sensitivity of 69% for predicting tuberculous peritonitis by using CT; according to this report, tuberculous peritonitis shows increased incidence of mesenteric macronodules larger than 5 mm in diameter, thin line covering the infiltrated omentum, and splenic abnormalities such as calcification or splenomegaly.

Vascular diseases

In patients with suspected mesenteric ischemia, perienteric or pericolonic changes appear to be somewhat different from those in inflammatory and neoplastic diseases. The presence of both diffuse mesenteric haziness and vascular engorgement are the hallmarks of vascular diseases which have outflow disturbance of mesenteric blood flow caused either by mesenteric or portal venous occlusion or by increased mesenteric or portal venous pressure (Fig. 11). In contrast, cases of mesenteric arterial occlusion, a disorder with inflow disturbance of the mesenteric vessels, do not show mesenteric engorgement. However, in most of the patients with mesenteric inflow disturbance, collateral circulations develop in the mesentery, retroperitoneum or in both. Unfortunately, CT does not clearly discriminate whether increased mesenteric vessels indicate mesenteric engorgement or abundant collateral circulation. Therefore, it is very important to scrutinize the presence of thromboembolism in mesenteric vessels if the mesenteric vessels are increased in number and diameter or mesenteric haziness is seen, and if advanced liver cirrhosis, which causes increased mesenteric and portal venous pressure, is excluded.

In patients suspected of having small bowel obstruction due to bowel adhesions and bands, volvulus and hernia, observing mesenteric vascular changes is very important to distinguish simple from strangulated intestinal obstruction. Although the presence of severe mesenteric haziness and vascular engorgement favors the diagnosis of strangulated obstruction (36) (Fig. 19), mild degree of such vascular changes is also demonstrated in simple obstruction. However, there may be a problem in determining the degree of these vascular changes on CT. Accordingly, the signs of mesenteric vascular engorgement and haziness should be interpreted cautiously on CT in patients for whom the decision of simple from strangulated intestinal obstruction is critical. An unusual mesenteric vascular course, such as mesenteric vascular twisting ('whirl' sign), is also known to be very specific for the diagnosis of strangulated obstruction (36) (Fig. 19); this sign was originally reported in patients with intestinal malrotation associated with volvulus (50), and we experienced this sign in asymptomatic patients who underwent gastrectomy with surgical maneuver of the small intestine.

Although mesenteric vascular changes are more commonly seen in patients with vascular disorders, a small group of patients with inflammatory bowel disease such as Crohn's disease, shows hypervascularity in the perienteric or pericolonic spaces or in the mesentery. This hypervascularity is found in the earlier or active stages of Crohn's disease rather than in the chronic stages (51) (Fig. 20). Although the cause of this finding is not well understood, some researchers hypothesize that hypervascularity is due to vasculitis with hypercoagulability leading to ischemia (52), and more recent studies have demonstrated an increased expression of somatostatin receptors in the veins of inflamed intestine (53). In addition, as bowel ischemia can develop in the colon proximal to cancers, a small tumor can be missed if pericolonic vas-

Fig. 20. Crohn's disease. Contrast-enhanced CT shows hypervascularity (arrows) in the pericolonic space surrounding the transverse colon. Also noted are mild concentrical bowel wall thickening (arrowheads) of the distal transverse and descending colon and small amount of ascites.

cular engorgement and haziness due to coexisting colonic ischemia are promiment.

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