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ABDOMINAL IMAGING

PICTORIAL ESSAY

CT findings in acute peritonitis: a pattern-based approach

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ABSTRACT

Many inflammatory and infectious entities may acutely affect the peritoneum causing a thickening of its layers. Unfortunately, several acute peritoneal diseases can have overlapping features, both clinically and at imaging. Therefore, the awareness of the clinical context, although useful, may be sometimes insufficient to identify the underlying cause. This article provides a specific computed tomography-based approach including morphologic characteristics of peritoneal thickening (e.g., smooth, irregular, or nodular) and ancillary findings to narrow the differential diagnosis of acute peritonitis.

Computed tomography (CT) became an important tool in the detection and characterization of acute abdominal involvement with the development of multidetector CT (MDCT) scanners. This technology makes the acquisition of isotropic data possible and affords the capability of performing high-resolution multiplanar reconstructions (1). Thus, CT imaging is often the initial modality in acute abdomen in a significant proportion of patients, and radiologists should have a high level of suspicion in detection and interpretation of peritoneal abnormalities.

As a wide variety of acute peritoneal diseases may present with similar clinical features, the clinicians ask the interpreting radiologist to provide a concise and focused differential diagnosis. However, several specific entities may manifest with overlapping CT findings.

This article provides an overview of MDCT appearances of acute peritoneal diseases based on the peritoneal thickening pattern and a detailed analysis of the associated findings.

Peritonitis: definition, clinical features, and etiology

Peritonitis is an inflammatory condition of the peritoneum; it may be infective or noninfective. Intra-abdominal infections have two major manifestations: bacterial peritonitis and, its late but localized stage, intra-abdominal abscess. Bacterial peritonitis can be classified as primary and secondary peritonitis. Primary peritonitis is usually defined as a diffuse bacterial infection of the peritoneal cavity occurring without loss of integrity of the digestive tract. Secondary bacterial peritonitis is defined as an acute infection of the peritoneal cavity, usually resulting from perforation or anastomotic disruption of the digestive tract (2). Sometimes secondary peritonitis may arise from acute abdominal inflammatory conditions, peritoneal dialysis, and systemic infections such as tuberculosis.

Noninfective peritonitis may result from sterile involvement of the peritoneum such as in eosinophilic peritonitis (3) or encapsulating peritoneal sclerosis (4). It may also be due to chemical peritoneal irritation as in biliary or vernix caseosa peritonitis.

The clinical diagnosis of peritonitis is based on acute abdominal pain, abdominal tenderness and guarding, fever, tachycardia, nausea, vomiting, and bloating; laboratory data such as leukocytosis and acidosis are supportive.

Normal vs. pathologic peritoneum: CT appearance

On MDCT, normal peritoneum appears as a fine, thin structure, and therefore it is hardly detectable. The pathologic involvement produces a thickening of the peritoneal layers, which become easily noticeable.

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According to the type of peritoneal involvement, it is possible to identify three different patterns. *1- Smooth uniform pattern:* peritoneal thickening is regular and of uniform thickness and shows a smooth interface with the omental fat (Fig. 1). *2- Irregular pattern:* peritoneal thickening shows a nonuniform thickness with focal segments being thicker than others; the interface between the thickened peritoneum and the omental fat appears rough and irregular; focal thicker segments show an obtuse angle with the peritoneum (Fig. 2). *3- Nodular pattern:* peritoneal thickening is absent or minimal; the predominant finding is well-defined nodules of soft tissue attenuation which are individually seen along the peritoneum and are outlined by the adjacent omental fat; nodules typically show variable diameters with some larger and others smaller in size (Fig. 3).

CT pattern-approach of peritonitis

Inflammatory and malignant diseases of the peritoneum can have a similar appearance. Moreover, different causes of peritonitis can show similar CT findings. Therefore, a CT pattern-approach may represent a further useful diagnostic tool for correct image assessment.

Before describing this approach, it is important to understand that the awareness of the patient's clinical history and presentation is essential for an accurate image interpretation. Furthermore, the use of CT-pattern approach cannot exclude a careful evaluation of the ancillary CT findings (e.g., free intraperitoneal air) that significantly contribute to make the correct diagnosis.

The smooth uniform thickening is the prevalent pattern in most cases of acute peritonitis, whereas the nodular pattern is relatively rare. Malignant lesions such as peritoneal carcinomatosis, peritoneal lymphomatosis, and mesothelioma show nodular thickening as the prevalent pattern (5). Nevertheless, although less frequently, the irregular as well as the nodular patterns may be seen in several types of acute benign peritoneal diseases**.** In these cases the appearance of the greater omentum and the small bowel mesentery may help to avoid false diagnosis of malignancy. As a matter of fact, in neoplastic diseases the omental involvement ranges from subtle, larger discrete nodules to a diffuse continuous mass, otherwise referred to as omental caking (6). Similarly, the involvement of small bowel mesentery by focal nodules or

Main points

- Acute peritonitis presents with nonspecific clinical and laboratory features.
- To date multidetector CT represents the best imaging modality to evaluate patients with acute abdominal pain. In this setting, radiologists should be aware of CT findings indicative of acute peritoneal diseases.
- CT pattern-approach, based on the detection of three different patterns (smooth regular, irregular, and nodular), may represent a useful diagnostic tool for a correct image assessment.
- Starting from patient's clinical history, the analysis of CT peritoneal pattern together with the associated ancillary findings is the clue for correct image interpretation and differential diagnosis.
- When using this approach, radiologists may accurately differentiate benign peritoneal diseases from malignant ones and may define the underlying pathology.

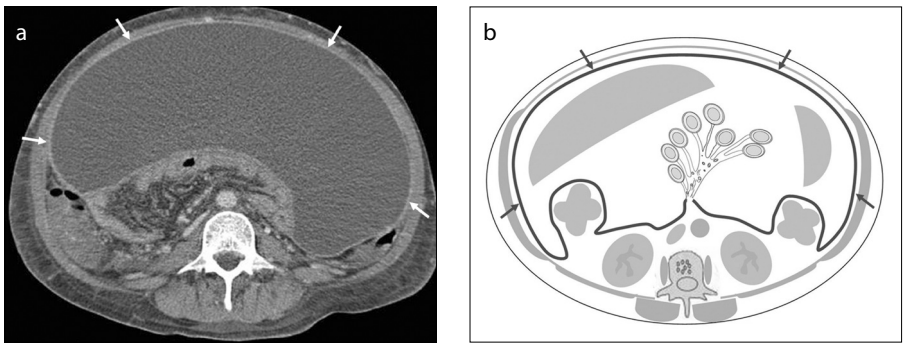


Figure 1. a, b. A 65-year-old man with hepatitis induced liver cirrhosis, fever, and abdominal pain. Axial contrast-enhanced MDCT image **(a)** and schematic drawing **(b)** show smooth, uniform thickening of the peritoneum (*arrows*) due to spontaneous bacterial peritonitis.

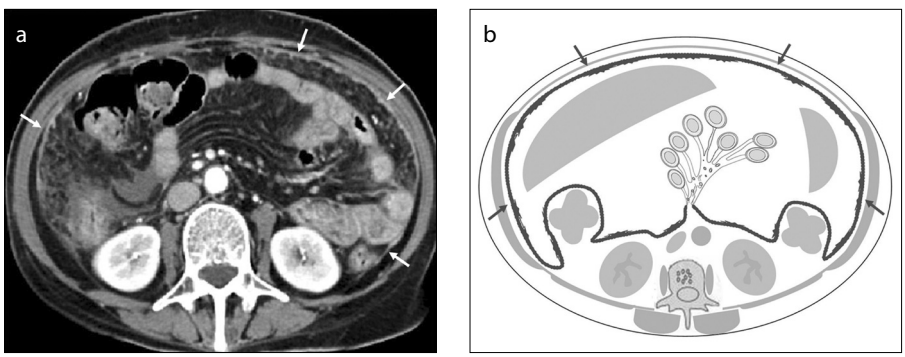


Figure 2. a, b. A 34-year-old man with HIV infection. Axial contrast-enhanced MDCT image **(a)** and schematic drawing **(b)** show irregular thickening of the peritoneum (*arrows*) due to proven tuberculous peritonitis.

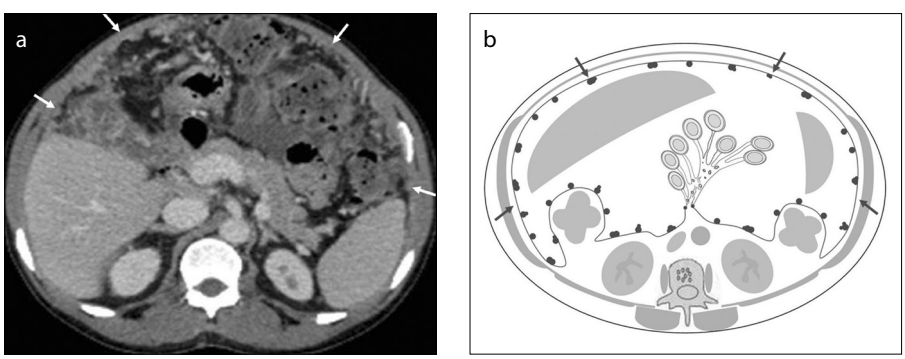


Figure 3. a, b. A 42-year-old immigrant woman from Ethiopia. Axial contrast-enhanced MDCT image **(a)** and schematic drawing **(b)** show nodular thickening of the peritoneum (*arrows*) due to proven tuberculous peritonitis.

masses is common in malignancy. According to the literature, metastatic cell growth occurs at natural sites of fluid accumulation (7). The lower small bowel mesentery near the terminal ileum is one of the natural sites where tumor initially deposits. Therefore, the terminal ileum is a critical area to evaluate when searching for evidence of peritoneal metastases (8). Different from malignancies, the omental involvement is uncommon in acute peritonitis whereas the small bowel mesentery can be frequently involved.

Several different entities characterized by diffuse and localized acute peritonitis will be discussed in the order of frequency, according to the peritoneal thickening pattern.

Smooth peritoneal pattern

Localized peritonitis secondary to acute abdominal inflammatory condition

Appendicitis, diverticulitis, or Crohn's disease may be responsible for a localized peritonitis. Usually localized peritonitis is characterized by a small sized fluid-like collection surrounded by smoothly thickened and enhancing peritoneum abutting the involved gastrointestinal (GI) tract; these findings are associated with increased density within the adjacent mesentery.

Peritonitis secondary to perforation of the abdominal viscera

Perforation of the GI tract frequently leads to emergency conditions that require surgical management. Free fluid and air in the peritoneal cavity represent the hallmark findings at CT. Peritoneal thickening can be considered in the context of peritonitis secondary to a GI tract perforation, if present along with extraluminal gas associated with segmental bowel wall thickening, abnormal bowel wall enhancement, perivisceral fat stranding, and free fluid (Fig. 4).

Pelvic inflammatory disease

Pelvic inflammatory disease (PID) is characterized by smooth uniformly enhancing peritoneal thickening associated with pelvic fat haziness. The fallopian tubes exhibit an even greater degree of wall thickening and enhancement and are filled with complex fluid, which usually indicate pyosalpinx (9). Frank tubo-ovarian and pelvic abscesses are indicated by the presence of a thick-walled, complex fluid collection that may contain internal septa and a fluid-debris level (Fig. 5).

The intraperitoneal spread of PID can cause perihepatitis, which is an inflammation with smooth thickening of the peritoneal covering of the liver. In women with PID, perihepatitis associated with right upper abdominal pain is known as Fitz–Hugh–Curtis syndrome (9, 10). It has been demonstrated that hepatic capsular enhancement implying perihepatitis can be present in women with PID without right upper abdominal pain (9, 11). This means that hepatic capsular enhancement can be one of the useful ancillary CT findings for diagnosis of acute PID, regardless of association with Fitz–Hugh–Curtis syndrome.

Spontaneous bacterial peritonitis (SBP)

Spontaneous bacterial peritonitis (SBP) is a primary infectious peritonitis due to an infection of the ascitic fluid typically caused by *Escherichia coli*, *Streptococcus,* and *Klebsiella*, commonly occurring in patients with hepatic cirrhosis (prevalence of 8%–27%). Clinical criteria are positive culture of ascitic fluid, neutrophilic count of at least 250 cells for mm^3 in the ascitic fluid, and no obvious intra-abdominal source of infection. SBP may be caused by the combination of long-term bacteremia due to deficient defense mechanisms in the host, intrahepatic shunting, and decreased bactericidal activity that occurs in ascites (12).

Although the diagnosis may be based exclusively on the clinical scenario and the history of cirrhosis, the referring clinicians often request a MDCT to confirm the diagnosis and, mainly, to exclude a malignant peritoneal involvement. The key MDCT features are represented by smooth thickening of peritoneum that involves the whole abdominal cavity, with a relative sparing of mesenteric folds, associated with gross ascites (Fig. 1). Diagnosis can be confirmed by combining the peritoneal pattern thickening with the clinical data.

Biliary peritonitis

Biliary peritonitis is a relatively uncommon condition, often neglected and uniformly fatal if left undrained. Rupture of a pathologic gallbladder or rupture of biliary ducts or cholangitic abscess secondary to obstruction of biliary tree are known causes. Blunt trauma is another cause due to gallbladder injury, while extrahepatic bile duct injury contributed to few reported cases. Iatrogenic biliary injuries are feared complications, which were reported to occur in approximately 0.2%–0.3% during the open cholecystectomy era; its incidence has increased up to 0.9% following the introduction of laparoscopic cholecystectomy (13, 14). The clinical picture is determined by the amount and rate of leak of bile into the abdominal cavity. The clinical scenario combined with history and MDCT location of intraperitoneal fluid should raise the suspicion of biliary peritonitis. Loculated fluid is often located in the projection of the cystic duct seat, at the hepatic hilum, and in the subhepatic space. A slight smooth peritoneal thickening is noticeable in diffuse biliary peritonitis.

Wet type tuberculous peritonitis

Wet type tuberculous peritonitis is characterized by large amounts of free or loculated viscous fluid (15). On MDCT, a smooth peritoneal thickening with pronounced enhancement suggests the wet-type tuberculous peritonitis, when

Figure 4. A 69-year-old woman with sudden onset of abdominal distension and severe abdominal pain, initially localized in the right inferior quadrant then diffuse to the whole abdomen, associated with nausea, chill, and leukocytosis. Axial MDCT image shows free intraperitoneal air (*asterisks*), ascites, smooth pelvic peritoneal thickening (*arrows*), and bowel wall thickening (*open arrows*) indicative of peritonitis caused by intestinal perforation.

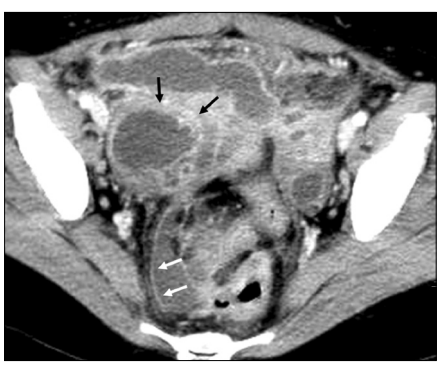


Figure 5. A 32-year-old woman with acute pelvic pain and leukocytosis. Axial contrast-enhanced MDCT image shows a right tubo-ovarian abscess (*black arrows*) with fluid collections surrounded by smoothly thickened and enhanced peritoneum (*white arrows*).

combined with free ascitic fluid and thickened strands with crowded vascular bundles within the mesentery. The omentum shows the typical smudged appearance characterized by ill-defined soft tissue densities (15) (Fig. 6). The smooth peritoneal thickening pattern coupled with the typical omentum and mesentery appearance differentiates tuberculous peritonitis from peritoneal carcinomatosis (5). Furthermore, all ancillary CT findings, such as splenomegaly and calcifications of the spleen, involvement of the ileocecal wall, retroperitoneal and peripancreatic lymphadenopathy with a hypodense center and ring-enhancement, are deemed suggestive of tuberculous peritonitis. The diagnosis still requires a high index of suspicion based on clinical history that is essential once the suggestive findings have been demonstrated by MDCT.

Nowadays, when speaking about tuberculosis, it has to be considered that *Mycobacterium tuberculosis* is one of the commonest pathogens known to cause immune reconstitution syndrome in HIV-positive patients receiving highly active antiretroviral therapy, with reported incidence varying from 8% to 43% (16). In these cases abdominal tuberculosis refers to the involvement of the digestive organs, mainly abdominal lymph nodes, liver, pancreas, and spleen. Intra-abdominal lymphadenopathy is the commonest, and the only feature in more than half (55%) of the cases (17). In most cases (80%–90%) tuberculous adenopathies show a characteristic appearance including internal low-attenuation caseation or liquefaction, and peripheral contrast enhancement (17). Additionally, multiple centimetric hypodense lesions are often seen in the liver and spleen. Peritonitis is a rare manifestation of tuberculosis-associated immune reconstitution syndrome. When present, helpful features suggesting the diagnosis include minimal, smooth peritoneal thickening, inhomogeneously infiltrated omentum, associated ileocecal disease, and necrotic lymph nodes.

Eosinophilic peritonitis

Eosinophilic peritonitis is a rare condition of unknown etiology characterized by eosinophilic infiltration of the GI tract, involving subserosal layer. It is often associated with peripheral eosinophilia and an allergic diathesis (3). MDCT findings are characterized by a slightly smooth thickening of the peritoneum with ascites that is not associated with soft tissue infiltration of omentum and/or mesentery. Gastric and/or bowel wall thickening may also be seen (Fig. 7). These findings combined with high peripheral eosinophil count should raise suspicion of eosinophilic peritonitis. An endoscopic evaluation of upper GI tract with biopsy usually confirms the eosinophilic infiltration of the gastric wall.

Vernix caseosa peritonitis

Vernix caseosa peritonitis (VCP) is a rare complication of cesarean section caused by spillage of amniotic fluid or vernix caseosa into the peritoneal cavity. The diagnosis should be suspected in any patient presenting with post-cesarean delivery acute abdomen. Vernix caseosa can result in a profound systemic inflammatory response that necessitates maternal laparotomy and may lead to erroneous resection of intra-abdominal organs. Diagnosis is often difficult due to lack of awareness of the condition and may only be made following histologic examination. The characteristic intraoperative finding is a cheesy white exudate that coats the visceral organs, which are not inflamed themselves (18, 19). Histologic examination of the cheesy exudates is the only way to diagnose VCP. The principal symptoms of VCP are generalized severe abdominal pain, pyrexia, peritonism, and elevated white cell count. MDCT reveals intraperitoneal fluid collections and multiple small abdominal abscesses. Increased awareness of this condition is crucial so that it may be considered in the differential diagnosis of post-cesarean acute abdomen thereby avoiding the unnecessary removal of healthy intra-abdominal organs.

Irregular peritoneal pattern

Encapsulating peritoneal sclerosis

Encapsulating peritoneal sclerosis (EPS) may be idiopathic or secondary to chronic ambulatory peritoneal dialysis. Clinical features include recurrent abdominal pain, nausea, vomiting, abdominal mass, bowel obstruction, and weight loss. It is characterized by a diffuse inflammatory process resulting in widespread peritoneal fibrosis. CT hallmarks are a thin irregular peritoneal thickening, the presence of small bowel loops congregated to the center of the abdomen encased by a thick membrane, loculated fluid collections or gross ascites, peritoneal and serosal bowel wall calcification, and calcifications over liver

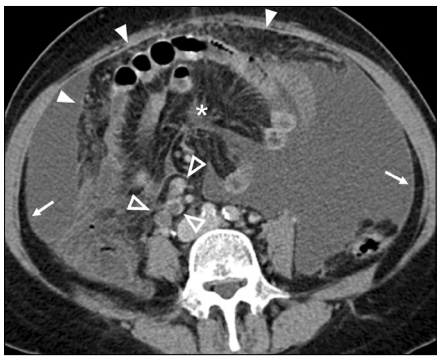


Figure 6. A 54-year-old woman with HIV infection presenting with fever, general ill health, and abdominal pain due to proven tuberculous peritonitis. Axial MDCT image shows ascites and diffuse abdominopelvic smooth peritoneal thickening (*arrows*), associated with a "smudged" appearance of the omental fat (*arrowheads*), soft tissue strands with crowded vascular bundles in the small bowel mesentery (*asterisk*) and caseous lymph nodes (*open arrowheads*).

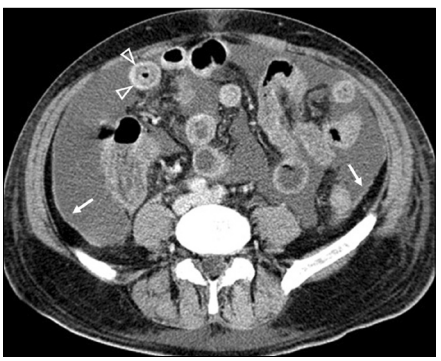


Figure 7. A 51-year-old man with clinical acute abdomen and an increased white cell count with eosinophilia. Axial contrast-enhanced MDCT image shows a diffuse smooth peritoneal thickening (*arrows*) with ascites associated with a stratified ileal wall thickening (*open arrowheads*). Endoscopic biopsy of the stomach demonstrated increased number of mucosal eosinophils, confirming the diagnosis of eosinophilic gastroenteritis and peritonitis.

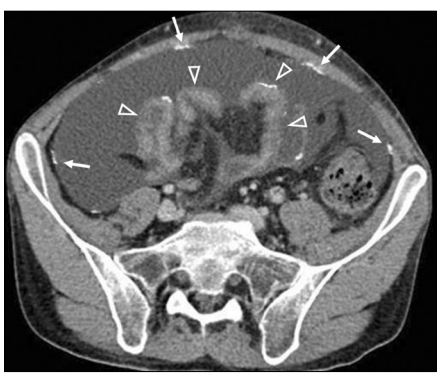


Figure 8. A 45-year-old man on continuous ambulatory peritoneal dialysis with complaints of weight loss, persistent nausea, and abdominal discomfort. Axial contrast-enhanced abdominal CT scan shows fluid within abdomen surrounded by thickened, partially calcified parietal (*arrows*) and visceral (*open arrowheads*) peritoneum.

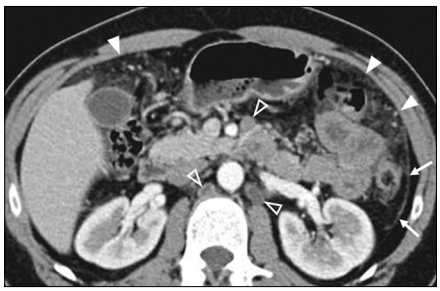


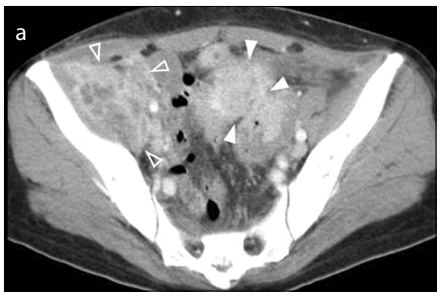
Figure 9. A 52-year-old HIV positive man with abdominal pain, low fever, and anorexia due to proven tuberculous peritonitis. Axial MDCT image shows irregular peritoneal thickening (*arrows*) and a smudged involvement of the omentum (*arrowheads*), associated with caseous lymph nodes (*open arrowheads*).

Figure 10. A 31-year-old immigrant woman from Ethiopia with high fever, abdominal distension and severe abdominal pain due to proven tuberculous peritonitis. Axial contrast-enhanced MDCT image shows diffuse nodular peritoneal (*arrows*) and mesenteric (*asterisk*) thickening.

capsule, spleen, and posterior peritoneal wall (4) (Fig. 8). Although peritoneal thickening and calcifications are also seen in pseudomyxoma peritonei, certain peritoneal tumor deposits, and peritoneal mesothelioma, combining all CT findings with the appropriate clinical setting (i.e., small bowel dysfunction with abdominal pain and progressive loss of ultrafiltration in patients with peritoneal dialysis) allows an early, reliable, and noninvasive diagnosis of EPS (4).

"Dry" or "plastic" type tuberculous peritonitis

Dry or plastic type tuberculous peritonitis is characterized by caseous nodules, fibrous peritoneal reaction and dense adhesions (15). When an irregular peritoneal thickening pattern is seen, tuberculous peritonitis should be considered if associated with omental smudged pattern and enlarged caseous lymph nodes. Moreover, other ancillary findings including thickening of the ileocecal wall, splenomegaly, and splenic calcifications may assist in guiding diagnosis in the proper clinical scenario (Fig. 9).



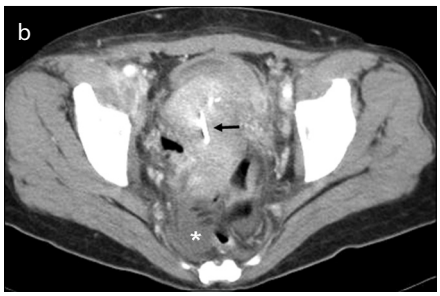


Figure 11. a, b. A 41-year-old woman with a history of long-term intrauterine device (*black arrow*, **b**) and mild fever, abdominal pain, and leukocytosis due to proven pelvic actinomycosis. Axial contrast-enhanced MDCT images **(a, b)** show intra- (*arrowheads*, **a**) and extra peritoneal (*open arrowheads*, **a**) masses with strong enhancement in the solid component and minimal ascites (*asterisk*, **b**).

Nodular peritoneal pattern

Peritonitis caused by abdominal viscera perforation induced by malignancy

Different from benign peritonitis, nodular peritoneal thickening is the hallmark of peritonitis induced by GI tract perforation due to primary or metastatic neoplastic bowel involvement with peritoneal spread. In fact, peritoneal carcinomatosis may be due to a primary abdominal tumor, such as gastric or colorectal or pancreatic or ovarian cancer (20), or an extra-abdominal tumor, such as breast carcinoma, melanoma, or lung cancer (21). Usually diffuse peritoneal involvement is characterized by parietal and visceral nodular implants which cover and encase the small bowel loops, leading to obstruction, and occasionally to perforation. Colon adenocarcinoma can lead to perforation proximal to the mass. The most commonly involved segments to perforate include the sigmoid colon and the cecum (21). On CT, identifying signs of perforation in the setting of irregular colonic wall thickening and infiltrative pericolonic soft tissue can favor the diagnosis.

"Fibrotic fixed" type tuberculous peritonitis

Fibrotic fixed type tuberculous peritonitis, characterized by omental mass formation and matted bowel loops and mesentery, may show a nodular peritoneal thickening pattern (Fig. 10). These findings make the differentiation from neoplastic peritoneal involvement challenging. Thus, this condition represents a "great mimicker." However, when supported by clinical features, the radiologist has to consider tuberculous peritonitis as an alternative diagnosis to peritoneal carcinomatosis (5, 15).

Abdominopelvic actinomycosis

Actinomycosis is a rare infection which manifests with abscess formation and dense fibrosis and involves the ileocecal region, ovary, and fallopian tube (22). Pelvic actinomycosis is usually associated with a history of long-term intrauterine contraceptive device use. The common CT finding is a strongly enhancing solid mass with a tendency of violating normal anatomic boundaries. The strong contrast enhancement is due to the presence of granulation tissue. Ascites is usually minimal or absent (22). These features may raise concern for neoplastic disease which has to be considered in the differential diagnosis. Combining clinical history (pain, leukocytosis, long-term history of intrauterine device) with CT findings of an infiltrative mass showing dense contrast enhancement without significant ascites, pelvic actinomycosis should be considered before planning surgery (22) (Fig. 11). Moreover, tubo-ovarian abscess is usually more solid in actinomycosis than it is in PID.

Conclusion

Assessment of peritoneal thickening pattern may help to differentiate peritonitis from malignant peritoneal involvement. Indeed, smooth uniform thickening is the prevalent pattern in inflammatory involvement, whereas nodular pattern is common in neoplastic diseases. In case of a smooth pattern, radiologists can accurately identify the underlying pathology by considering the results along with ancillary CT findings and the clinical data. In acute peritoneal diseases presenting with uncommon irregular

or nodular peritoneal thickening patterns, radiologists should be aware that the diagnosis may include not only neoplastic diseases but also inflammatory conditions such as tuberculous peritonitis, EPS, and actinomycosis.

Conflict of interest disclosure

The authors declared no conflicts of interest.

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