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■ REVIEW ■

Ultrasound Examination of Gastrointestinal Tract Diseases

With recent technical advances, increasing use of sonography in the initial evaluation of patients with abdominal disease may allow the detection of unexpected tumor within the abdominal cavity. Easiness of sonographic detection of bowel pathology, purposely or unexpectedly, warrants the inclusion of bowel loops during ultrasound examination when a patient complains of symptoms indicating diseases of the bowel. In patients complaining of acute abdominal symptoms or nonspecific gastrointestinal symptoms and showing signs such as abdominal pain, diarrhea, hematochezia, change of bowel habit, or bowel obstruction, sonography may reveal the primary causes and may play a definitive role in making a diagnosis. On ultrasonography, abnormal lesions may appear as fungating mass with eccentrically located bowel lumen (pseudokidney sign) or symmetrical or asymmetrical, encircling thickening of the colonic wall (target sign). In patients with mass or wall thickening detected on ultrasonography, additional work-up such as barium study, CT or endoscopy would be occasionally necessary for making a specific diagnosis.

Key Words: *Intestinal Diseases; Intestinal Neoplasms; Constriction, Pathologic; Inflammation; Intestinal Obstruction; Ultrasonography*

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INTRODUCTION

Gastrointestinal tract sonography is often frustrating. Gas and feces within the small intestine and colon make visibility of the bowel loops difficult or even impossible, and therefore many doctors believe that abdominal sonography is useless in evaluating the gastrointestinal tract. Nevertheless, intestinal wall, especially when abnormally thickened by either inflammation or tumor, may produce sonographic signature, referred to as "target sign" or "pseudokidney sign", and with careful examination, these sonographic signatures can be picked up easily (1). With the increasing use of sonography in the evaluation of patients with abdominal symptoms, pathology of gastrointestinal tract can be detected incidentally or purposely. Inflammation of the vermiform appendix, the smallest segment of the gastrointestinal tract, can be successfully diagnosed by ultrasonography.

This article provides an overview of sonographic manifestations of gastrointestinal diseases, emphasizing the utility of sonography in the evaluation of gastric cancer, inflammatory and neoplastic bowel diseases, and in acute abdomen of gastrointestinal tract origin.

TECHNIQUE

Sonography is usually performed with commercially available scanners using 3.5- or 5.0 MHz sector or linear transducers. By moving the transducer slowly over the abdomen with gentle compression, adjacent bowel loops can be displaced. Scanning through the course of the colon is done along both flanks up and down for the ascending and descending colon, across the midline of the upper part of the abdomen for the transverse colon, along the left side of the lower part of the abdomen from the descending colon toward the pelvic cavity for the sigmoid colon, and across the midline of the pelvic cavity for the rectum. Small intestinal loops are in the midabdomen and may contain a small amount of gas or fluid. Differentiation of the colon from small bowel loops and abnormal segment of the bowel could be made by the location and the course of the bowel loops. Absence of luminal content in abnormal segments of the bowel enables the sonographers to easily recognize a mass or mural thickening easily. Graded compression technique to the maximally tender area may be useful in the diagnosis of acute appendicitis (2), diverticulitis, or acute appendagitis. Usually

additional two to three minutes is required to examine the bowel after general abdominal examination.

For the examination of the stomach, patients ingest 600-800 mL of boiled water and transabdominal sonography is performed (3). Patients are usually in supine position but sometimes a sitting position is needed for better evaluation of the greater curvature aspect. Oblique or decubitus position is helpful in the evaluation of the high gastric body. Sonographic examination is carried out using a 5-7 MHz transducer. With these transducers, the entire stomach from the cardia to the antrum can be scanned in sagittal and transverse planes. The focal zone can be adjusted according to the depth of the lesions with some pressure if needed.

SONOGRAPHIC FINDINGS

Sonography of normal bowel

The normal intestinal wall is visualized as a single, circular, hypoechoic layer surrounding the hyperechoic bowel content such as gas, food stuff or feces, or mixture of the two. The hypoechoic layer is considered muscle layer; the submucosal layer, normally seen in gastric wall as a middle hyperechoic layer, is too thin to be visualized. The hypoechoic wall becomes indistinct during peristalsis at the stage of distension. The normal thickness at contraction stage is 2-3 mm and wall thickness beyond 4 mm is considered abnormal (4).

Sonography of normal stomach

Five distinctive layers can be depicted frequently by abdominal sonography: a first, inner hyperechoic layer representing the interface between gastric fluid and the mucosal surface; the second hypoechoic layer representing the deep mucosa; the third, middle, hyperechoic layer representing the submucosa; the fourth hypoechoic layer representing the muscle proper; and the fifth, outer hyperechoic layer representing serosa and serosal fat (5). The frequency of visualization of each five layer depends on the part of the stomach, the antrum being visualized in about 90% of the time. The total thickness of the gastric wall as measured on sonography is 6-7 mm. The gastric wall thickness beyond 10 mm is abnormal (5).

Sonographic signatures of the diseased bowel

Sonographic abnormalities reflect the pathology, i.e. either a bulky mass or segmental thickening of the bowel wall. A mass on sonography may be small or large, and usually lobulated in contour possessing echogenic center due to air and bowel content in the lumen or ulcer, simulating sonographic appearances of kidney ("pseudokidney sign") (Fig. 1) (6). The cluster of high amplitude echoes denoting intraluminal gas and fecal content may be visible as eccentrically located. Sometimes, a mass in the ileocecal area may produce intussusception.

Fig. 1. Pseudokidney sign. A 56-year-old man with jejunal adenocarcinoma. Thickened wall (arrow) and air filled central lumen simulate "kidney".

The other sonographic signature is bowel wall thickening, either diffuse or segmental. Inflammatory bowel disease usually presents with diffuse uniform thickening whereas tumor of the bowel presents with segmental, irregular, eccentric, or encircling thickening with echogenic center ("target sign") (Fig. 2) (7). The central echo clusters are rather small because the pathologic lumen is usually narrow. Tumor of the bowel may frequently result in bowel obstruction and thus the tumor mass can be detected on sonography during a work-up of bowel obstruction.

THE ROLE OF ULTRASONOGRAPHY IN GASTRIC CANCER

Double-contrast upper gastrointestinal series and flexible fiberoptic endoscopy have significantly improved the diagnostic accuracy in gastric cancer, both in the detection of the lesion and in the determination of depth of tumor infiltration (8). Major difficulties encountered with upper gastrointestinal series and endoscopy are their inherent incapacity to enable the correct staging of the depth of tumor infiltration, as these studies predict the

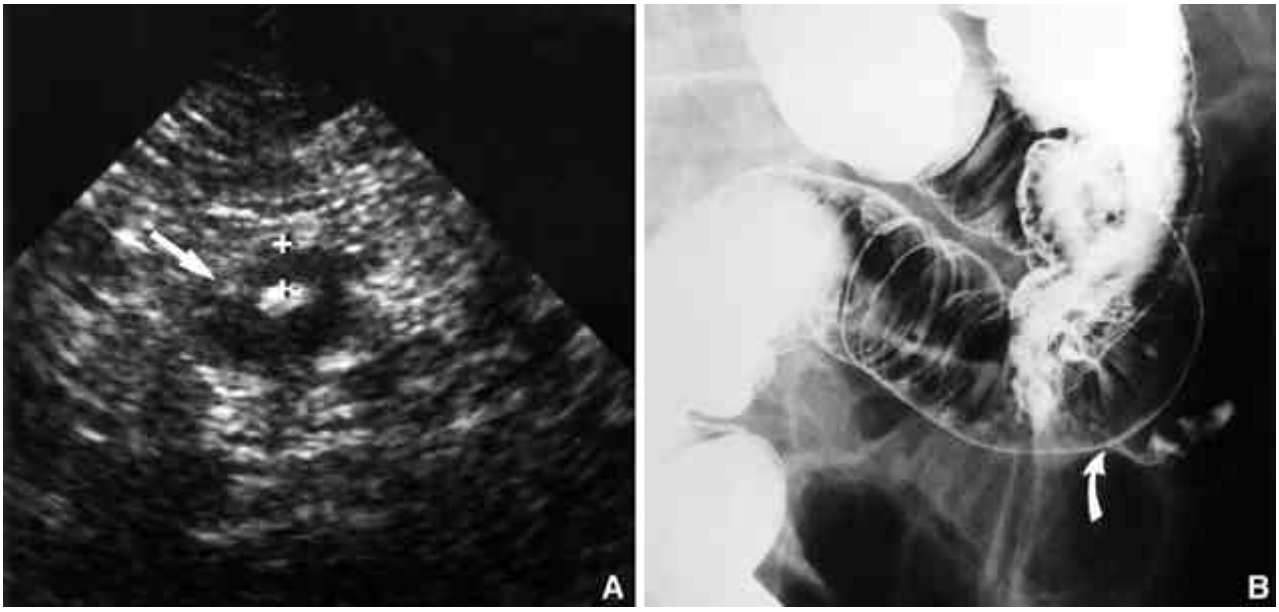

Fig. 2. Target sign. A 65-year-old woman with sigmoid cancer with colon obstruction. Sonogram (A) shows echofree outer zone representing thickened wall and echogenic center representing luminal air, simulating a "target". Barium enema (B) shows tightly stenotic segment (curved arrow) at the junction of the descending colon and sigmoid colon representing carcinoma.

depth of tumor infiltration on the basis of internal surface morphology (9).

Recent reports have indicated that endoscopic ultrasonography is a useful method in the determination of tumor penetration within the gastric wall, with the reported accuracy being 83-91% (10-13). Discrimination of individual layers of the gastric wall is possible on endoscopic sonography as a result of direct contact of the high frequency transducers to the gastric lesions. Endoscopic sonography, however, causes noticeable discomfort to patients, and the procedure cannot be performed successfully in some patients.

With abdominal sonography, the depth of tumor penetration can be determined as cancer limited to the mucosa-submucosa (early cancer) or cancer invading the muscle or serosa (advanced cancer). As the third hyperechoic layer on sonography represents the submucosa (5, 13), the criterion of early gastric cancer is an intact third hyperechoic layer. The accuracy of T staging with abdominal sonography is 84% (3), which is slightly lower than that with endoscopic sonography (3). However, abdominal sonographic staging is rather subjective and time-consuming procedure, and it is difficult to find a small early cancer.

The sliding sign denotes different movement of each abdominal organ during respiratory movement at abdominal sonography. For example, the liver moves separately from the right kidney during deep respiratory movements. This sign was reported to be helpful in localizing a large upper abdominal mass, especially in patients with little intraabdominal fat (14). The sliding sign was also proved to be useful in the determination of gastric cancer invasion onto the pancreas, the accuracy being 90% (15). Usually, it is difficult to determine the stomach cancer invasion onto the pancreas by CT with accuracy being 20-60% (16). The sliding sign may also be useful for any intraabdominal tumor invasion onto adjacent organs.

Accurate detection and localization of enlarged lymph nodes is impossible on ultrasonography as both the stomach and lymph nodes are movable (17, 18). Furthermore, enlarged nodes do not necessarily mean metastasis.

Although there are some limitation in the detection and staging of the gastric cancer, sonography can provide global abdominal information, for example, direct invasion onto the liver or pancreas, presence of ascites, liver metastasis, ovarian metastasis, and rectal shelf. Therefore, ultrasound can be used as a complimentary role in planning of treatment for the patients with gastric cancer.

SONOGRAPHY OF INFLAMMATORY BOWEL DISEASES

Inflammatory bowel diseases such as ulcerative colitis, Crohn's disease, tuberculous ileocolitis, and vasculitis such as Behçet's syndrome and ischemic colitis may produce mucosal inflammation, erosion, and ulceration of various intensities in different areas. Progression of these diseases results in thickening of the bowel wall due to various causes such as inflammatory cell infiltration, ede-

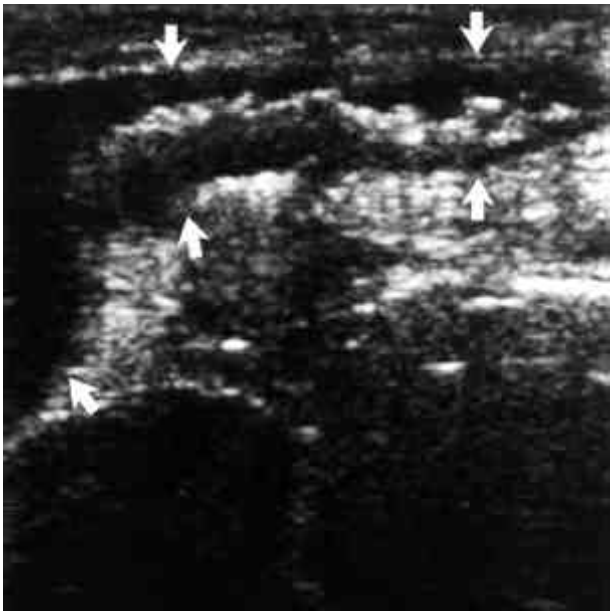

Fig. 3. Diffuse thickening of bowel wall. A 52-year-old woman with Behcet disease. Note diffuse uniform thickening of the terminal ileum (arrows).

Fig. 4. A 45-year-old man with lymphoma. The patient complained of movable mass in the midabdomen. Sonogram shows an oval, freely movable, hypoechoic mass in the midabdomen.

ma, fibrosis, or in combination (19-21).

In patients with inflammatory bowel diseases, sonography may show segmental or generalized mural thickening of the small bowel (Fig. 3) or colon (22-30). Frequently, layers of bowel wall are preserved. Mural thickening is fairly easy to recognize because the lumen of inflamed bowel is empty or nearly empty; this finding is considered to be present when the hypoechoic layer of the colon or small bowel is greater than 4 mm (4). Sonographic findings reflect thickening of the bowel wall and spasm, with resultant paucity of luminal content. However, mucosal changes cannot be seen. Sonographic findings in inflammatory bowel diseases are quite nonspecific but understanding of lesion sites may help in establishing a diagnosis. In Crohn's disease, the main areas are the small bowel and the ascending colon, whereas in ulcerative colitis, the rectum and the descending colon are commonly involved (20). In tuberculous enteritis (31) and Behçet's syndrome, the main lesion sites are the terminal ileum and the cecum. In ischemic colitis, the involved area depends on the vessel involved; the most frequent areas are the splenic flexure and descending colon.

The availability of sonographic equipment and the reasonable reliability of detecting mural thickening of the bowel on sonograms make sonography useful in initial imaging and follow-up in patients with suspected inflammatory bowel disease (1, 20, 25, 32), especially in those showing severe signs and symptoms with risk for perforation, in uncooperative patients, and in pregnant patients (28). Also, it should be stressed that the evaluation of the bowel be performed in patients with unexplained abdominal pain but no abnormal findings from routine abdominal sonography (28, 33).

SONOGRAPHY IN NEOPLASTIC BOWEL DISEASES

Sonography in small bowel tumor

The most common small bowel tumors include lymphoma, adenocarcinoma, and stromal tumors. These tumors may produce wall thickening or exophytic, fungating mass (Fig. 4), resulting in bowel obstruction, intussusception (Fig. 5), gastrointestinal bleeding, or palpable mass. Adenocarcinoma often presents with bowel obstruction and lymphoma and stromal tumor present with palpable mass.

When small bowel tumor presents with mass, the mass can be easily detected on ultrasound (34-37). Frequently, small bowel tumor is movable and this may be confirmed by pressing and pushing by a transducer. Sometimes, a large excavation in a stromal tumor can be delineated. Lymphoma may produce segmental wall thickening. Enlarged mesenteric or periaortic lymph nodes can be depicted. Adenocarcinoma producing bowel obstruction may be depicted during the sonographic evaluation of bowel obstruction. However, as the mesenteric small intestine is long and winding and movable,

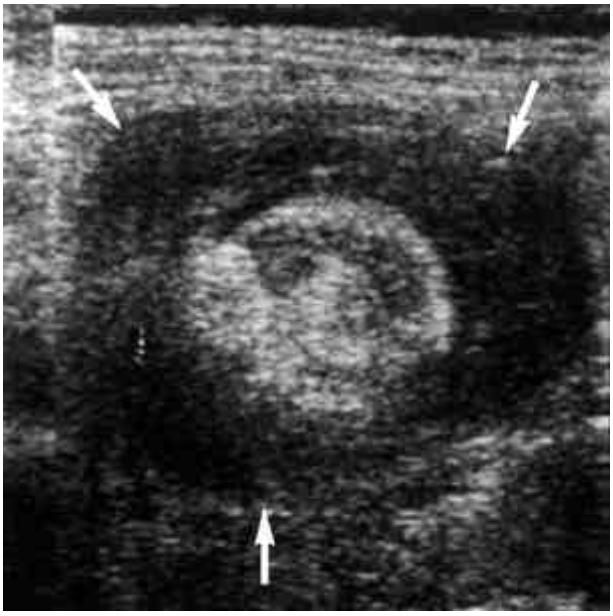

Fig. 5. A 45-year-old man with ileocolic intussusception caused by a ileal lymphoma. Sonogram shows a round tumor with central echocomplex (arrows) mimicking "multilayered target".

small tumor cannot be easily detected.

Sonography in colorectal cancer

Pathologically colorectal cancer may present as a fungating mass, either within or outside the lumen or as a short segmental wall thickening. Sonographic appearances reflect the pathology, that is, either a bulky mass or segmental thickening of the colonic wall (7, 38). A colon mass on sonography may be small or relatively large, up to 10 cm or more, and is usually irregular or lobulated in contour. The cluster of high-amplitude echoes denoting intraluminal gas and fecal content may be visible, eccentrically located around the mass (39).

The other common sonographic appearance of colorectal cancer is segmental, eccentric, or circumferential thickening of the colonic wall. The pathologic segment usually does not contain feces or gas, making sonographic visualization relatively easy. The mural thickening may be irregular but not as severe as in fungating type of carcinoma. The central echo clusters are small (target sign) because the pathologic lumen is usually narrow. This type of carcinoma may frequently result in colonic obstruction, and thus the tumor mass can be detected on sonography as a cause of colonic obstruction (38). As compared with colonic malignancy, inflammatory diseases may present with a typical target appearance, and mural thickening is usually thinner and more uniform in thickness and involves a longer segment (28). It should be stressed that negative sonographic examination is of little diagnostic value; sonography is not helpful in detecting a small mass (1, 38) or an early stage of cancer (40).

SONOGRAPHY IN ACUTE ABDOMEN

Plain films are woefully weak tools in patients with acute abdomen, such as acute appendicitis, acute cholecystitis, acute pancreatitis, and acute gynecological diseases (41, 42). Except for bowel obstruction or perforation, plain abdominal films usually do not provide information that leads us to make a specific diagnosis (41). In fact, sonography has been replacing radiography in many acute abdominal conditions (43), becoming the diagnostic procedure of choice in patients with acute appendicitis (2, 41), acute cholecystitis, bile duct calculi (45), intussusception (Fig. 5), acute gynecological diseases (41), intraabdominal abscess (46), and in the evaluation of traumatic patients (47).

Sonography in acute appendicitis

Graded compression ultrasonography has been widely used in the diagnosis of acute appendicitis and widely accepted as an accurate diagnostic modality (2, 48-51). The criterion used for the diagnosis of appendicitis is visualization of a blind ending, noncompressible appendix with a maximal diameter greater than 6 mm, or target sign on axial scan (1), the sensitivity being 80-93% (48, 49). Recently, usefulness of color Doppler sonography was reported (52). Appendicitis confined to a part of the appendix, especially focal appendicitis confined to the tip has been stressed (53).

Sonography in diverticulitis

Sonographic manifestations of diverticulitis are visualization of diverticula, thickening of colon wall, thickening of pericolic fat, and mural or pericolic abscess (54-56). Diverticula may appear as round or oval echogenic foci adjacent to the thickened colonic wall surrounded by hypoechoic rind. Thickening of colonic wall is due to hypertrophy of colonic muscles. Pericolic abscesses are present as hypoechoic mass adjacent to the thickened wall or diverticula. The sensitivity of sonography for the diagnosis of diverticulitis ranges from 84% to 100% (54, 56, 57). False negative results may occur if inflammation is mild (58).

Sonography in intestinal obstruction

Sonography has been widely applied for evaluating various abdominal diseases, but there have been few

reports concerning bowel obstruction. It may be attributable to the fact that the presence of abundant gas in the intestinal tract prevents satisfactory examination of the bowel and that adhesions, the most common cause of intestinal obstruction, are not visible on a sonogram.

All authors "selling" emergency sonography were dealing with acute conditions (43, 46, 47, 59-62) other than intestinal obstruction and bowel perforation. Several articles have dealt with the usefulness of sonography in intestinal obstruction – for example, in Peutz-Jeghers syndrome (63), small bowel bezoar (64, 65, 69), closed-loop obstruction (66), midgut malrotation (67, 68) afferent loop syndrome (69), and gall-stone ileus (70) – but these were mostly case reports.

In a prospective study of 48 patients, sonography was positive in 25% of patients in whom plain radiographs were considered normal, and the cause of obstruction was verified in 13% (71). In another study, the accuracy of preoperative sonography in establishing the diagnosis of small bowel obstruction was reported as high as 89% (72). The level of obstruction could be accurately predicted in 76% of cases by analyzing the pattern of valvulae conniventes as well as by the location of the involved bowel. The causes of obstruction, such as tumor, bezoar, gallstone, or recurrent cancer in afferent loop syndrome, were predicted. There was no sonographically demonstrable cause of obstruction when adhesions or internal hernia were the cause of obstruction. These results indicate that sonography is useful in the diagnosis of small bowel obstruction (71, 72).

Sonography appears to have advantages for the diagnosis of proximal obstruction, such as duodenal or proximal jejunal obstruction. In such cases, simple abdominal radiographs often appear normal or do not show gas because frequent vomiting results in lack of air in the obstructed segment. Lee et al. (69) reported that in seven cases of afferent loop syndrome diagnosed with sonography, abdominal radiographs were normal in all but one case. The lack of bowel gas makes sonographic examination easy. The superior mesenteric artery and vein are useful landmarks in the diagnosis of duodenal obstruction such as afferent loop or proximal jejunal obstruction since the dilated lumen of the third portion of the duodenum crosses the midline anterior to the aorta and behind the superior mesenteric artery and vein. In addition, the relative position of these vessels is an important clue in the diagnosis of rotation anomaly and midgut volvulus (67, 68).

Sonography may be valuable in the examination of patients with known or suspected colonic obstruction (7, 38). It is relatively easy to determine the level of obstruction and to identify its cause. Neoplastic lesions, the most common cause of colonic obstruction, can be detected easily. When findings on abdominal radiographs are conclusive for colonic obstruction, either a barium enema or abdominal sonography can be done (Fig. 2). When findings on abdominal radiographs are inconclusive or normal in patients with suspected colonic obstruction, sonography can be used as the next procedure in lieu of CT or barium enema to establish the diagnosis of obstruction and to identify its cause (38). Moreover, sonography may be better suited for pregnant woman or critically ill patients in whom the instillation of contrast material creates a risk of perforation.

Sonography in perforation of the gastrointestinal tract

Localized gas collections related to bowel perforations may be detectable, particularly if they are associated with other sonographic abnormalities, such as thickened bowel loop (73). Lee et al. (74) reported sonographic visualization of small amount of free gas in patients with hollow viscus perforation even when the abdominal radiographs did not delineate free gas. They also addressed that the cause of hollow viscus perforation could be detected by sonography. Meticulous examination focused on the patient's problem may yield a causative diagnosis of peritonitis due to perforated gastric or duodenal ulcer (75). Acute panperitonitis, one of the common causes of acute abdomen, produces diffuse inflammation of the peritoneum. Although it is impossible to evaluate peritoneal inflammation or thickening with sonography, there may be a small amount of peritoneal fluid. Sonography may be valuable in the investigation of causes of peritonitis; perforated appendicitis (76, 77) or diverticulitis (53, 54) can be suspected by meticulous examination.

CONCLUSION

With the recent technical advances, increasing use of sonography in the initial evaluation of the patients with abdominal disease may allow detection of unexpected tumor within the abdominal cavity. Sonographic detectability of bowel pathology, purposely or unexpectedly, warrants the inclusion of the bowel loops during ultrasound examination when a patient complains of symptoms indicating diseases of the small intestine and colon. In patients complaining of nonspecific symptoms and signs of intestinal diseases such as abdominal pain, diarrhea, hematochezia, change of bowel habit, or bowel obstruction, sonography may reveal fungating mass with eccentrically located bowel lumen (pseudokidney sign), or symmetrical or asymmetrical, encircling thickening of the colonic wall (target sign). In cases with detected mass or wall thickening, appropriate diagnosis should be made

by performing barium enema or colonoscopy. It is important to emphasize that a negative sonographic examination is of little diagnostic value as sonography is not helpful in detecting a small mass or early stage cancer.

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