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Transabdominal ultrasound of the gastrointestinal tract

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**Introduction**

Over the past two decades, US has gained increasingly in importance as a tool for diagnosis of different gastrointestinal diseases. Improvements in ultrasound technology on the one hand and increasing familiarity with sonographic findings in a variety of gastrointestinal disorders on the other hand have broadened its applications. The spectrum of indications comprises not only acute conditions such as appendicitis, diverticulitis, or bowel obstruction but also a number of subacute and chronic diseases.

The ability of US (similar to CT and MRI) to evaluate the transmural inflammatory or neoplastic changes within its surrounding structures is one of the major advantages over endoscopy and contrast radiography. This can contribute considerably to a correct diagnosis and to monitor disease activity. US provides more detailed information on bowel wall layers than CT. Other advantages include wide availability, non-invasive usage and can be performed without preparation.

There are however, some relevant limitations of US: the alimentary tract, especially the small bowel, cannot be visualized continuously over its entire length; many of the findings are nonspecific; obtaining and interpreting the images is highly operator dependent; image quality may be poor in obese patients in whom scanning with high-frequency probes cannot be performed; overlying gas may hinder the demonstration of relevant structures; technical influences such as depth penetration and Color Doppler sensitivity may also be relevant limiting factors.

**Technical considerations**

Imaging of the alimentary tract requires not only abdominal probes (2-5 MHz) but also high-frequency linear or convex probes (5 to 15 MHz). Tissue harmonic imaging allows better delineation of wall layers. Modern technical equipment also includes Color and Power Doppler imaging. The usage of Color Doppler imaging has been described in a variety of gastrointestinal disorders, particularly in patients with Crohn's disease, ischemic disease, and celiac disease. Informations regarding the main mesenteric vessels (systolic and diastolic velocities, resistance index) combined with information on end-organ vascularity in the affected segments of the gastrointestinal tract may contribute to a correct diagnosis. Panoramic imaging may also be useful in visualization of longer portions of the intestine.
Contrast-enhanced US was introduced in the last few years. Low mechanical index and second-generation microbubble contrast agent enable visualization of vascularity during a few minutes. Differentiation of inflammatory disease from ischemic disease and from scarry tissue or better delineation of abscess formations are possible applications for this new modality.

Transrectal and transvaginal US can be used complementary to transabdominal US for evaluation of different intestinal diseases in the small pelvis. High-frequency probes allow for excellent visualization of this region. Perineal ultrasound is another technique that can provide detailed information about perianal structures. This approach is particularly helpful in the initial evaluation of patients with perianal fistulas.

**Anatomy and normal appearance of the gastrointestinal tract**

Wall thickness of the alimentary tract differs from part to part and depends largely on the state of distension or contraction. Under normal conditions stomach thickness measures from 3-6 mm, small bowel from 1-3 mm, and the colon from 0,5-4 mm. A contracted intestinal segment should not be misinterpreted as a thickened wall.

High-resolution transducers usually allow for visualization of five concentric layers of the normal gastric or bowel wall (Fig. 1). Various experimental studies have shown that the five layers on sonographic images closely correspond to the histological layers of the wall.

- outer hyperechoic layer – serosa and interface to the serosa
- outer hypoechoic layer – muscularis propria
- middle hyperechoic layer – submucosa
- inner hypoechoic layer – mucosa
- inner hyperechoic layer – superficial mucosal interface
Figure 1a, b. Gastric wall layers. Cross section (a) and zoomed longitudinal section (b) of the gastric antrum show the different wall layers. (sif: serosal interface; mp: muscularis propria; sm: submucosa; m: mucosa; mif: mucosal interface; l: lumen)

The different gut parts can be identified by their topographical position and specific morphological criteria. The muscular layer of the stomach, especially that of the antrum, is more pronounced than in other parts of the intestine. In a non-distended condition the mucosal folds of the gastric corpus and fundus are well demonstrable (Fig. 2a). The valvulae conniventes are typical of the small intestine. They decrease in number and height from the proximal jejunum to the distal ileum. They are best visible when bowel loops are fluid filled (Fig. 2b). The colon is characterized by its haustration which using US is best visible at the ascending and transverse colon. The left hemicolon is seen more often in a contracted condition (Fig. 2c).
Figure 2a. Stomach. Cross section of the gastric corpus with mucosal folds protruding to the lumen.

Figure 2b. Small bowel. Longitudinal section of a jejunal segment showing the numerous valvulae conniventes.

Figure 2c. Colon. Longitudinal scan of the ascending colon with its typical haustration.
Certain gut parts, such as the cardia, the gastric antrum, the duodenum, the ileocecal region, and the ascending and descending colon can be displayed routinely. Other parts such as the rectum, the lower sigmoid colon, and the left colonic flexure cannot always be shown satisfactorily. Another limitation is that the small bowel cannot be scanned continuously.

The gastrointestinal tract is supplied by three main visceral arteries: the celiac trunk, the superior mesenteric artery and the inferior mesenteric artery. Arteries, veins, nerves, and lymphatics run in the mesentery to and from the bowel segments.

Different sonographic criteria are taken into consideration when making a diagnosis: wall-thickness; stratification; echogenicity; length of the affected segment; luminal width; vascularization; peristalsis; associated findings in adjacent tissue.

**Examination technique**

Examination of the gastrointestinal tract usually starts with a systemic survey using an abdominal probe to get an overview over the different parts of the gastrointestinal tract. Subsequently examination proceeds with a high-frequency probe to obtain details and focus on the actual problem. In patients with localized abdominal pain the examination can initially be focused on this area. The standardized evaluation should optimally take place after overnight fasting, however this is not a precondition in urgent situations. In order to avoid interfering bowel gas in cases of bowel obstruction, it is recommended to assess the abdomen from a more lateral aspect through both flanks.

The stomach is scanned in longitudinal and transverse sections via a subxiphoidal approach from the cardia to the pylorus. Using the left liver lobe as acoustic window and provided good conditions, it is possible to scan the distal esophagus by tilting the probe cranially in the epigastrium. The fundus of the stomach can be demonstrated in a translienal view. The duodenum is identified by its “C-shaped” course around the pancreatic head and by the location of the third part of the duodenum which lies between the aorta and the superior mesenteric vessels (Fig. 3a).

The small bowel cannot be evaluated continuously. Systemic examination is performed by making vertical, parallel, and overlapping lanes with the transducer. The jejunum is usually located in the left upper and mid abdomen and the ileum in the right mid and lower abdomen.
The right iliac vessels are a landmark of the ileocecal region. Fluid-filled small bowel loops allow optimal visualization of the valvulae conniventes (Fig. 3b).

It is also important to obtain a systemic way of scanning the colon which is usually performed in transverse sections for each segment. First, the ascending colon is identified in the right upper quadrant and followed to the cecum or in reverse order. Then the colon is followed from the right colonic flexure along the transverse colon to the splenic flexure. The descending colon is identified by its laterodorsal position and scanned caudally to the sigmoid colon which takes a variable course over the left iliac vessels to the small pelvis. The rectum is visualized through the filled bladder (Fig. 3c).

Assessment of the gastrointestinal tract is usually performed with the graded compression technique. Interfering bowel loops and gas are then displaced and probes with higher frequency can be used allowing for more detailed information from the bowel wall and surrounding structures.

**Figure 3a.** Examination technique of the upper gastrointestinal tract. The stomach and the duodenum can be scanned by standardized longitudinal and transverse sections through the upper abdomen.
**Figure 3b.** Examination technique of the small bowel. The small bowel is scanned systematically by parallel overlapping lanes (like “mawing the lawn”). The terminal ileum can be demonstrated on its course over the psoas muscle and the iliac vessels.

**Figure 3c.** Examination technique of the large bowel. Systematical examination is usually performed in cross sections of the colonic segments.

**Appendicitis**

Acute appendicitis is the most common cause for acute surgery in Western countries. Because only 50-60% of patients present with typical clinical symptoms, appendicitis is a common
clinical problem. Children and adolescents are most often affected. Without the use of imaging methods the incidence of negative laparotomies may be up to 45% especially in women of child-bearing age.

The appendix is a blind-ending, tubular structure that arises from the cecum. The normal appendix shows the different wall layers similar to the rest of the intestine, frequently courses from the iliac fossa medial and caudal over the iliopsoas muscle, is oval shaped under compression, and contains some gas or fecal material. The position of the appendix varies however, in that it continues in different directions or even retrocecal and that also the cecum may have a variable position.

Appendicitis is often triggered by luminal obstruction due to infectious swelling of the wall, fecaliths, lymphatic hyperplasia, food remnants, and other rare causes. Increase in intraluminal pressure, tissue damage, and pathogen entry into the appendiceal wall lead to transmural inflammation. The most important sonographic criteria of acute appendicitis are:

- A noncompressible appendix with a diameter >6 mm; either the wall is thickened by the acute inflammation or the lumen is distended and filled with purulent content; initially the wall layers are preserved but the more the inflammation extends, the more the layers are destroyed.
- Point of maximum tenderness over the appendix.
- Hyperechoic changes of the surrounding fatty tissue and loss of compressibility; in more severe cases hypoechoic changes and fibrinopurulent exsudate may be visible; adjacent bowel loops such as the cecum and terminal ileum are often involved and thickened.

(Fig. 4; Video 1)
Figure 4a, b. Appendicitis. Longitudinal view of the thickened appendix (a). The wall layers are visible but the hyperechoic submucosa is partly disrupted in this case of phlegmonous appendicitis. On the transverse view (b) the appendix is visible twice due to its winding course. This scan also demonstrates the inflammatory changes of the periappendiceal mesenteric and omental fat (arrows) better.
Figure 4c. Appendicitis. In this case no significant wall thickening is present but the lumen is distended and filled with purulent content.

In the case of a perforated appendix the appendiceal wall is at least partly destroyed and signs of local peritonitis are present. If a perityphlitic abscess forms, a retention of mixed echogenicity with or without gas bubbles can be demonstrated. Free intraperitoneal gas is only rarely seen (Fig. 5).

Most common causes of false-negative sonographic results are: only the tip of the appendix is inflamed; atypical appendiceal position (small pelvis, retrocecal); a gangrenous gas-filled appendix; a perforated, non identifiable appendix.

Especially in obese patients and when suspicion of appendicitis is high, CT is the next step if US is unable to identify the appendix. MRI is an alternative method in young patients and pregnant women.

The most important differential diagnoses of acute appendicitis include inflammatory diseases of the bowel, various gynaecological and urological diseases, perforated cecal carcinoma, omental infarction as well as a number of rare findings. Some acute conditions of the abdominal wall and of the retroperitoneum such as an incarcerated hernia or a hematoma of the psoas muscle may also mimic appendicitis.
**Figure 5a.** Perityphilitic abscess. A hypoechoic fluid collection with gas bubbles is visible in the right lower quadrant just behind the thickened cecum (arrows). The appendix was almost completely destroyed.

**Figure 5b.** Perforated appendix. The proximal part of the appendix is well delineated whereas the distal part is destroyed (arrows) in this case of a perforation at the tip of the appendix.

**Diverticulitis**

Diverticulitis is a frequent cause of left lower quadrant pain and the number is increasing. Almost all clinically significant cases of diverticulitis are a result of microperforation of the thin-walled pseudodiverticula which are predominantly located in the sigmoid colon.

US and CT are the imaging methods of choice as inflammation primarily involves the pericolic structures, particularly the fatty tissue of the mesocolon and epiploic appendages.
The presence of the following three criteria at the point of maximum tenderness allows a specific sonographic diagnosis of diverticulitis:

- **short segmental bowel-wall thickening**: the bowel wall layers are usually preserved; hypertrophy of the muscular layer is frequently seen;
- **alteration of the pericolic fat** ranging from hyperechoic noncompressible fat to hypoechoic phlegmonous inflammation with fibrinopurulent exsudate;
- demonstration of the inflamed diverticulum; in contrast to normal diverticula they are hypoechoic or hyperechoic with a hypoechoic rim and are surrounded by hyperechoic fatty tissue;  

(Fig. 6; Video 2)

Right-sided diverticulitis tends to occur in younger patients and is more frequent in the Far East. The sonographic signs are identical to those of left-sided diverticulitis and US usually permits differentiation from acute appendicitis.

The lower sigmoid colon is difficult to assess by transabdominal US. Therefore, additional transvaginal US or transrectal US provides relevant information on abnormalities in this segment in 10 to 20 percent of patients.

**Figure 6a.** Sigmoid diverticulitis. This transverse scan of the sigmoid colon shows all typical criteria of diverticulitis. The wall layers of the thickened colonic wall are preserved. The inflamed diverticulum contains a fecalith and is surrounded by a hypoechoic rim and hyperechoic fatty tissue (arrows).
Figure 6b. Sigmoid diverticulitis. Colour Doppler image demonstrates hypervascularity in the colonic wall, in the wall of the diverticulum, and in the inflamed peridiverticular fat (arrows).

The typical complications of diverticulitis include abscess formation, fistulas, perforation and stenosis. Hypoechoic abscesses are usually well detectable with US whereas predominantly hyperechoic, gas-containing abscesses are sometimes difficult to differentiate from bowel loops (Fig. 7). In this case and providing clinical signs and sonographic results are discrepant, CT should be performed. Fistulas may present as hypoechoic bands with central gas bubbles. Gas in the urinary bladder is a frequent indirect sign of a sigmoid-vesical fistula. The typical signs of perforation are described in the chapter “Perforation”.

Differential diagnoses of diverticulitis include epiploic appendagitis, ischemic colitis, bowel obstruction, penetrating or perforated sigmoid cancer, sigmoid volvulus, left sided ureteral calculus, torsion of adnexal masses, and acute conditions of the abdominal wall or retroperitoneum.
Figure 7. Peridiverticular abscess. This complex gas-containing lesion (arrows) adjacent to the sigmoid colon (arrowheads) represents a peridiverticular abscess.

Intraabdominal focal fat infarction

Omental infarction and epiploic appendagitis can be summarized with the term “intraabdominal focal fat infarction”. US and CT features allow a reliable diagnosis. Both conditions occur more frequently than generally assumed and sometimes discrimination of omental infarction and epiploic appendagitis is not possible with certainty. Both omental infarction and epiploic appendagitis are self-limiting conditions, and correct diagnosis avoids unnecessary laparotomy.

Segmental Omental infarction results from either venous thrombosis or torsion of a portion of the omentum usually located in the right upper or lower quadrant. US shows a hyperechoic noncompressible intraabdominal mass which usually adheres to the parietal peritoneum (Fig. 8). In contrast to epiploic appendagitis however, the mass is larger and central hypoechoic areas are more common.
Figure 8. Omental infarction. A hyperechoic noncompressible mass is shown in the right lower quadrant on this US scan. Colour flow is only visible in the peripheral zone of this segmental infarction of the omentum. The mass adheres to the peritoneum of the anterior abdominal wall.

Epiploic appendagitis is one differential diagnosis of diverticulitis. Infarction of an epiploic appendage is located generally in one of the lower quadrants, more frequently on the left than on the right side. At the point of maximum tenderness US shows a moderately hyperechoic, ovoid, and noncompressible mass directly under the abdominal wall which frequently adheres to the parietal peritoneum. The mass may be surrounded by a hypoechoic rim and bowel-wall thickening is usually absent (Video 3). On Colour Doppler US or contrast-enhanced US the central necrotic appendage is avascular whereas the surrounding fatty tissue shows moderate hypervascularity.

Bowel obstruction

Patients with clinical signs of bowel obstruction such as abdominal pain, abdominal distension, and vomiting need immediate diagnostic evaluation. Currently simple radiographs are for the most part replaced by US and CT. These methods allow for earlier proof of bowel obstruction. The cause of obstruction can then be partially demonstrated and alternative diagnoses established.

The level of obstruction can be determined by careful analysis of dilated bowel segments. The duodenum can be recognized next to the pancreatic head and the third part can be recognized because it passes to the left side posterior to the superior mesenteric vessels. The dilated jejunum can be distinguished from the ileum by the pattern of the valvulae conniventes and to some degree by the location in the abdomen. The colon is characterized by
its typical haustration. Moreover, the ascending and the descending colon are fixed to the retroperitoneum laterodorsally in the abdominal cavity.

**Gastric outlet and duodenal obstruction**

Chronic duodenal ulcer and tumours of the stomach or the pancreatic head are the most common causes of upper gastrointestinal obstruction. Plain x-rays are frequently false negative in these cases as vomiting results in lack of air in the obstructed segment. US easily depicts the dilated stomach with ingested food and fluid-fluid levels (Fig. 9). The dilated duodenum or the dilated segment in an afferent-loop syndrome is also reliably demonstrable.

Delayed gastric emptying may also be caused by inadequate peristalsis due to a number of diseases.

**Figure 9.** Upper gastrointestinal obstruction. US image shows dilatation of the stomach with a fluid-fluid level. The cause of obstruction is visible just behind the antrum. A metastatic lesion of the upper jejunum (not shown) led to an intussusception.

**Small bowel obstruction**

About two thirds of small bowel obstructions are caused by adhesions. In this situation usually no abnormality is visible at the point of transition from dilated bowel to normal bowel. Other reasons of small bowel obstruction such as tumours, hernias, Crohn’s disease, bezoars, or a perforated gallstone (Fig. 10c) can be demonstrated by US.

Small bowel obstruction must be considered to be present when:

- the lumen of the fluid-filled small bowel loops is \( \geq 3 \) cm;
peristalsis of the dilated segment is increased;
- bowel loops distal to the stenosis are collapsed.

A small amount of intraperitoneal fluid is frequently present (Fig. 10; Video 4). Difficulties may arise when the obstruction becomes prolonged and the dilated segment becomes paralytic. This situation should not be mistaken for paralytic ileus. Contracted bowel loops distal to the stenosis still allow correct diagnosis.

An akinetic dilated bowel loop, thickening of the bowel wall and the leaves of the mesentery, and increased intraperitoneal fluid show suspicion of strangulation requiring immediate surgery. Closed-loop obstruction with a typical “omega”-shaped distended loop or a conglomerate of fluid-filled loops is such a situation in which strangulation frequently occurs.

Figure 10a, b. Small bowel obstruction. Cross section (a) in the left mid abdomen shows dilated fluid-filled small-bowel loops and the contracted descending colon (black arrow). Free fluid in the peritoneal cavity (white arrows) is also present. The numerous valvulae conniventes protruding to the dilated lumen are characteristic for the jejunum (b).
Large bowel obstruction

Tumours of the colon are the most common cause of large bowel obstruction. Other causes include volvulus, inflammation, and scar shrinkage due to inflammation or ischemia. US shows the dilated colon with usually hyperechoic content (Fig. 11). Due to disturbing gas it is sometimes difficult to get a clear overview and to determine the site of stenosis. In this situation CT would be the next method in establishing the correct diagnosis.
Figure 11a, b. Large bowel obstruction. The descending colon is dilated and filled with feces and gas (a). Massive dilatation and obscuring gas may hinder adequate evaluation of the underlying cause. A carcinoma of the sigmoid colon (arrows) with a stenotic irregular lumen was the cause of the obstruction in this patient (b).

Bowel obstruction must be differentiated from paralytic ileus (Fig. 12) and other conditions leading to dilatation of the lumen. In paralytic ileus usually both the small bowel and the large bowel are dilated and peristalsis is reduced. Stool impaction in elderly and bedridden patients is also an important differential diagnosis.
**Figure 12.** Paralytic ileus. Numerous fluid-filled, dilated, and aperistaltic small bowel loops are visible in this patient after cesarean section. The large bowel (not shown) was also dilated and partly fluid-filled.

**Perforation**

The detection of gas in the peritoneal cavity is the clue to the diagnosis of perforation of the alimentary tract. US is more sensitive than plain film for diagnosing pneumoperitoneum or pneumo-retroperitoneum, but CT is the most accurate method.

US displays pneumoperitoneum as a hyperechoic line or as small gas bubbles with reverberation artefacts between the visceral and the parietal peritoneum. This is best visible anterior to the liver surface or immediately below the anterior abdominal wall in the supine position or left decubitus position. Extraluminal gas moves by changing the patient’s position and disappears when pressure is increasingly applied (**Fig. 13; Video 5**). Similar to plain film, a short time frame may occur after changing the patient’s position before small amounts of gas move to typical areas and become visible on sonograms.

Pneumoperitoneum and extraluminal fluid are demonstrable in the upper abdomen as a consequence of gastric or duodenal perforation. The most common causes are perforated gastric or duodenal ulcers. Evidence of gas in the fissure for ligamentum teres is a further hint and may be the single sign in cases of contained perforation.

If perforation of the small bowel occurs, extraluminal fluid with bright echoes and extraluminal gas are the predominant signs. Some of the reasons are perforated foreign bodies, ischemic disease (gangrene), and blunt trauma.
Pneumoperitoneum is also the predominant sign in colonic perforation. Two thirds occur due to diverticulitis. Other causes include colonic ischemia, bowel obstruction, perforated neoplasms, or iatrogenic perforation.

Retroperitoneal perforation with pneumo-retroperitoneum obscures retroperitoneal vessels and organs (Fig. 14). In the upper abdomen the duodenum is the typical location of retroperitoneal perforation caused primarily by perforated duodenal ulcer or by endoscopic sphincterotomy. Most cases in the lower abdomen are due to perforated sigmoid diverticulitis or iatrogenic from endoscopy or postsurgical dehiscence.

**Figure 13a.** Perforation. A small gas collection anterior to the left liver lobe is a typical sign of gastrointestinal perforation.

**Figure 13b.** Perforation. This figure also clearly shows a gas collection in the peritoneal cavity. The ascites allows optimal delineation of the peritoneal space. Slight thickening of bowel loops is also present.
**Figure 14.** Retroperitoneal perforation. The large amount of gas bubbles (arrows) around the right kidney and gas collections (arrows) obscuring the large retroperitoneal vessels are typical of a retroperitoneal perforation.

**Infectious enterocolitis**

Infectious enterocolitis is usually a self-limiting disease caused by a number of microorganisms. Diagnosis is confirmed clinically and on the basis of stool analysis. However, US can be helpful in assessing the extent of disease, narrowing the differential diagnoses in atypical cases, and allowing for earlier treatment of severe colitis and consequently preventing the development of serious life-threatening conditions for the patient.

Simple **enteritis** is characterized by increased fluid in the small bowel and hyperperistalsis. In contrast to small bowel obstruction, width of bowel loops is within the normal limit (< 25mm). The colon is often visible in a contracted condition but significant wall thickening is usually absent.

**Infectious enterocolitis** predominantly affects the right colon, less frequently the left colon, or manifests as pancolitis. A longitudinal view of the colon shows the typical haustration pattern. The mucosa and the submucosa are thickened but stratification is preserved and inflammation is limited to the colon (**Fig. 15**). Colour Doppler US demonstrates increased vascularity. Sonographic appearance of different types of colitis shows considerable overlap so that a specific diagnosis cannot be established.
Some pathological microorganisms such as Yersinia, Campylobacter, and Salmonella may also specifically infect the ileocecal region which is known as **infectious ileocecitis**. The typical US findings are a symmetrical thickening of the terminal ileum and the cecum confined to the mucosa and submucosa and enlarged mesenteric lymph nodes in the ileocecal region (Fig. 16). Correct US diagnosis can prevent unnecessary surgery for the patient if pain is the predominate symptom in such cases.

**Figure 15.** Infectious colitis. This longitudinal view of the ascending colon shows the so-called accordion sign, a consequence of wall thickening and contraction. A hyperechoic swelling of the submucosa is especially prevalent.

**Figure 16a, b.** Infectious ileocecitis. Both the terminal Ileum (arrow) and the cecum (arrowheads) (a) are thickened on this transverse scan in the right lower quadrant. The mesenteric lymphnodes (b) are moderately enlarged and tender on graded compression.
Pseudomembranous colitis

Pseudomembranous colitis usually occurs as a complication of antibiotic therapy with overgrowing Clostridium difficile bacteria. Severe pseudomembranous colitis is a potentially life-threatening condition and early diagnosis is essential in safeguarding the patient from this stage of disease.

Pseudomembranous colitis frequently manifests as pancolitis but may also be segmental. Wall thickness increases with severity of disease and stratification becomes indistinct (Fig. 17). Alteration of the pericolic fat and ascites are further signs in severe cases. In cases of marked pancolitis after antibiotic therapy, medical treatment should be started immediately.
**Figure 17a, b.** Pseudomembranous colitis. A longitudinal scan of the sigmoid colon (a) and a transverse scan with a high-frequency transducer (b) show marked wall thickening with partly indistinct stratification. Hyperechoic alteration of the pericolic fat and ascites (arrow) are also visible.

**Neutropenic enterocolitis**

Neutropenic enterocolitis is a complication following chemotherapy or transplantation and in patients with other immunosuppressive conditions. It is characterized by ileal and, to a variable extent, also right-sided colonic involvement. Bowel loops are thickened and stratification may be preserved or also be partly destroyed. In addition, alteration of the adjacent mesenteric fat and ascites may be present (Fig. 18). In the clinical context a correct diagnosis can frequently be established by means of US.
Figure 18. Neutropenic enterocolitis. This sonogram shows thickened ileal loops in a patient after chemotherapy. The partly destroyed stratification (hypoechoic changes of the submucosa) and the hyperechoic alteration of the mesenteric fat are signs of transmural inflammation.

Inflammatory bowel disease

Both Crohn’s disease and ulcerative colitis typically occur in young adults but may also affect children or elderly patients. At times, clinical symptoms such as cramping abdominal pain, diarrhoea, and rectal bleeding precede a definite diagnosis for months. US signs of chronic inflammatory bowel disease, especially in Crohn’s disease, contribute to earlier endoscopic and histological proof. B-mode US, Colour Doppler imaging, and more recently contrast-enhanced US, could provide additional information on disease activity and treatment success.

Crohn’s disease

Crohn’s disease predominantly involves the distal ileum and the colon. The affected bowel segment appears markedly thickened and the lumen is narrowed resulting in the classic sonographic “target sign” on transverse images. In contrast to ulcerative colitis, involvement is discontinuous with intervals of normal bowel producing “skip areas”. Transmural inflammation through all layers of the intestinal wall is another typical sign of the disease and can lead to complete loss of stratification. The mesentery and other adjacent structures are frequently involved in the inflammatory process. The affected bowel is then surrounded by noncompressible fatty tissue which is sometimes traversed by fingerlike hypoechoic bands.
The evidence of hypertrophic fat around the bowel is also called the “creeping fat sign”. Enlargement of mesenteric lymph nodes is frequently present, usually in the right lower quadrant (Fig. 19; Video 6).

**Figure 19a.** Crohn’s disease. A cross section in the right lower quadrant shows the thickened terminal ileum. Stratification is partly preserved and partly destroyed. The inflamed bowel loop is surrounded by hyperechoic mesenteric fat.

**Figure 19b.** Crohn’s disease. Severe inflammation of the mesentery is visible as a hypoechoic irregular mass next to a thickened ileal loop. On Colour Doppler US (not shown) hypervascularization was visible in the hypoechoic areas.
**Figure 19c.** Crohn’s disease. Hypervascularization of the terminal ileum in a patient with Crohn’s disease.

![Image of hypervascularization](image1)

Possible complications of Crohn’s disease include fistulas, abscess formation, bowel obstruction, stenosis and rarely perforation (Fig. 20). Fistulas are visible as hypoechoic tracts with hyperechoic gas inclusions. Abscesses are seen as poorly defined, mostly hypoechoic focal masses that can contain hyperechoic gas (Video 6).

**Figure 20a.** Crohn’s disease. Gas bubbles in the bowel wall and the adjacent mesentery are indicative of a small fistulous tract (arrow).

![Image of gas bubbles](image2)
Figure 20b. Crohn’s disease. Panoramic view of the ileum shows dominantly fibrotic stenosis with moderate dilatation of non-involved proximal ileal loops.

Many studies have been published concerning pulsed Doppler and Color Doppler imaging of disease activity. Color Doppler has also been used to facilitate differentiation of inflammatory from fibrotic stenosis in patients with obstructive Crohn’s disease. However, results remain somewhat controversial because neovascularization overlaps with increased perfusion in acute inflammation.

Ulcerative colitis

Colon involvement in ulcerative colitis is continuous from the rectum and extends more or less to the upper colon. Bowel wall thickening is usually less marked and stratification is preserved because inflammation is predominantly located in the mucosa. In cases of acute inflammation the submucosa is thickened mainly due to oedema, and tends to become more hypoechoic with the severity of disease (Fig. 21). The muscular layer and the pericolic fat are usually not involved. After resolution of the acute inflammation, the colon wall returns to its normal appearance or remains after several recurrences slightly thickened with a hyperechoic submucosa.

Toxic megacolon is a potentially lethal complication of ulcerative colitis in which the colon is distended and signs of toxicity are present.
**Figure 21a.** Ulcerative colitis. A panoramic view of the sigmoid colon shows moderate thickening of the colon with preserved bowel-wall layers in a case of subacute ulcerative colitis.

**Figure 21b.** Ulcerative colitis. An acute episode of ulcerative colitis led to this marked hypoechoic thickening of the colonic wall. Stratification is indistinct and hypervascularization is present.

**Celiac disease**

Celiac disease is a chronic disease with mucosal damage and impaired nutrient absorption as a consequence of inflammatory reaction to gliadin, a gluten protein found in wheat. The classic clinical presentation includes diarrhea, steatorrhea, flatulence, weight loss, and fatigue. Many patients present with nonspecific symptoms and US, therefore, may play a useful role in shortening the diagnostic process.
The combination of a number of nonspecific US signs allows for increasing suspicion of celiac disease (Fig. 22; Video 7).

- abnormal fluid-filled small intestine with hyperperistalsis; transient intussusception as a consequence of hyperperistalsis is frequently seen;
- moderately dilated and flaccid small-bowel loops (diameter up to 3.5cm)
- slight thickening of the small-bowel wall and the valvulae conniventes; reduced number of jejunal folds and increase in number of ileal folds;
- enlarged mesenteric lymph nodes; the architecture of the lymph nodes is preserved;
- dilated caliber of superior mesenteric vessels;
- small amount of free fluid in the abdominal cavity;
- increased echogenicity of the liver despite low body mass index in these individuals.

Diagnosis is confirmed by biopsy of the mucosa of the proximal small intestine and clinical and histological improvement following implementation of a gluten-free diet. This diet becomes the treatment of choice for the duration of life.

**Figure 22a, b.** Celiac disease. A sonogram in the lower abdomen (a) shows fluid-filled, moderately dilated, but flaccid small bowel loops. Peristalsis was markedly increased. Mesenteric vessels on a transverse scan of the upper abdomen (b) are widened as a consequence of chronic hypervascularization.
Ischemic disease

Early diagnosis of bowel ischemia is essential in the management of patients with acute abdominal pain as ischemic tolerance of the intestines is low. Acute mesenteric ischemia is caused by arterial occlusion, venous occlusion, or nonocclusive disease. Patency of the main mesenteric vessels does not exclude ischemic disease.

US is often the first imaging method performed in patients with acute abdominal pain. However, early diagnosis of bowel ischemia is difficult. Overlying gas often hinders the evaluation of the main mesenteric vessels, segmental and subsegmental arteries cannot be demonstrated completely, and sensitivity of Colour Doppler to demonstrate microperfusion in the bowel wall is inadequate. Introduction of contrast-enhanced US may contribute to overcome some of these problems. Angiography and increasingly multidetector CT are the imaging methods of choice if US is unable to reliably demonstrate the mesenteric vessels.

Bowel infarction

Acute mesenteric occlusion is often associated with multimorbidity and a high lethality. Segmental ischemic disease has a better prognostic outcome because surgical treatment is possible even in the late phase.

Although angiography is considered the best method to diagnose mesenteric embolism or thrombosis, this method is invasive and not suitable for patients who are only suspected of having the disease. As a consequence, this method is often performed late. A delay in definite
therapy results in high morbidity and mortality. Nowadays multidetector CT angiography and advances in US contrast media could contribute to earlier diagnosis.

In cases of arterial occlusion, a short early and intermediate phase with non-specific hyperperistalsis in US examination is followed by the necrotic phase. A paralytic ileus with dilated fluid-filled loops develops and intramural gas collections or portal venous gas may be visible (Fig. 23).

In cases of strangulation and venous thrombosis, the sonographic signs are more pronounced and better visible (Fig. 24a). Bowel wall thickening and ascites are often the predominant signs.

The lack of Colour Doppler signals in thickened bowel loops is highly susceptible of bowel ischemia (Fig. 24b). Sensitivity to demonstrate microperfusion is inadequate, especially in the depth. Initial experience with contrast-enhanced US shows promising data for assessing bowel ischemia. However, its definite role remains unclear and it also holds true for this method that visible vascularization does not exclude nonocclusive ischemic disease.

**Figure 23.** Small bowel infarction. Paralytic fluid-filled small-bowel loops show gas bubbles in the bowel wall as a consequence of mesenteric embolism with small bowel infarction and gangrene. Ascites is visible between the bowel loops.
**Figure 24a.** Small bowel infarction. Significant hypoechoic thickening of a small bowel segment is visible in a patient with thrombosis of the mesenteric vein and hemorrhagic infarction due to Factor V Leiden thrombophilia.

![Image of small bowel infarction with hypoechoic thickening](image1)

**Figure 24b.** Small bowel infarction. An aperistaltic small bowel segment shows no vascularization in the thickened wall due to hemorrhagic infarction.

![Image of small bowel infarction with aperistalsis](image2)

**Chronic ischemia**

Chronic mesenteric ischemia can be differentiated from acute ischemia. Sonographic results are better in this case as conditions for investigation are usually better. Main causes of chronic mesenteric ischemia are stenoses of the main mesenteric vessels or occlusions with collateral circulation (Fig. 25, 26).

Circumscribed increases in flow velocity in Colour Doppler US have to be proven with pulsed Doppler US. In healthy individuals peak systolic velocity ranges from 100-150 cm/s in
the celiac trunc and from 100-180 cm/s in the superior mesenteric artery. Systolic velocities of more than 250-300 cm/s are sensitive indicators of severe arterial stenosis. Peak velocities distal to the stenosis are reduced.

Doppler ultrasonography has been advocated as a reasonably accurate screening modality for the detection of high-grade superior mesenteric artery stenoses. Sensitivity exceeding 90 percent and a negative predictive value of close to 99 percent has been reported in patients with more than a 50 percent stenosis. A positive study should be followed by angiography, which can further establish the feasibility of revascularization.

**Figure 25.** SMA occlusion. The superior mesenteric artery is occluded a few centimeters from the origin. Colour flow in different directions is visible proximal and distal to the occlusion due to retrograd inflow via collateral vessels.

**Figure 26.** SMA stenosis. At the origin of the superior mesenteric artery pulsed Doppler shows systolic acceleration up to 4m/sec and turbulent flow indicative of a high-grade stenosis.
Ischemic colitis

Mild abdominal pain, diarrhoea, and mild rectal bleeding in elderly patients are clinical signs of ischemic colitis. Most cases are transient forms which need medical treatment. Urgent surgical interventions due to gangrene or perforation are quite rare.

The left hemicolon from the splenic flexure to the sigmoid colon is the most frequent localization of ischemic colitis. A sudden transient from the normal colon to the hypoechoic thickened ischemic segment is a typical US sign. In the acute stage of disease, the bowel wall layers are less distinctly differentiated and colour flow is barely visible (Fig. 27). In the subacute stage reperative changes may cause increased vascularity which in turn is a good prognostic sign.

Ischemic colitis of the right hemicolon or of the cecum alone is rare. However, ischemic colitis should be suspected in elderly patients if wall thickening is combined with reduced vascular flow.

Figure 27a, b. Ischemic colitis. A longitudinal sonogram (a) of the descending colon shows moderate wall thickening with indistinct stratification. Only few vessels could be demonstrated using Colour Doppler US (b).
Tumorous disease

Abdominal US is often the first imaging method that patients with gastrointestinal tumours undergo when they present with non-specific symptoms. Careful sonographic evaluation of the gastrointestinal tract may disclose focal masses. Tumours may be seen as polypoid lesions or as semicircumferential / circumferential wall thickening with wall layers frequently being destroyed. Local lymph node enlargement and focal liver lesions are signs of metastatic spread.

Gastric tumours

Gastric cancer produces a localized or diffuse hypoechoic wall thickening with destruction of normal layered appearance. US is not primarily used to diagnose gastric cancer but may give additional information about local tumour infiltration. It may also be helpful in cases of scirrhous-type gastric cancer if endoscopy with biopsy is negative although significant thickening of the gastric wall is visible on US examination (Fig. 28).

Other causes of gastric wall thickening such as severe gastritis, portal hypertension, or pancreatitis must be differentiated from tumorous disease. Endoscopic examination with biopsy usually confirms the benign or malign genesis of the wall thickening.

The stomach is the most common site of gastrointestinal Non-Hodgkin’s Lymphoma followed by the small intestine and the colon. Circumferential, profoundly hypoechoic, and extensive wall thickening is indicative of a lymphoma. Pseudocystic lymph node enlargement is frequently present.
Gastrointestinal stromal tumours (GIST) are KIT(CD 117)-positive, mesenchymal tumours originating from the interstitial cells of Cajal which are located in the muscular layer. 60% occur in the stomach and 30% in the small intestine (Fig. 29). In the case of small tumours, the bulging mucosal surface is regular, but in the case of larger tumours, ulceration may be present and be the cause of gastrointestinal bleeding.

**Figure 28.** Gastric cancer. Wall thickening of the gastric antrum is clearly visible. The muscular layer is discernible but the mucosal and submucosal layer cannot be distinguished due to tumorous infiltration by a scirrhous carcinoma.

**Figure 29a.** GIST. A longitudinal sonogram of the gastric antrum shows a hypoechoic ovoid mass originating from the outer hypoechoic layer of the anterior wall.
**Figure 29b.** GIST. This circumscribed lesion originating from the gastric wall was better demonstrable after ingestion of 500ml of fluid. The wall layers are preserved and the mucosal and submucosal layer are clearly visible.

**Tumours of the small bowel**

Small bowel tumours are relatively rare. The most common tumours are neuroendocrine carcinomas (carcinoids), lymphomas, adenocarcinomas, gastrointestinal stromal tumours, and lipomas. Carcinoid tumours are small and mesenteric lymph node metastases are often detected earlier than the primary tumour (Fig. 30). GISTs are seen as focal hypoechoic masses protruding from the bowel wall. Intussusception may occur as a consequence of such a mass (Fig. 31). Both tumours are hypervascularized on Colour Doppler US. Lipomas are typically visible as hyperechoic, ovoid, and smooth delineated lesions (Fig. 32). Hypoechoic “pseudocystic” appearance of bowel wall thickening and of enlarged lymph nodes is indicative of an intestinal lymphoma (Fig. 33).
Figure 30. Neuroendocrine carcinoma of the ileum. A polypoid tumor was detected in the ileum in an asymptomatic patient. The tumor probably originates from the mucosa and is hypervascularized. Histologic examination revealed a neuroendocrine carcinoma with small lymph node metastases.

Figure 31a, b. GIST and Intussusception. A patient with episodes of cramping abdominal pain and iron deficiency anemia showed a target lesion in the mid abdomen indicative of intussusception (a). The central hypoechoic mass acted as the leading point. Colour Doppler US (b) revealed hypervascularization of the tumor.
Figure 32. Jejunal lipoma. A homogenous hyperechoic mass fills the lumen of a jejunal loop. Episodes of abdominal pain were caused by recurrent intussusception (not shown).
**Figure 33.** Ileal Non-Hodgkin lymphoma. Marked hypoechoic wall thickening of an ileal loop is present in a patient with high-grade Non-Hodkin lymphoma. Wall layers are not longer discernible.

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**Tumours of the colon**

Colorectal cancer is the second most common tumour in the Western world. Colonoscopy and radiological methods are the screening methods for these carcinomas which usually evolve from adenomatous polyps over several years.

In experienced hands, US can demonstrate a high percentage of T3 and T4 tumours and approximately one third of T1 and T2 tumours. Polyps are only demonstrable in a minority of cases. Colour Doppler US can help to differentiate polyps from hypoechoic fecal material (Fig. 34; Video 8). Carcinomas usually present as hypoechoic short segmental and asymmetric wall thickening. The hypoechoic wall thickening with the central hyperechoic luminal content is also called the pseudokidney sign. Bowel wall layers are increasingly destroyed with tumour progression (Fig. 35; Video 9). Loss of outer smooth delineation of the colonic wall is indicative of tumorous infiltration to the pericolic fat and adjacent organs (Fig. 36). Patients with colonic cancer are also evaluated for local lymph node enlargement and focal liver lesions as a sign of metastatic spread.

Other tumours of the colon include lymphomas (Fig. 37), GISTs, and lipomas. Lipomas and GISTs arise from the submucosa and the muscularis propria. Lipomas are hyperechoic in contrast to GISTs and lymphomas. GISTs and lymphomas are usually hypervascularized on Colour Doppler US.
**Figure 34.** Colonic polyp. Power Doppler US clearly shows vascularity in the ovoid hypoechoic lesion in the transverse colon.

**Figure 35a, b.** Sigmoid carcinoma. Longitudinal section of the sigmoid colon (a) shows circumscribed wall thickening with destruction of wall layers. Hypervascularization and irregular vessels (b) are also typical of colon carcinomas.
Figure 36. T4-carcinoma of the transverse colon. US scan shows the irregular lumen with hyperechoic content and the huge hypoechoic carcinoma infiltrating the anterior abdominal wall (arrowheads).
pediatric diseases

There are some diseases which typically occur in newborn and in childhood. Because clinical evaluation of these patients is sometimes difficult, accurate sonographic diagnosis is essential.

Congenital malformations

Congenital malformations include duplication cysts, malrotation of the gut, and obstruction by duodenal or anal atresia. Some malformations show typical US appearance, others need further evaluation. Huge dilatation of the proximal duodenum and the stomach in duodenal atresia and direct visualization of the meconium-filled rectum in anal atresia are typical sonographic signs. In anal atresia perineal US and 3-D US can help for more accurate measurement of the length of the atretic canal and thus for adequate therapeutic management.

Intussusception

Intussusception is the most common acute abdominal disorder of early childhood. Usually the ileocolic type of intussusception is present. US is now the imaging method of choice for this diagnosis with a sensitivity of approximately 100%.

The sonographic appearance of intussusception has been described as a “doughnut” or “target” or “onion” sign with multiple concentric rings surrounding an echogenic center.
which corresponds to the mesenteric fat (Fig. 38). US can also be used in monitoring of hydrostatic reduction.

Substantial amounts of fluid in the intussusception which represents trapped peritoneal fluid, is associated with irreducibility and ischemia. The lack of perfusion in the intussusceptum on Colour Doppler US is also indicative of ischemia. In this situation surgery should be performed.

Figure 38. Intussusception. In this case of ileocolic intussusception the outer concentric rings represent the colonic wall (arrowheads). The central intussusceptum consists of ileal loops (arrows) and the hyperechoic mesentery (kindly provided by H. Nemec).

Hypertrophic pyloric stenosis

Hypertrophic pyloric stenosis clinically presents as vomiting in the third to fourth week of life and is associated with good appetite. Gastric peristalsis may be visible and a pyloric tumour is palpable.

The typical sonographic signs are a muscle thickness of at least 4mm and a channel length of at least 16mm (Fig. 39). US may also be helpful in the decision for surgical or conservative treatment.
**Figure 39a, b.** Hypertrophic pyloric stenosis. US clearly shows hypertrophic pyloric stenosis as cause of gastric dilatation (a). Measurement of the channel length and of muscular thickness performed in another child (b) (kindly provided by H. Nemec).

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**Necrotizing enterocolitis**

Necrotizing enterocolitis (NEC) is one of the most common new-born life-threatening gastrointestinal diseases affecting 1-5% in the neonatal intensive care unit. Early detection of severely ischemic or necrotic bowel loops before perforation can improve the high morbidity and mortality in NEC.

The major advantages of US over plain radiography are that it can depict intraabdominal fluid, bowel wall thickness, and bowel wall perfusion. The lack of perfusion in US is highly suggestive of necrotic bowel and may be seen prior to visualization of portal venous gas or free intraperitoneal gas.
Other pediatric diseases

Other pediatric diseases with bowel wall thickening in US include vasculitis, inflammation and ischemia. The most common site of gastrointestinal involvement in patients with Henoch-Schönlein purpura is the distal portion of the small bowel. Color Doppler flow is increased in these patients as it is in patients with inflammation of the bowel wall (enterocolitis; Crohn’s disease). Both bowel wall stratification and nonstratification may be visible in vascular and inflammatory causes of bowel wall thickening. Ischemic colitis secondary to hemolytic uremic syndrome often presents with wall thickening of more than 10 mm and absence of colour Doppler signals.

US has proven to be a reliable tool for evaluation of gastro-oesophageal reflux in the first year of life. Using standardized protocols and meals, conventional US and Colour Doppler US can depict and document episodes of reflux.

Sonographic findings are of great help in examining patients with signs of malabsorption. In addition to the abnormal appearance of the small bowel with increased fluid and hyperperistalsis, some patients with celiac disease show slight ascites, pericardial fluid, or liver tissue texture changes.

Conclusion

US is a first stage imaging method for patients with acute abdominal symptoms and provides correct diagnosis in a high percentage. US is also a valuable tool for monitoring acute and chronic intestinal diseases. It gives additional information to endoscopic and radiological examinations. Sonographic results, determining the part of the gastrointestinal tract involved, can contribute to a well-directed further evaluation.

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