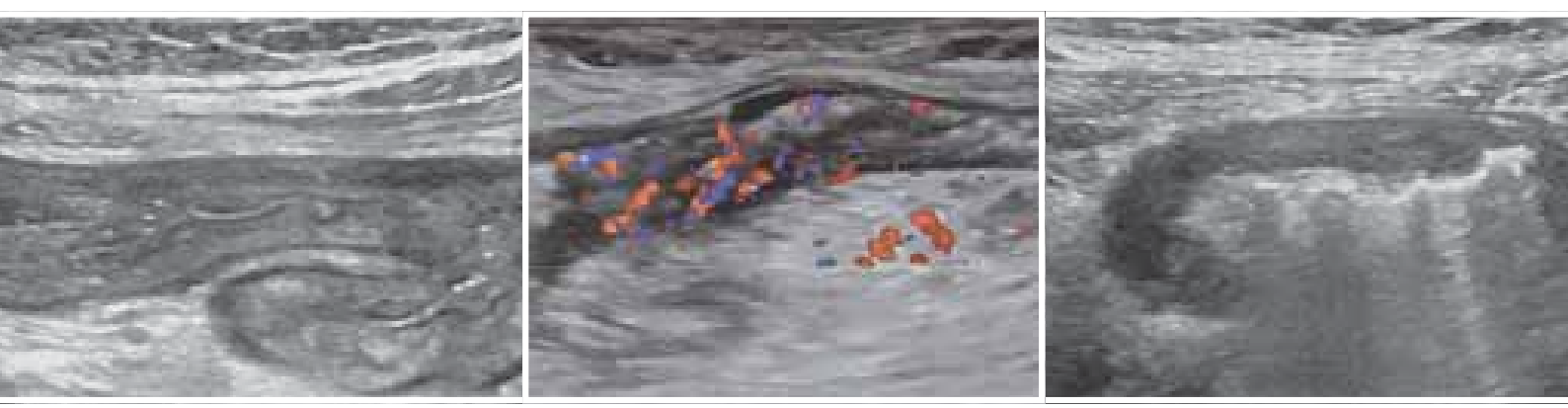
Inflammatory Bowel Diseases

Sonographic Diagnostics



G. von Boyen, M. Mauch, K. Seitz
Medizinische Klinik, SRH Klinik Sigmaringen (Germany)

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G. von Boyen, M. Mauch, K. Seitz
Medizinische Klinik, SRH Klinik Sigmaringen (Germany)

Authors' address:

Prof. Dr. Georg von Boyen
Dr. Martin Mauch
PD Dr. Karlheinz Seitz
Medizinische Klinik
m. S. Gastroenterologie, Kardiologie,
Hämato-Onkologie & Palliativmedizin
und Intensivmedizin
SRH Klinik Sigmaringen
Akademisches Lehrkrankenhaus der
Universität Tübingen
Hohenzollernstr. 40
72488 Sigmaringen
Germany

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Preface

Contrary to what many may assume, the history of ultrasound examination of the gastrointestinal tract goes back to the beginning of the 1970s, making it one of the earliest clinical applications of ultrasound diagnostics.

Back then, it appeared that radiologists and gastroenterologists had found their "ideal" examination methods: endoscopy with inspection and targeted biopsy of the mucous membrane in the upper gastrointestinal tract (GI tract) and in the colon and terminal ileum, and radiology for the small bowel with imaging using the Sellink technique. In addition, radiologists (in competition with specialists in endoscopy of the stomach, duodenum and colon) insisted upon double contrast imaging. At that time, the use of ultrasound diagnostics in the GI tract was hardly even on the radar of experts, and most ridiculed it – if they paid it any heed at all.

The method was also greatly underestimated among the ultrasound community. One criticism of the method was that the resolution was only 2.5–3 MHz, and it was believed that it could not compete with X-ray and endoscopy in that respect. Another criticism was that gastric air and intestinal gas hindered the procedure; however, the importance of these factors was greatly overestimated. All upper abdominal sonographies were performed in the morning in a fasted patient, and many departments prepared the patient with defoaming agents, or even laxatives, in a manner similar to the procedure for gall bladder and kidney X-rays. What an error, and what a misconception!

In those days, the sonography procedure often ended with the assessment "could not be sufficiently evaluated due to intestinal air" – but with the exception of the duodenal bulb, the small bowel is usually free of gas. The message does not appear to have reached everyone yet. Nor is everyone aware that it is easy to work around gas in the colon (where the amount of gas can vary), if it is even present in the section being imaged at all.

Another perennial argument against sonography of the GI tract is the subjectivity of the method. The terms objectivity and subjectivity are stubbornly feeding into prejudices here. The diagnostic criteria are objective and the method can be both learned and taught. The counter-argument is that as with almost all medical procedures, the results of examinations depend on the limits of the method and the level of training and skill of the user.

Initially, the very important characteristics that make sonography of the GI tract stand out, such as its non-invasive nature, the lack of contraindications, the fact that it can be carried out at any time without the need for preparation, the fact that it can be easily repeated, and the fact that it allows assessment of peristalsis, were not recognized. In addition, sonography allows visualization of the regions surrounding the GI tract, and it can be used when radiological or endoscopic examinations cannot be used, or when they are not providing the required information.

In some ultrasound centers, sonography was already being used to great effect as early as the beginning of the 1970s, and people mainly heard about it through word of mouth at ultrasound courses and conferences, and through publications in conference transcripts, which often received very little attention. Whereas radiologists quickly switched to computed tomography (CT) and magnetic resonance imaging (MRI) for diagnostics, in endosonography, endoscopists had discovered a new tool for their repertoire. By 1976, the first prototype of an ultrasound endoscope had been presented, and ten years later it became possible to use sonography to identify the wall layers of the stomach, which represented a revolutionary new diagnostic step.

The use of sonography in inflammatory bowel disease (IBD) has now been thoroughly investigated. A PubMed search for Crohn's disease and ultrasound yields more than 3500 hits.

Transabdominal sonography of the GI tract has become a standard and recognized method for initial imaging in gastroenterology, and this fact is reflected by its inclusion in the guidelines. What puts this technique at a disadvantage compared to endoscopy is the lack of comparably intensive training among practitioners, and the lack of a comparable level of appreciation of this wonderful technique, which represents the epitome of the art of medicine.

Introduction

When it comes to differentiating between the different types of inflammatory bowel disease (IBD), the medical history and the morphological examination methods are the most important factors ("imaging in the clinical context"). In accordance with the guidelines, sonography should be used as a second procedure in addition to endoscopy during initial diagnostics. Magnetic resonance imaging (MRI) and computed tomography (CT) are diagnostic options for inflammatory changes in the small bowel. When used correctly, sonography and MRI are of comparable value in IBD, and they are absolutely indispensable for follow-up monitoring.

Although radiological imaging is the most commonly used technique in the USA and in Asian countries, in Europe, the current guidelines (European Crohn's and Colitis Organisation [ECCO]; German Society for Gastroenterology, Digestive and Metabolic Diseases [DGVS]) state that sonography is the preferred method for cross-sectional imaging. With today's high-resolution, high-end devices, B-mode ultrasound provides high-resolution, high-quality overview images of the gastrointestinal tract and the surrounding structures. In addition, contrast-enhanced ultrasound (CEUS) can be used to quantify bowel wall perfusion (inflammatory hyperemia) and to better visualize abscesses and fistulae.

Cross-sectional imaging in inflammatory bowel disease

1. Ultrasound diagnostics:
   - Conventional B-mode image high resolution (5–12 MHz)
   - (Hydrocolonic sonography)
   - Color Doppler sonography
   - Contrast-enhanced ultrasound (CEUS)
   - Perineal sonography
   - Transrectal sonography
   - Endosonography
2. Computed tomography
3. Magnetic resonance imaging
   - MR enteroclysis

Table 1

MR enteroclysis is another type of tomography (Table 1) that is very valuable in diagnosing complications of the upper small bowel. It is the more expensive and not universally available big sister of sonography, and it has the advantage that it provides seamless imaging, meaning that it is better at detecting some findings. The advantage of sonography over radiological tomography procedures is that the details are depicted more clearly. This is the result of a very high physical resolution and of the fact that the planes can be freely selected by the user. Another advantage of sonography is that it makes it possible to capture moving images. This provides valuable information about bowel peristalsis, blood flow, and the clinical relevance of stenoses.

The imaging procedures and the main imaging options that they provide are summarized in Table 2.

Diagnostic procedures for inflammatory bowel disease	
Sonography:	– Wall thickening, pathological wall layering (thickened mesenteric root, sclerolipomatosis of the mesentery) – Conglomerate tumor – Impaired (absent) peristalsis – Stenosis, fistula – Direct visualization of extraintestinal complications – Inflammatory activity/hyperemia (color Doppler) – (CEUS: no confirmed indication thus far) – Perineal and transrectal sonography/endosonography – Perianal diagnostics (fistulae, abscesses – possibly also in the lesser pelvis) – (Mostly quite limited compared to MRI overview)
X-ray: should no longer be performed due to the fact that it provides little relevant information and involves exposure to radiation	– Mucosal relief (wall thickening) – Impaired peristalsis – Pattern of disease – Stenosis, fistula
Endoscopy:	– Inspection of the mucous membranes – Detailed relief – Aphthae, ulcers, fissures – Pattern of disease, stenosis – Biopsy, histology
CT/MRI:	Diagnostic criteria similar to sonography Contrast medium must be used, still a very expensive procedure MRI: excellent visualization of fistulae in the lesser pelvis and the perianal region Alternatives: Endosonography (limited overview)

Table 2

The development of ultrasound diagnostics

Even as early as the beginning of the 1970s, sonography was providing surprisingly informative images. Of particular note was the fact that in the case of active Crohn's disease and advanced gastrointestinal carcinoma, the technique showed the typical infiltration of the bowel wall, also known as the cockade phenomenon or bull's eye (Fig. 1 and 2).

At that time, despite the relatively poor resolution, the procedure regularly allowed correct positive findings to be established in cases with evident bowel wall thickening. If a long segment of the bowel was affected, it was highly likely to be Crohn's disease, and in the case of shorter segment being affected, it was often (almost usually) a carcinoma. Back then, other intestinal diseases could barely be visualized by sonography at all. Problems with differential diagnosis only arose in isolated cases, such as in the case of a long section of infiltrating tumor growth (Fig. 2). Generally speaking, in these cases, the differential diagnosis decision could be made using the medical history.

The astonishing efficacy of the method of ultrasound diagnostics despite its limitations was mainly due to the fact that the diagnosis was often made at a very late stage, especially in the case of Crohn's disease.

The initial diagnosis of Crohn's disease was therefore frequently made in the context of extremely varied examination indications and with extensive findings in the upper abdominal sonogram. This situation has now become less common because more physicians are familiar with Crohn's disease. Therefore, in the past, diagnostic procedures could be shortened significantly in many cases.

The "yes/no" approach to the diagnosis of advanced tumors of the gastrointestinal tract and severe Crohn's disease persisted until about 1980. Nowadays, advances in sonography have made it possible to detect pathological findings much earlier. The sensitivity of ultrasound diagnostics has increased significantly, and its specificity has dropped accordingly. This in turn has made ultrasound examination and assessment much more difficult. Many diseases of the gastrointestinal tract (GI tract) need to be assessed in the context of a differential diagnosis.

Historical ultrasound images

Crohn's disease

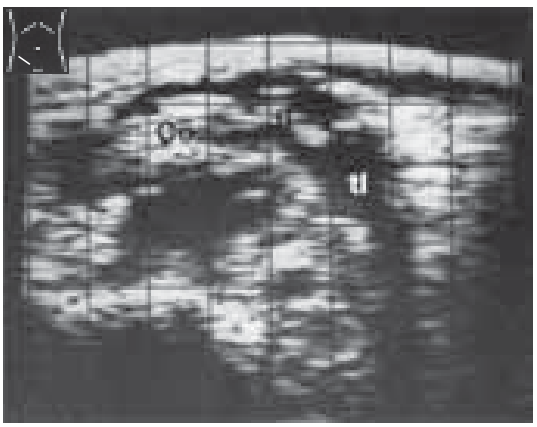


Fig. 1a

Ileocecal region affected by Crohn's disease. Entrance of the terminal ileum (tl) in the cecum (Cö) with wall thickening in the terminal ileum. Pronounced reaction in the surrounding tissue. Oblique slice of the right lower abdomen, grid length 2 cm.
(Image from the year 1977)

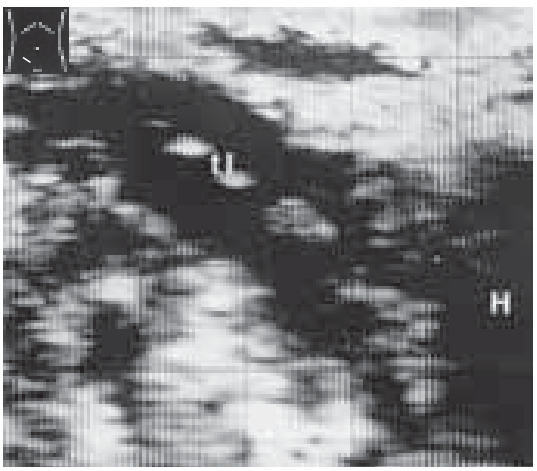


Fig. 1b

Elongated terminal ileum with wall thickening (tl) and lumen constriction in the presence of Crohn's disease. Section parallel to the right inguinal ligament, section touches the bladder (H).
(Vidoson 635, 1976)

Diffuse wall infiltration

Fig. 2a

Wall thickening of the cecum and the ascending colon with moderate lumen constriction in an 80-year-old female patient. Ventral longitudinal slice at the level of the psoas major muscle.
Cf. Fig. 2b on the right.
(Vidoson 635, 1975)

Fig. 2b

Diffuse metastasis of a gastric carcinoma in the cecum and the ascending colon. The finding was detected one year after palliative gastrectomy. The metastasis has used the normal bowel wall as a highway.

Normal bowel wall layers

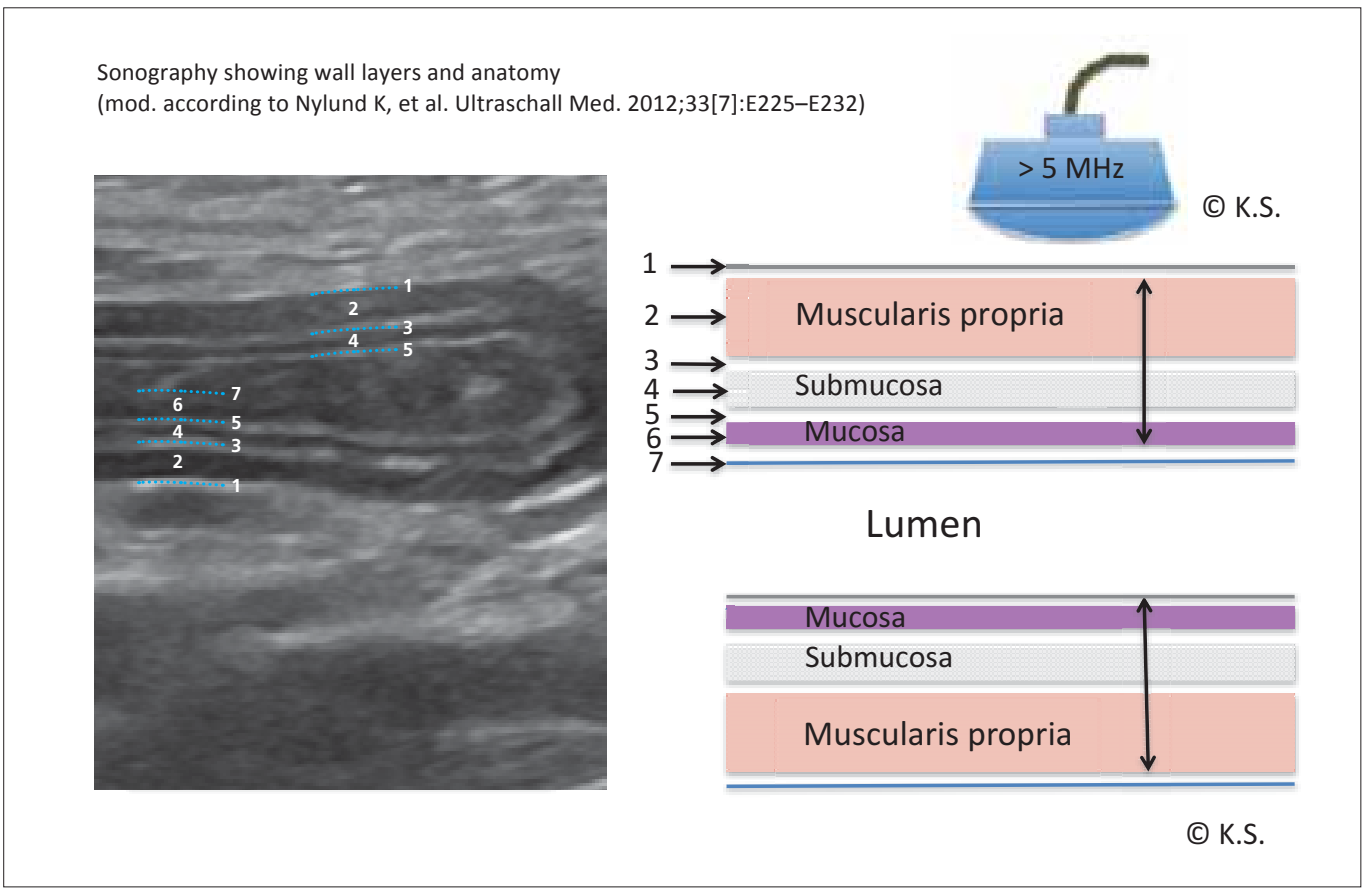


Fig. 3:
Diagram showing the gut wall and its anatomy (using the example of the stomach in this case).
The bowel wall layers can generally be distinguished using ultrasound frequencies > 5 MHz, but it is easier at frequencies > 10 MHz. The wall layers shown in the sonography do not correspond to the anatomy exactly. Five or seven layers are depicted. Layers three and five are ultrasound interface lines and do not correspond to any part of the anatomy. Line 1 corresponds to the entrance/exit echo on the bowel wall and not the anatomical serous membrane, line 7 corresponds to the impedance jump between mucosa and lumen/lumen contents. The wall layers cannot always be differentiated in optimum image quality. Therefore, in this example, only sonography layers 1–5 can be delimited at the anterior wall. The mucosa (layer 6) and the exit echo to the lumen cannot be delimited. The optimal wall thickness measurement (D) is shown in the diagram (double arrow). In the case of a transabdominal measurement, measurement is from the hypoechoic layer (muscularis propria) to the end of the hypoechoic signal, which corresponds to the mucosa. The thickness of the anterior GI wall is underestimated somewhat compared to the histology because the interface echo between the serous membrane and the M. propria is not included in the measurement. The interface echo between the lumen and the mucosa is included in the posterior wall measurement. Here, the wall thickness corresponds to the histological GI wall thickness without serous membrane/subserosa. The normal wall thickness throughout the intestine is 2 mm. Since routine wall thickness measurement often does not measure layers precisely and the reticles are sometimes not precisely positioned and measurement is also done at 3–5 MHz, measurement values < 4 mm are considered to be unconfirmed pathological values.

Conventional, high-resolution ultrasound diagnostics

High-end devices offer a much higher resolution thanks to their high frequency transducers. Nowadays, the gastrointestinal tract is usually examined using 5–12 MHz transducers. The disadvantage of these very high-resolution transducers is that although they have improved penetration capabilities, they often still cannot penetrate deep enough in the case of patients with larger amounts of fat or muscle.

Using this method, 7 wall layers (Fig. 3) can be distinguished in the sonography, moving from the inside to the outside:

1. Echogenic layer: Interface echo
2. Hypoechoic layer: Mucosa
3. Echogenic layer: Submucosa
4. Hypoechoic layer: Muscularis propria
5. Echogenic layer: Exit echo

The percutaneous imaging of the 5 wall layers (which do not correspond to the anatomical wall layers because the inner and outer layers are interface echoes) depends not only on the ultrasound frequency, but also on the imaging conditions (obesity, muscular abdominal wall, intestinal contents), and of course on the wall thickness. In some cases, it may be achievable using conventional 3.75 MHz standard transducers.

Hydrocolonic sonography

In this technique, the colon is cleared using laxatives, then 1.5 liters of water is introduced as an enema, making it possible to gain a continuous visualization of the large bowel in hypotonia. Using this method, even those wall sections that are far away from the transducer can be visualized well. Generally speaking, this frequently allows the bowel wall layers to be delimited. Some examiners value these advantages so highly that they decide to perform this examination, even though it clearly places a burden on the patient. However, the method has not been proven effective in practice. Furthermore, unlike endoscopic procedures, hydrocolonic sonography cannot show the mucous membrane relief or superficial lesions such as aphthae. The value of this method is therefore purely academic.

Color Doppler/duplex sonography

Color Doppler sonography is able to depict "inflammatory hyperemia", which is basically regarded as a sign of active inflammation. Even submucosal hyperemia can be detected. In the case of extensive disease, inflammatory hyperemia can even be detected quantitatively. Flow volume, flow velocity, and resistive indices are altered in the superior mesenteric artery and the inferior mesenteric artery. Quantitative flow measurement is used in research studies, but it is not used in routine diagnostics.

A semi-quantitative measurement of inflammatory hyperemia allows Limberg classification to be carried out. This diagnostic tool can be used to assess inflammatory activity in the affected sections of the gastrointestinal tract within the context of the patient's individual disease course.

Contrast-enhanced ultrasound (CEUS)

The newest generation of ultrasound contrast media (CM) can be used in bowel wall sonography. As with conventional bowel sonography, higher-frequency transducers should be preferred here. CEUS allows qualitative, and in principle also quantitative assessment of the vascularization of the bowel wall, and it has the potential to improve the reliability of assessments of disease activity in Crohn's disease. In some studies (albeit with small sample sizes), contrast enhancement has been found to correlate relatively well with clinical indices, with the severity of the disease as assessed by endoscopy, and with the histological findings. However, quantification of perfusion by CEUS is challenging and the method has not yet been sufficiently validated for use in everyday clinical practice.

CEUS could also prove helpful in distinguishing between fibrosis and inflammatory strictures. The inflammatory parts exhibit more contrast enhancement, whereas the fibrotic strictures exhibit only weak contrast enhancement.

CM is also helpful in distinguishing between abscesses and inflammatory infiltrates. Abscesses exhibit hyperenhancement in the periphery, as well as absent internal vascularization.

In summary, the studies on CEUS conducted to date have not yet provided any conclusive data with regard to use in routine diagnostics. With the emergence of the new concept of "deep remission" as a potential treatment aim for IBD, we can expect further studies comparing CEUS with endoscopic examinations for testing the diagnostic target of sustained deep remission.

Elastography

Elastography is an extension of ultrasound diagnostics and MRI. The latest studies have shown that tissue characteristics in Crohn's disease can be reliably determined using elastography. In particular, elastography is good at distinguishing between hard, scar-like strictures and soft, inflammatory stenosis. Thus far, we do not have sufficient proof of the value of this technique, and it is possible that further applications of the technique remain to be discovered.

Endosonography

Endosonography of the upper GI tract is rarely of much practical use when it comes to diagnosing inflammatory bowel disease. The exceptions to this rule are cases where the upper GI tract (stomach, duodenum) is severely affected by Crohn's disease. In these cases, endosonography is superior to MRI or CT for evaluation of fistulae or small abscesses. Endosonography of the colon has never progressed beyond the experimental stage.

Transrectal ultrasound diagnostics

The feasibility of transrectal ultrasound examination is limited in the case of Crohn's disease patients due to the perianal complications (stenoses and pain). In the absence of stenoses, abscesses and fistulae can be visualized well. The wall layers can be delimited extremely well and the wall thickness can be determined with precision. Depending on penetration depth, the specificity and sensitivity of this method is comparable to MRI when it comes to diagnostics for fistulae and abscesses. However, possibilities for visualization of complex systems of fistulae (for example in the case of infiltration into other organs) is limited due to the penetration depth.

Perineal sonography

Conventional perineal examination is underused in routine procedures, even though it has no contraindication, unlike transrectal sonography. The method is most likely capable of depicting fistulae and abscesses with the same level of diagnostic certainty as transrectal sonography.
The injection of saline solution with a few drops of CM into a fistula opening improves the depiction of the course of the fistula.

Radiological computed tomography and magnetic resonance imaging

Although sonography has had to fight hard for years in order to gain acceptance as a diagnostic procedure, the USA and Asian countries mainly use computed tomography and magnetic resonance imaging in the case of chronic and acute inflammatory bowel diseases. The diagnostic criteria are basically the same, as are the examination results. One aspect worth highlighting is the excellent depiction of larger and more complex systems of fistulae in the lesser pelvis and in the anal region provided by magnetic resonance imaging. The advantages and disadvantages of these examination methods and the costs associated with them are well known so we will not repeat them here.

MR enteroclysis is very valuable when performed by a practiced hand, and its fundamental advantage over sonography is that it provides an unrestricted overview (continuous visualization of the entire small bowel). However, the suitability of this method for short-term follow-up of stenoses, abscesses, or fistulae is limited due to the high costs involved, the need to prepare the patient the day before, and the fact that it is uncomfortable for the patient. The results of radiological tomography and sonography depend on experience and are roughly equivalent.

Unfortunately, ultrasound diagnostics in the gastrointestinal tract are subject to certain unavoidable method limitations (Table 3).

Limitations of the ultrasound diagnostic method in the gastrointestinal tract

- Complex anatomy
- View obstructed by air
- No continuous visualization of the GI tract
- Changes are non-specific
- High operator dependency (experience!)

Table 3

The examination is generally done using linear or convex scanners. Sector scanners with a small contact surface are less suitable.

Often, the stomach, the duodenum, and the colon, and frequently also the appendix and some of the small bowel can be visualized from the normal GI tract (Fig. 4). From the stomach, the antrum, the lesser curvature, the cardia region, and the anterior wall can be particularly well visualized. The antrum and the anterior wall are shown in the upper abdominal longitudinal slice and transverse slice, and the cardia region is shown in the subcostal oblique slice. The stomach wall is 5–7 mm thick. Depending on the state of contraction, it can exceed 7 mm, especially at the pylorus. Devices with the new type of design show five discernible wall layers, although as explained previously, these do not correspond to the anatomical wall layers.

The duodenum can be visualized in transverse slices as far as the duodenojejunal flexure using suitable compression of the abdominal wall. The pars descendens can also be visualized in a longitudinal slice moving from ventrolateral to dorsal to inwards of the gallbladder.

It is not possible to follow the entire course of the normal small bowel (Fig. 5a–e) in a continuous manner, however the entire lower abdomen can be systematically examined for pathological changes, and in particular for wall thickening. Depending on extent to which they are filled, the loops of the small bowel can be visualized in sections. The presence or absence of the plicae circulares can be used as the basis for distinguishing between the jejunum and the ileum. The entrance to the terminal ileum and the ileocecal valve can usually be detected (Fig. 5g). The entrance of the terminal ileum is searched for using oblique slices that are roughly parallel to the inguinal ligament. The nor-

mal appendix can frequently be visualized (> 60%), (Fig. 5e and f).

The large bowel is followed along its course in a continuous manner, starting from the cecum, using longitudinal and transverse slices. The normal wall thickness is about 2 mm to 3 mm at most. In most cases, only the ventral colon wall (the wall facing the transducer) can be visualized. The colon is easily recognizable thanks to its haustration (Fig. 5h). It is not possible to visualize the entire course of the colon continuously when it is not filled with fluid, and for the same reason, the normal sigmoid cannot be visualized completely (Fig. 5i–l). The anterior side of the rectum can be seen behind the bladder or the uterus. Ulcerative proctitis can by all means be diagnosed, even though ultrasound is not the method of choice for this.

The method makes it possible not only to systematically visualize the normal gastrointestinal tract sections, but also to observe the process of peristalsis. The examination of the gastrointestinal tract is usually performed with the patient having fasted, but the state of being filled with fluid is advantageous for the examination of the small bowel and for observing peristalsis.

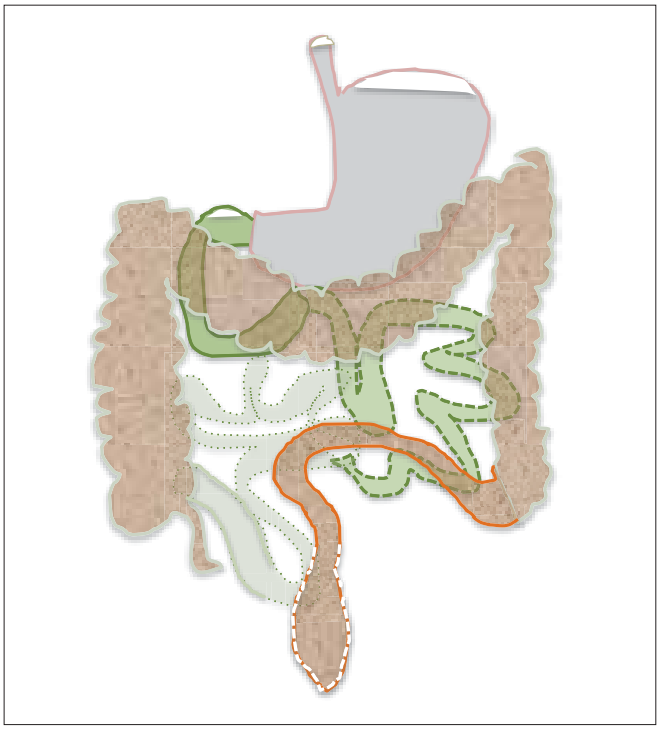


Fig. 4:
Visualization capabilities of sonography in the normal GI tract. The following can be delimited in the sonography with certainty: Cardia, antrum, duodenum, terminal ileum, colon (haustration), and the proximal section of the sigmoid. When the procedure is performed by an experienced sonographer, the normal appendix can be visualized in adults in 60% of cases. However, it is not possible to map the precise topography of the loops of the small bowel. Transcutaneous imaging of the rectum has little value.

Therefore, when examining the small bowel, the administration of a bolus of approximately 0.7–1.0 liters of fluid (e.g. orange juice) is recommended because it allows changes in the walls to be identified more easily. This method of filling the stomach and intestine with fluid, which has been recommended by various authors, is certainly widely underused. The procedure is not very popular because where there is a clinical suspicion of disease in the intestine, sonography cannot be used as a diagnostic procedure to rule it out, and endoscopy is already indicated as the diagnostic method of choice in any case.

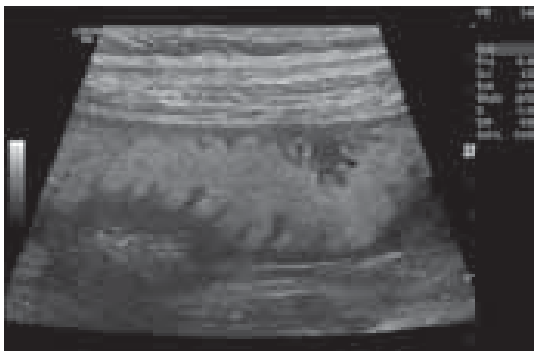
Hydrocolonic sonography (cf. p. 13) can provide brilliant images in individual cases and may even be capable of depicting the wall layers of the sections of the gastrointestinal tract that are far away from the transducer, but since it cannot replace colonoscopy, it is obsolete because of the complex preparation required.

Macroscopic findings of inflammatory bowel disease form the basis of ultrasound diagnostics, but not all of these findings can be detected by sonography. Tables 4 and 5 provide a summary of the most important macroscopic and microscopic characteristics that allow us to distinguish between ulcerative colitis and Crohn's disease.

In the case inflammatory bowel disease (IBD) that has already been diagnosed, sonography of the bowel wall is one of the most important and useful diagnostic tools for follow-up. This is confirmed by the current European (ECCO) and German (DGVS) guidelines for IBD, both of which strongly recommend the method based on the evidence.

Ultrasound images of the normal intestinal tract

Fig. 5a



Normal jejunum in longitudinal slice. The thin walls and the plicae circulares can be seen clearly.

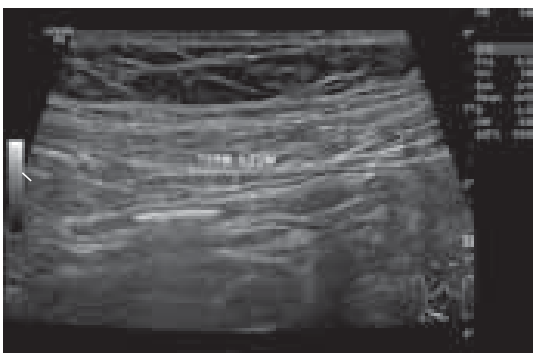
Fig. 5b

Transverse slice of a normal jejunum with visualization of normal bowel wall vessels.

Fig. 5c

Junction between the normal jejunum and the ileum in longitudinal slice. Jejunum with high plicae circulares and ileum with low plicae circulares.

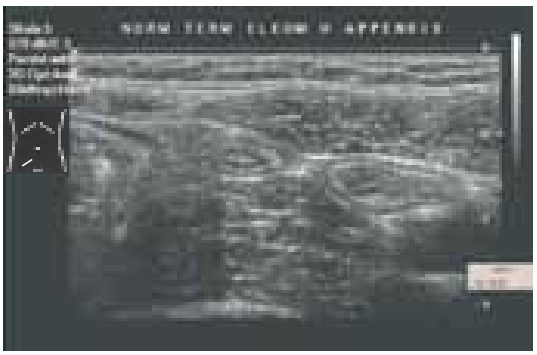
Fig. 5d



Normal terminal ileum in longitudinal slice.

Ultrasound images of the normal intestinal tract

Fig. 5e

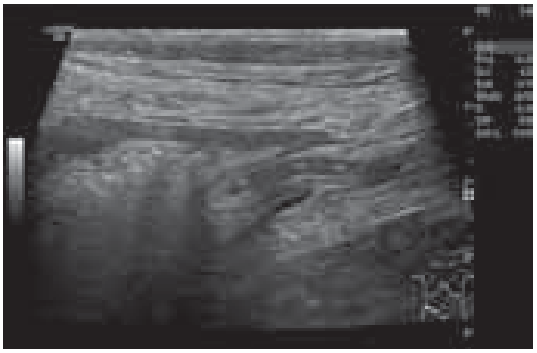


The normal terminal ileum and the normal appendix can be seen in the transverse slice as two "cockades/bull's eyes" of different sizes.

Fig. 5f

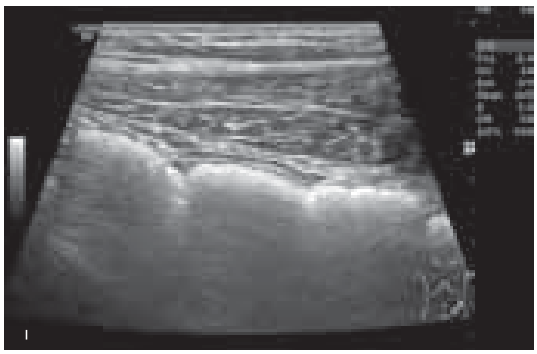
Normal appendix in longitudinal slice; Iliac vessels in transverse slice, shown on the right in the image.

Fig. 5g



Normal ileocecal valve with cecum (area of air on the left of the image) and terminal ileum.

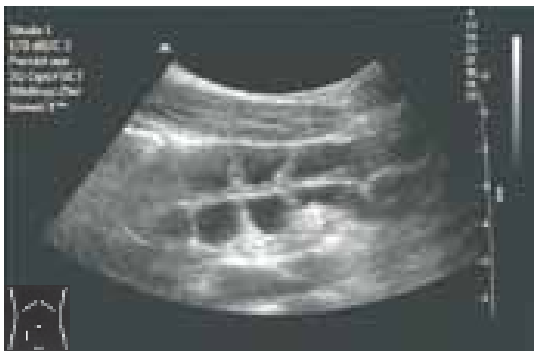
Fig. 5h



Colon with normal haustration: From the normal colon, it is often only possible to see the cap-shaped, gas-filled haustra.

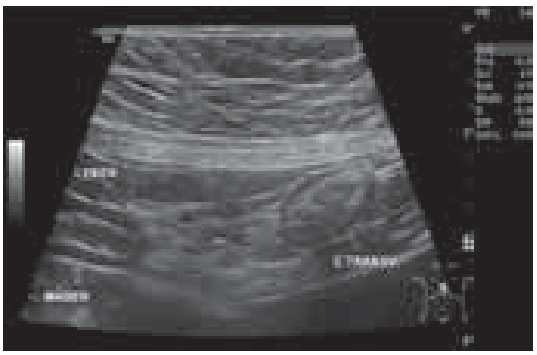
Ultrasound images of the normal intestinal tract

Fig. 5i



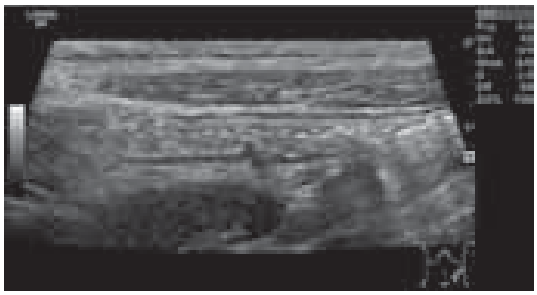
During lavage, the colon unfolds, the haustra are filled with liquid, and sometimes the teniae become visible. Lavage can be a significant help in the assessment of the bowel wall using sonography.

Fig. 5j



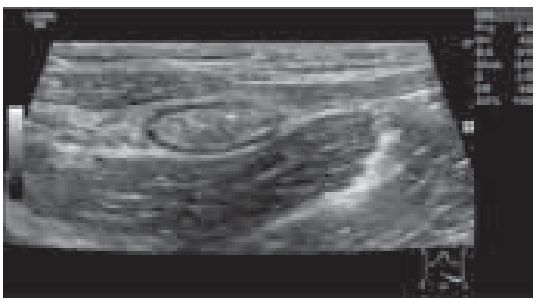
Upper abdomen, longitudinal slice: normal transverse colon transverse.

Fig. 5k



Normal sigmoid in longitudinal slice.

Fig. 5l



Normal sigmoid in transverse slice. Between the abdominal wall and the psoas major muscle.

Macroscopic diagnostic criteria for Crohn's disease and ulcerative colitis

	Crohn's disease	Ulcerative colitis
Spread	discontinuous, segmental	continuous from the rectum onwards, diffuse
Involvement of the rectum	< 50% (rectum only 15–25%)	100%
Involvement of the ileum	up to 50%	< 10% (backwash ileitis)
Anal lesions	up to 50% chronic fissures and fistulae	fistulae in rare cases
Bowel wall		
Wall thickness	slight – strong thickening, fibrosed	normal – slight thickening
Mucosa/submucosa	cobble stones, skip lesions aphthous ulcers fissures	hemorrhagic edematous ulcerated
Pseudopolyps	rare	frequent
Hyperemia	mild, only in the case of acute flare-up	severe
Mesenteric serosa	fibrotic thickening sclerolipomatosis granulomas	mostly normal
Strictures	frequent	rare
Fistulae	frequent	none
Bowel shortening	yes muscular	yes (fibrous, segmental)
Toxic megacolon	rare (< 2%)	rare (< 5%) more common in the case of whole colon involvement
Function		
Subileus/ileus	more common	

Table 4

Important distinguishing features detectable by microscopy	
Crohn's disease	**Ulcerative colitis**
transmural "disproportional" inflammation	inflammation limited to the mucosa
fissural ulcerations	flat erosions/ulcerations
fistula	possibly pseudopolyps
submucosa widened	submucosa normal or mild inflammatory infiltrates near the lumen
subserosal lymphangiectasia	–
epitheloid cell granulomas	
involvement of myenteric plexus (plexitis, high rate of recurrence)	

Table 5

Characteristic sonographic finding: Bowel wall thickening

The characteristic sonographic finding is visualization of bowel wall thickening as a result of inflammatory or tumorous infiltration (Fig. 6a). The more pronounced the finding, the more easily it can be detected. This is particularly true for circular bowel wall thickening and wall thickening over a long section of the bowel. Whether or not it is detected depends on where it is located and above all, on the amount of care taken by the examiner. More extensive findings in the small bowel may be masked by meteorism or concealed by the convoluted bowel loops if they are not searched for in a targeted manner. Many findings can only be detected by systematically searching the lower abdomen using controlled compression, possibly after filling with fluid. If the bowel wall does not have circular thickening then it is particularly easy to overlook pathologies.

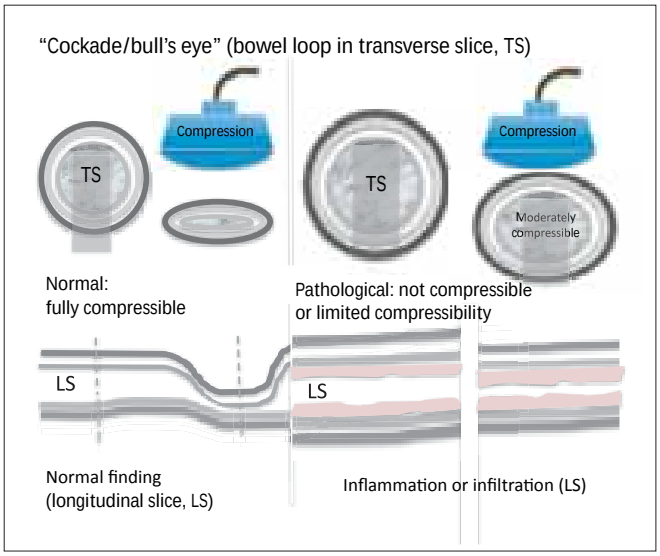


Fig. 6a:
Diagram showing the bowel wall with inflammatory infiltrates. Depending on the characteristics and the level of involvement of the wall layers, wall thickening of varying severity occurs. The bowel wall usually becomes stiffer and less compressible.

Characteristic ultrasound findings in the case of Crohn's disease

In Crohn's disease, early-stage findings or discrete changes usually cannot be detected by sonography. The characteristic finding is long sections of pronounced bowel wall thickening with lumen constriction, particularly in the terminal ileum and the cecum (Fig. 6b and 7). The bowel wall thickening and lumen constriction may be uneven. The lumen can often only be recognized by individual echoes lined up like a string of pearls. Peristalsis is absent in the affected section of the gastrointestinal tract. In addition, in the case of inflammatory infiltrates, the bowel is either not compressible or barely compressible when performing palpation under visual control or when compressing using the transducer. The findings, which appear monstrous in places, are not exclusively the result of bowel wall thickening – they are also the result of the additional thickening of the mesentery, the enlargement of the associated lymph nodes, the impaired lymphatic drainage, and the fatty tissue proliferating across the bowel wall ("echogenic halo").

If several neighboring bowel loops are affected, these can be followed loop by loop using a high-resolution scanner. If the imaging conditions are good, involvement of several segments that are located apart from each other can be detected. If several loops are found in a hypoechoic conglomerate and cannot be separated by palpations or transducer compression, this indicates the presence of a conglomerate tumor. This type of tumor is generally painful on palpation. If hypoechoic tracks of inflammation are found, abscesses and fistulae should be searched for.

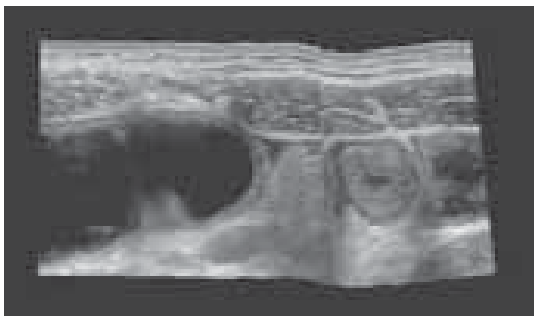
Crohn's disease

Fig. 6b

Crohn's disease: Visualization of a typical long section of disease in the terminal ileum using the "panoramic technique".

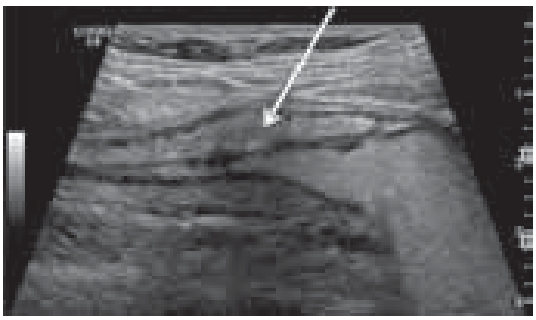
Crohn's disease

Fig. 6c



Crohn's disease: Below the abdominal wall, we see a dilated section of the lower jejunum next to a transverse view of stenosis of the small bowel with wall thickening and only a very small lumen ("cockade/bull's eye") remaining.

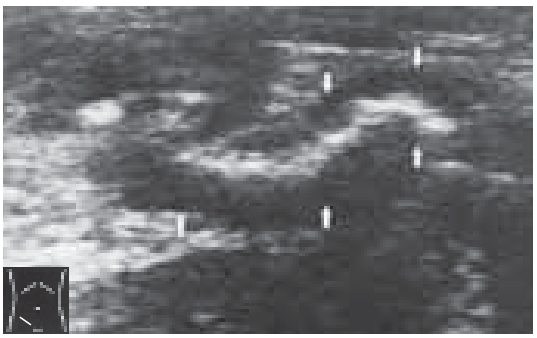
Fig. 6d



Crohn's disease: Terminal ileum with echogenic submucosa with wall thickening (arrow) and consecutive prestenotic dilatation.

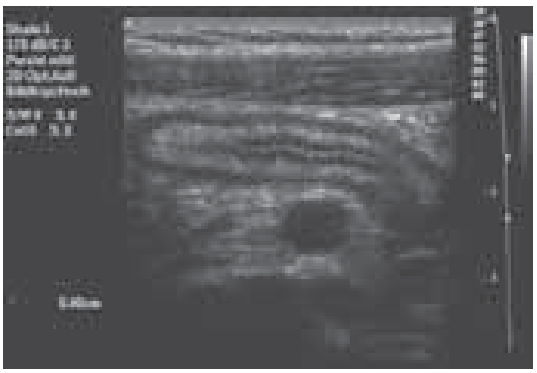
Crohn's disease: terminal ileum and appendix

Fig. 7a



Typical sonographic finding in the case of Crohn's disease with ileocecal involvement: striking wall thickening in the terminal ileum (↑) and the cecum (⇑) with lumen constriction (visualization using an earlier mid-range device, 5 MHz, approx. 1985).

Fig. 7b



Concomitant involvement of the appendix in Crohn's disease. Both the appendix wall and the appendix as a whole exhibit thickening. Wall layers are accentuated and can be clearly delimited.

Figure 8 is a diagram of the changes associated with Crohn's disease that can potentially be visualized by sonography. Figures 9–18 show typical sonographic findings. Table 6 shows the sonographic findings in Crohn's disease in contrast to ulcerative colitis findings.

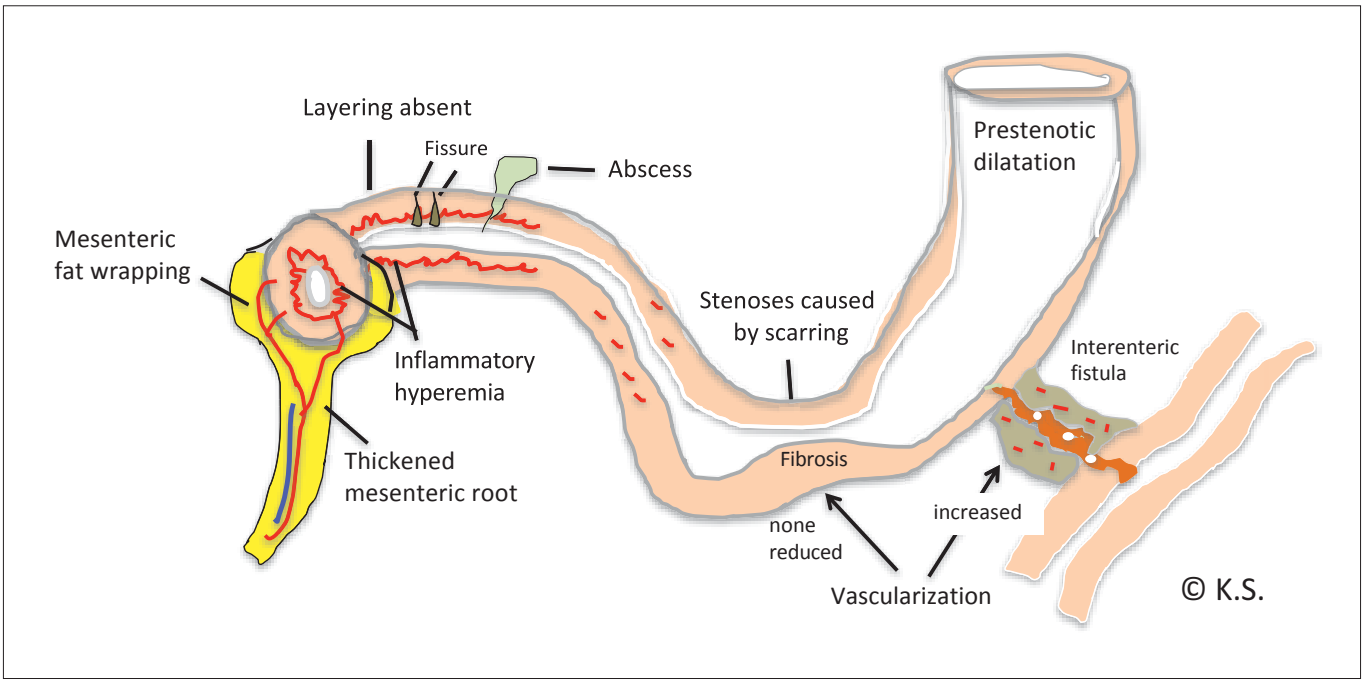
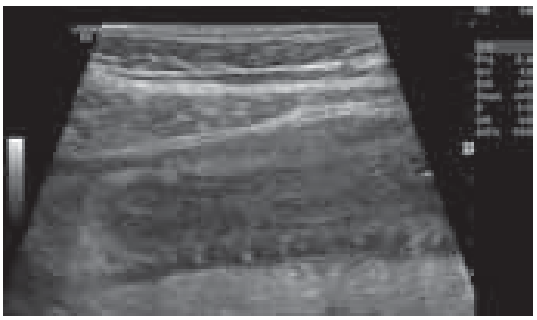


Fig. 8:
Diagram showing the findings that can be visualized by sonography in Crohn's disease: long section of wall thickening with reaction in the surrounding tissue and inflammatory hyperemia, lumen constriction, and formation of fistulae and abscesses.

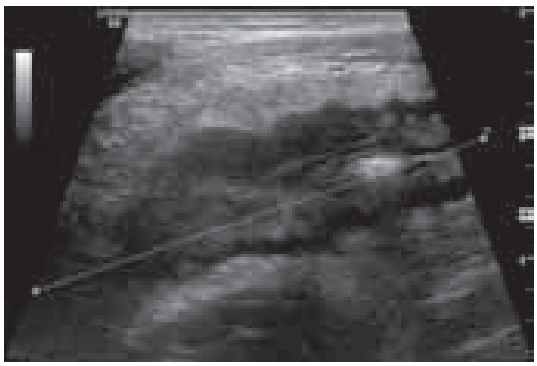
Crohn's disease: terminal ileum

Fig. 9a



Active Crohn's terminal ileitis: Wall layers partially absent.

Fig. 9b

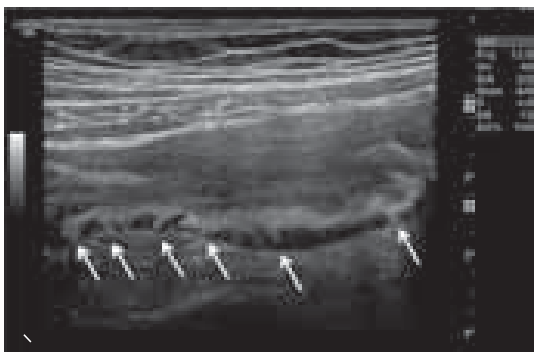


Active Crohn's terminal ileitis: Wall layers completely absent. Pronounced lipomatous mesenteric thickening.

Fig. 9c

Stenosed ileocecal valve in the presence of Crohn's ileocolitis. Despite the detailed visualization of the pathological anatomy complete with wall thickening and reaction in the surrounding tissue, so far, there is no correlate for the "cobblestone" pattern that is found in radiological examinations.

Fig. 9d

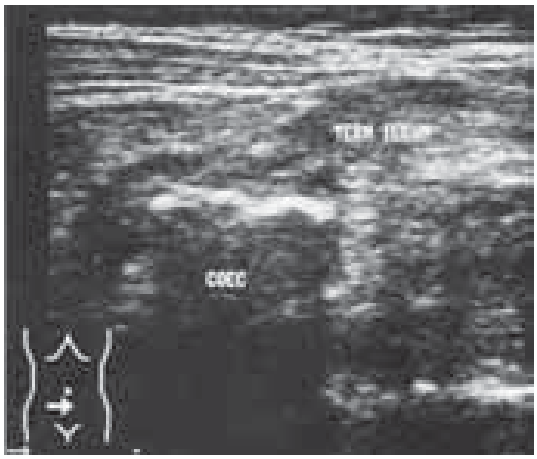


Active Crohn's terminal ileitis: thickened dorsal wall of the terminal ileum with numerous intramural fissures (hyperechoic strands in the hypoechoic muscularis propria, arrows).

Crohn's disease: ileocecal involvement

Figures 10a and b: Crohn's disease with typical positioning of the terminal ileum and cecum.

Fig. 10a



Opening from the terminal ileum (with wall thickening) into the cecum, which exhibits pronounced wall thickening (mid-range device, 5 MHz, approx. 1985).

Fig. 10b

Historical equivalent X-ray image: We see irregular wall thickening of the cecum and the terminal ileum. The gap between the neighboring bowel loops is enlarged. Unlike in the sonography, the wall thickening is only shown indirectly.

Crohn's disease: ileocecal involvement

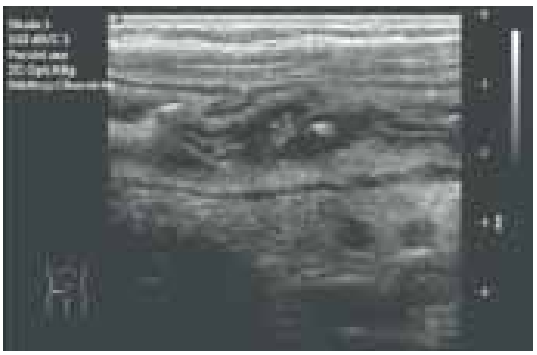


Fig. 10c

Crohn's terminal ileitis with moderate wall thickening and preserved wall layers. The hyperechoic submucosa is particularly thickened.

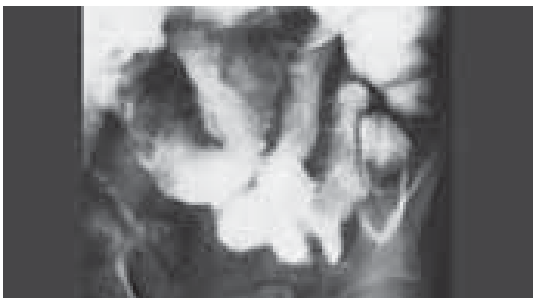


Fig. 10d

Example image of cobblestone relief, no significant lumen restriction in the region of the terminal ileum, comparable wall thickening and enlarged prestenotic small bowel loop. This image, which provides a good visualization, is a historical image taken around 1978.

Crohn's disease: colonic involvement

Figures 11a–d: acute flare-up of Crohn's pancolitis. There is wall thickening of varying degrees throughout the colon; haustration is absent.

Fig. 11a

Cecum with deep ulceration and neighboring reactive enlarged lymph node.

Fig. 11b

Transverse colon.

Fig. 11c

Aboral transverse colon with splenic flexure. The hypertrophy of the mesenterial fat frames the affected section of the gastrointestinal tract, improving visualization and allowing better recognition.

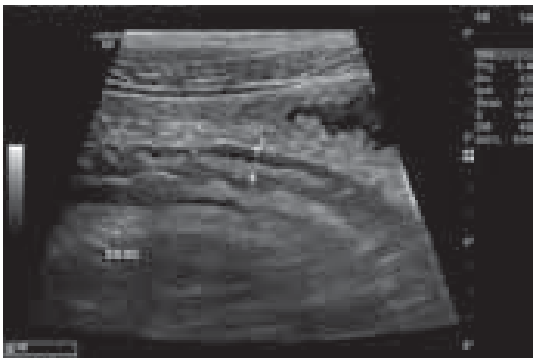


Fig. 11d

Crohn's colitis. Descending colon with moderate wall thickening and preserved layers. The hyperechoic submucosa dominates.

Crohn's disease: small bowel in longitudinal slice and transverse slice

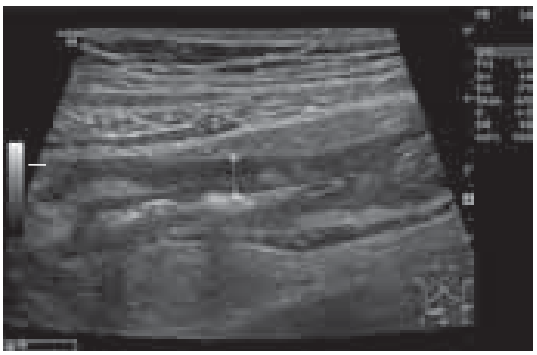


Fig. 12a

Terminal ileum in active Crohn's disease with asymmetrical wall thickening in longitudinal slice.

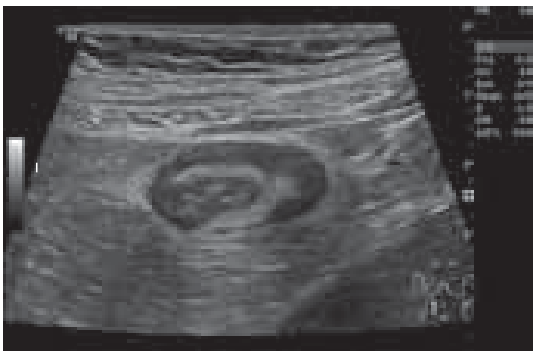


Fig. 12b

The same bowel loop as the one shown in the transverse slice in Fig. 12a. Asymmetrical circular wall thickening.

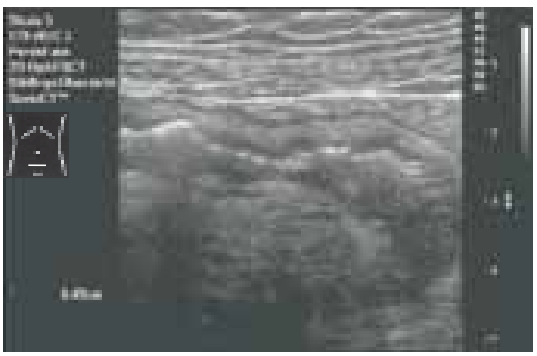


Fig. 12c

Crohn's disease: longitudinal slice showing stiff bowel loop with wall thickening, narrowed lumen, widened echogenic submucosa: "layered type", fatty, thickened mesentery in the surrounding region.

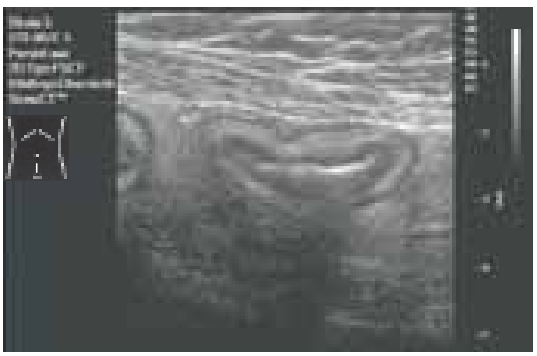
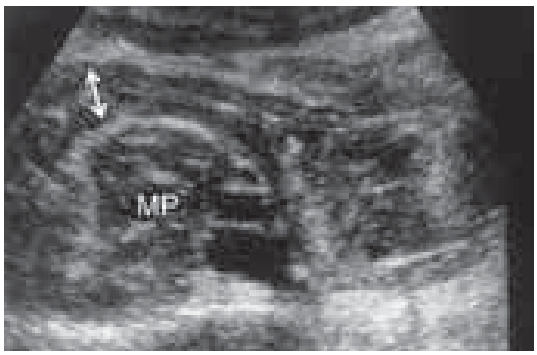


Fig. 12d

The same bowel loop as the one shown in the transverse slice in Fig. 12c.

Crohn's disease: inflammatory bowel conglomerate and formation of fistulae

Fig. 13a



"Pseudo-conglomerate tumor". Cave: not a conglomerate tumor, but rather a hypoechoic terminal ileum exhibiting wall thickening (distance mark) over the hypoechoic psoas major muscle (MP).

Fig. 13b

Interenteric fistula in the presence of a small bowel conglomerate adhered due to inflammation in the right lower abdomen in Crohn's disease.

Crohn's disease: follow-up monitoring

Figures 14a–d: Crohn's colitis in the further course.

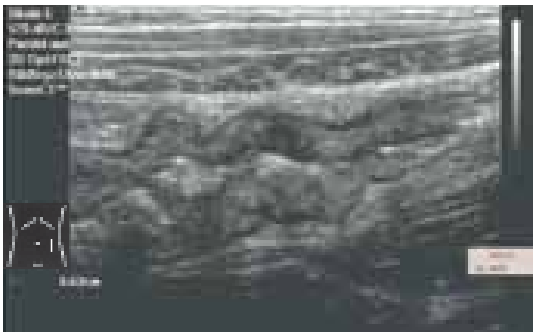


Fig. 14a

Descending colon with mild wall thickening in the chronic stage with intermittent abdominal pain.

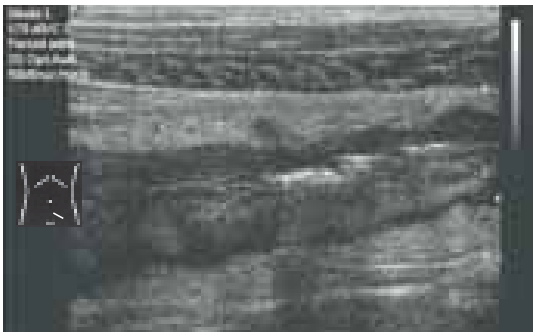


Fig. 14b

3½ months later, acute flare-up with poor general condition, severe abdominal pain, and bloody diarrhea: conspicuous hypoechoic colon without discernible wall layering.

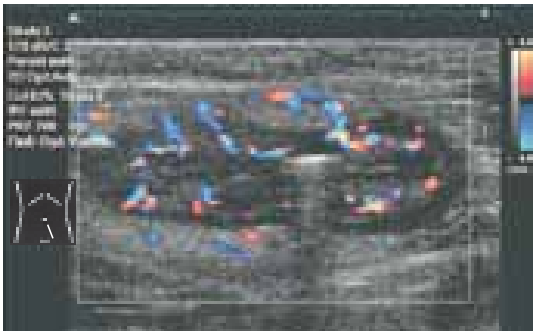


Fig. 14c

At this point in time, the same section of the colon exhibits conspicuous vascularization, which is evaluated as inflammatory hyperemia (Limberg 4).

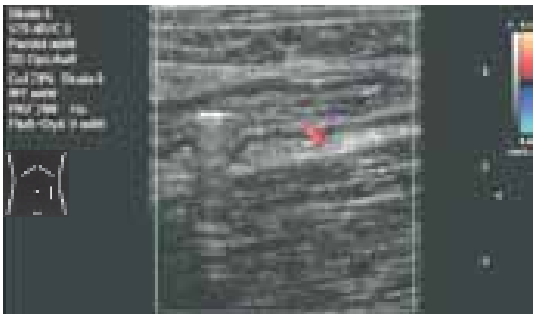


Fig. 14d

About eight weeks later, the colon is found to be in the remission phase, there are no symptoms, and imaging is inconspicuous compared to previous images. The submucosa is clearly visible, and the inflammatory hyperemia of the acute flare-up can no longer be detected.

Crohn's disease: follow-up monitoring

Figures 15a–f: various findings established in follow-up monitoring of Crohn's disease lasting many years.

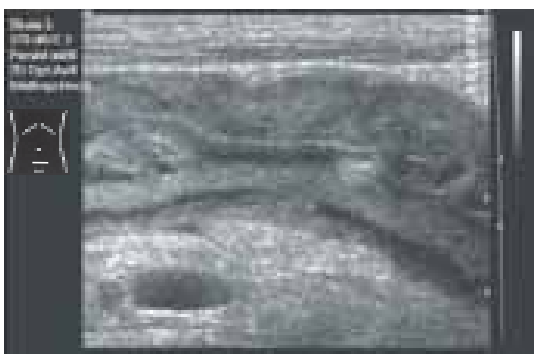


Fig. 15a Small bowel segment with stenosis and even, three-layered wall thickening, conspicuous widening of the submucosa.

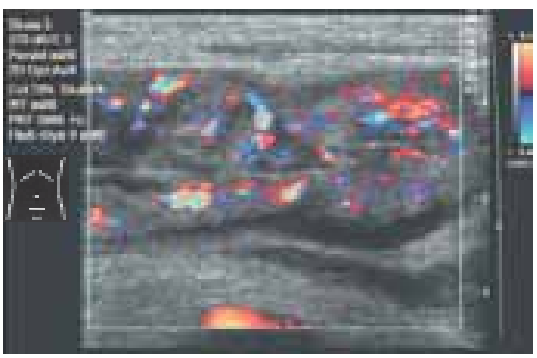


Fig. 15b Visualization of small bowel stenosis with inflammatory hyperemia in color Doppler.

Fig. 15c Prestenotic dilatation of a small bowel segment.

Fig. 15d Small bowel segment with prestenotic dilatation exhibiting funnel-shaped dilatation at the point where the stenosis begins.

Crohn's disease: follow-up monitoring

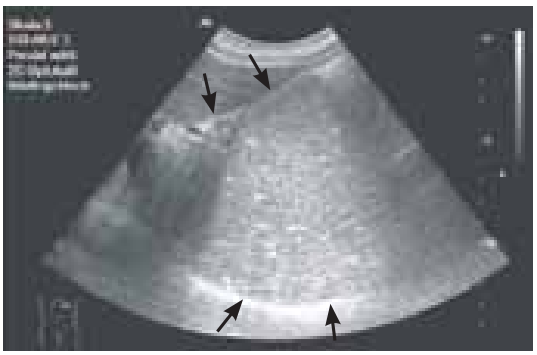


Fig. 15e

The patient reports vomiting and an increasing sensation of fullness. The sonography shows pronounced gastric retention. The image shows the immense size of the body of the stomach.

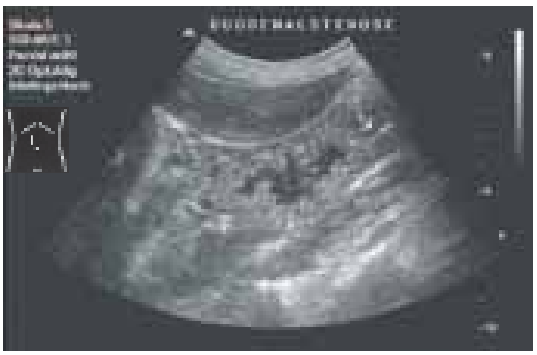


Fig. 15f

The cause – duodenal stenosis – can be seen in the image (arrow). The duodenum exhibits wall thickening and awl-shaped occlusion. One of the most difficult and not always achievable aims of sonography is to detect several stenoses arranged one behind the other in Crohn's disease.

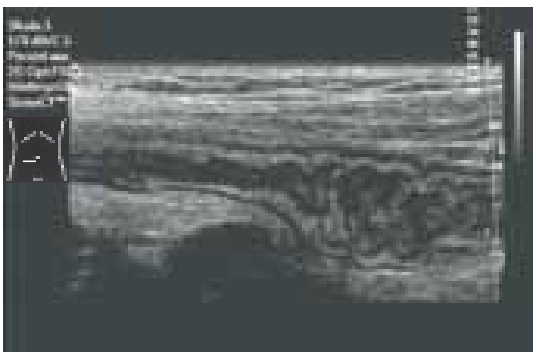


Fig. 16

Stenosis in a neoterminal ileum.

Crohn's recurrence

Figures 17a–c: Crohn's recurrence with anastomotic stenosis.

Fig. 17a

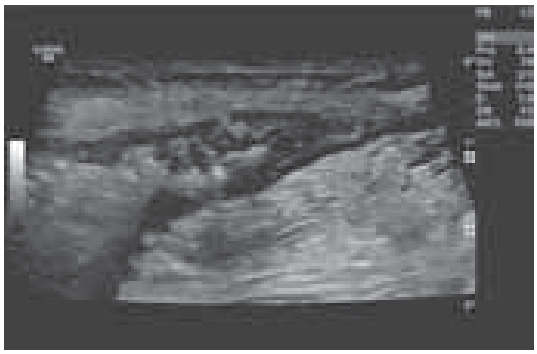
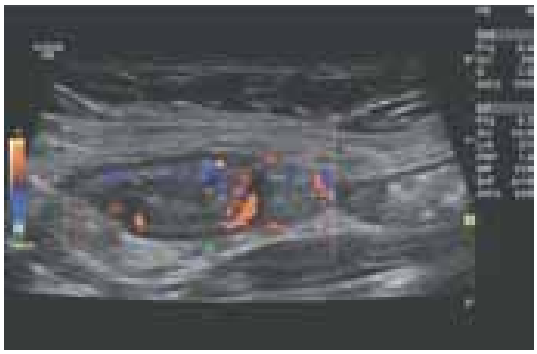


Fig. 17b

a and b) anastomosis with wall thickening in longitudinal slice, striking inflammatory hyperemia in color Doppler.

Fig. 17c



Anastomotic stenosis in transverse slice.

Crohn's disease: stenoses caused by scarring

Figures 18a and b: anastomotic stenosis caused by scarring.

Fig. 18a

The sonography shows a narrow and pronounced hypoechoic section of the gastrointestinal tract which is however not exhibiting wall thickening in this case. The anastomosis is contrasted by the surrounding thickened, hyperechoic mesentery. The upstream section of the small bowel is only visible due to a strong accumulation of gas (echogenic with extinction phenomenon).

Fig. 18b

Corresponding endoscopic view of the stenosis.

Ultrasound imaging characteristics that help differentiate between Crohn's disease and ulcerative colitis

Crohn's disease:	Mainly manifests in the right lower abdomen (e.g. involvement of the terminal ileum, skip lesions), long sections of wall thickening with lumen constriction, wall thickness frequently ≥ 5–7 mm, loss of haustration, "echogenic halo" around the affected bowel loops (sclerolipomatosis), fistulae, stenosis. Visualization of mildly enlarged mesenteric lymph nodes, possibly: inflammatory hyperemia, intramural fistula, absence of wall layering, conglomerate tumor, abscess.
Ulcerative colitis:	Mainly manifests in the left lower abdomen, wall thickness ≤ 5 mm, in rare cases up to 7 mm, colonic involvement mostly continuous, or pronounced in the distal region, loss of haustration, wall layers are usually preserved, inflammatory hyperemia depending on activity.

Table 6

Discrete findings, color Doppler and signs of inflammatory activity

Changes in bowel wall layering

Crohn's disease is not always associated with excessive thickening of the bowel wall and the characteristic ileocolic localization. More subtle findings can only be detected by an experienced examiner using a high-resolution transducer. Less evident and less specific findings such as mild wall thickening, blurred wall layers, and impaired peristalsis cannot be considered proof, and are merely a starting point for further targeted diagnostics.
The earliest detectable change is the widening of the mucosal layer (mucosal inflammation and edema). However, this finding is non-specific and may be detected in the case of enteritis of any etiology (Fig. 19).

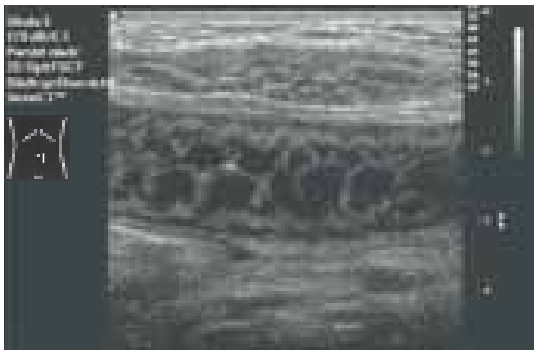


Fig. 19 Jejunum with pronounced mucosal edema, non-specific finding, in this case the early phase of subileus with intra-abdominal adhesion.

Indications of inflammatory activity in sonography

- Hypoechoic wall thickening
- Layering absent
- Increased vascularization – Limberg stages 3 and 4

So far, attempts to define and categorize the types of wall layering, the various types of disease course, and the various types of inflammatory activity that occur in Crohn's disease have been unsatisfactory. It is generally accepted that hypoechoic bowel wall thickening (Fig. 7a, 9a, 9b, 14c) without discernible wall layering is found in the case of higher disease activity. Sometimes, an intramural fistula can also be visualized. Frequently, the submucosa is particularly pronounced ("layered type").

Color Doppler/duplex sonography

Due to the various diagnostic problems, the fact that it is often difficult to clinically evaluate disease activity in Crohn's disease, the unsatisfactory nature of the available scores, and the current controversy surrounding endoscopic evaluation of activity compared to clinical signs, it seems natural to search for other parameters that could be used to diagnose and monitor the disease. Increased vascularization of the bowel wall, particularly when it is detectable in the submucosa, is considered a sign of inflammatory hyperemia, and therefore also a sign of disease activity in Crohn's disease. It should be noted that improved device sensitivity has increased the number of vessels that can be visualized in hyperemia. Even in normal tissues, it is now increasingly possible to visualize vessels in the bowel wall.

This means that although the sensitivity of detection of inflammatory hyperemia using color Doppler sonography is limited, the method provides data that are useful for estimating inflammatory activity within an individual patient over the course of their disease. From a methodological point of view, power Doppler sonography with determination of vascularization according to the Limberg classification (Fig. 20a) is the method with the most data to support it. Limberg stage 1 is characterized by a thickened bowel wall (hypoechoic, sometimes also hyperechoic submucosa, partial absence of layering) without intramural vessels. In stage 2, short vessels can be detected in the bowel wall, which exhibits inflammatory infiltrates; in Limberg stage 3, long vessel sections are found in a homogeneously hypoechoic, thickened wall. If long vessels can be followed back to the adjacent mesentery, then the stage is Limberg stage 4 (Fig. 20b–f).

This method can be used in routine diagnostics to assess treatment response, or to help distinguish inflammatory stenosis from stenosis caused by scarring.

The determination of blood flow velocity in the superior or inferior mesenteric artery is not very feasible in clinical practice, and its scientific value is also the subject of controversy. One criticism of this method is that it is questionable whether measurement in a vessel with a large supply area can even be representative in the case of a disease whose distribution varies in terms of localization. Another is that the method has many methodological problems and limitations (number of measurements, variances, angular errors, etc.) (cf. Fig. 47). It does not appear possible for this method to become part of routine diagnostics based on the data that are currently available.

Limberg classification

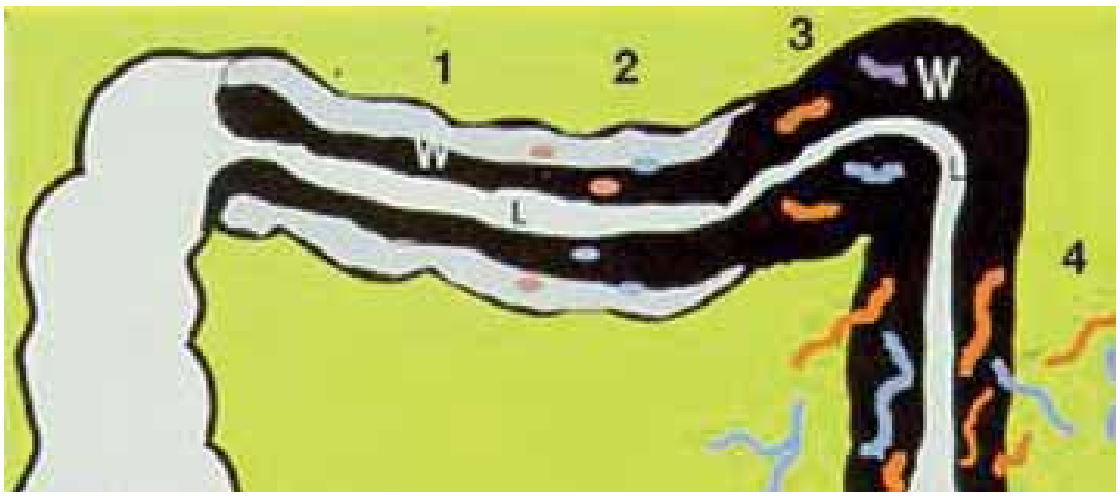


Fig. 20a

The method of classifying color Doppler sonographic findings suggested by Limberg has proven effective in practice and is therefore widely used.
Diagram of Limberg stages

Stage 1: bowel wall thickening, layers partially preserved, no vessels
Stage 2: bowel wall thickening, layers partially preserved, some short vessels visible
Stage 3: bowel wall thickening, layers absent, long vessels visible
Stage 4: bowel wall thickening, layers absent, long vessels visible as far as the surrounding mesentery

(cited from: Limberg B. Diagnostik von chronisch-entzündlichen Darmerkrankungen durch Sonografie. Z Gastroenterol. 1999;37(6):495–508.)

Limberg classification

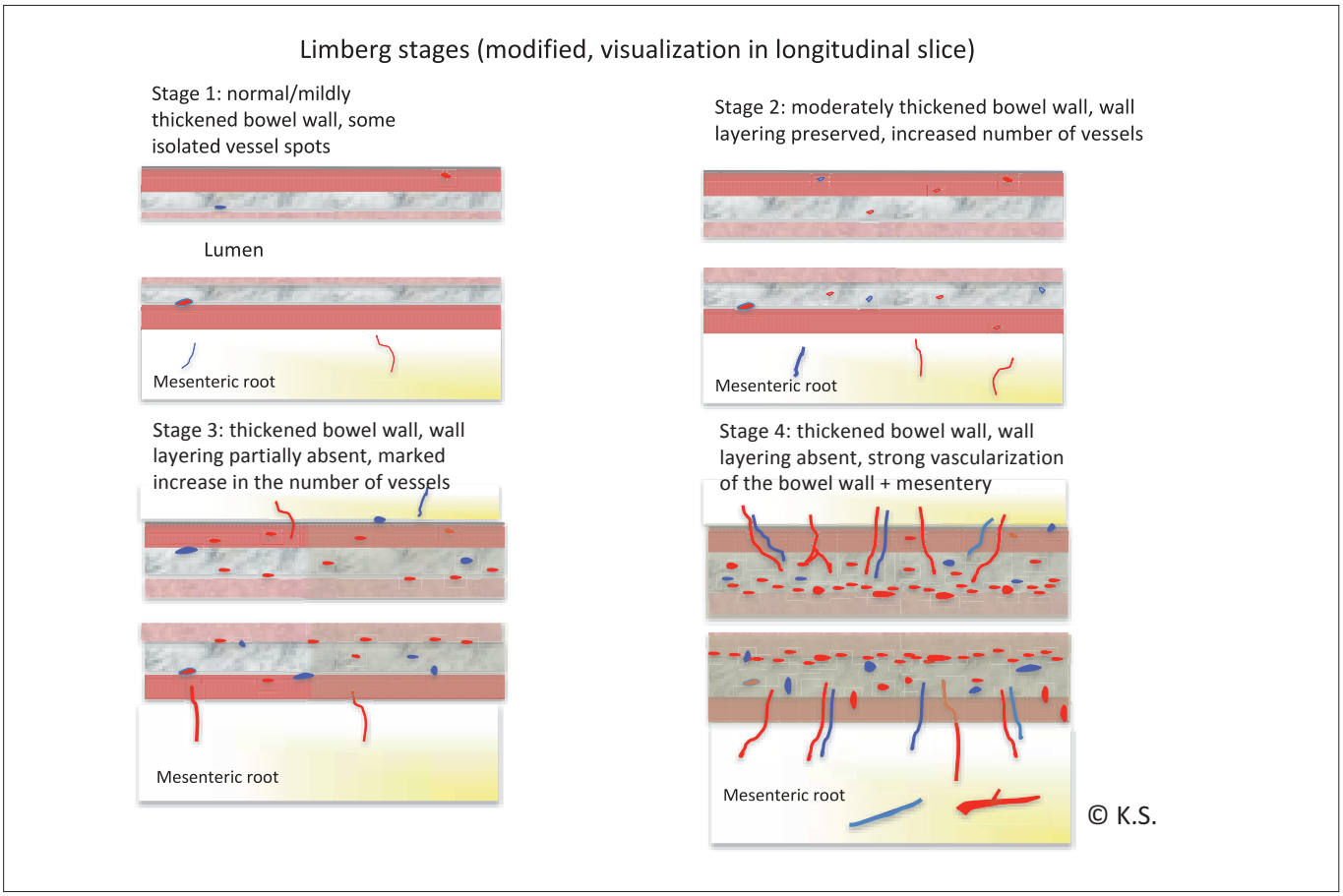
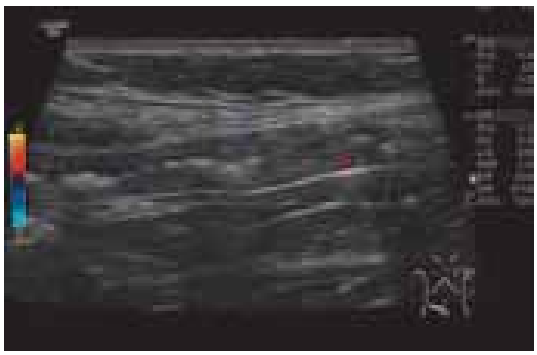


Fig. 20b:
Modified Limberg classification, adapted for modern ultrasound devices with better image resolution.

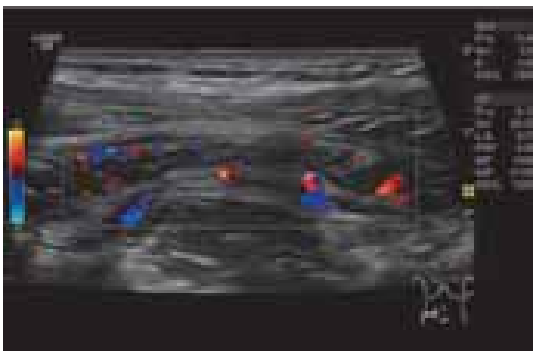
Limberg stages (Crohn's disease, terminal ileum)

Fig. 20c



Limberg stage 1.

Fig. 20d



Limberg stage 2.

Fig. 20e

Limberg stage 3.

Fig. 20f

Limberg stage 4.

Complications associated with Crohn's disease

Sonography is valuable in its own right when it comes to the detection of typical Crohn's-associated complications (Table 7, Fig. 21).
Subileus and ileus in particular are easier to detect at an early stage using this method compared to an X-ray overview. Elements that can be recognized in the sonography include the dilated, fluid-filled bowel loops (Fig. 22–23) with impaired peristalsis. Stenosis may also be detectable. In the late stage, the air caused by the complete ileus (X-ray: formation of "air-fluid levels") means that hardly any details can be seen anymore in the sonography.
Depending on their stage of maturation, abscesses can be found as more or less sharply delimited, weakly echogenic to echo-free masses with varying degrees of sound conduction improvement. Sufficiently mature abscesses can be punctured under ultrasound guidance and treated by aspiration or drainage (Fig. 24–30).
Obstructive nephropathy can be detected easily. The location of the obstruction can also be detected because as these patients are predominantly slim, the hydroureter can easily be followed in a continuous manner until the location of the stenosis is reached. Small, high-frequency sector scanners are the most suitable devices for such inves-

Crohn's disease complications detectable by sonography

1. Ascites (non-specific)
2. Inflammatory conglomerate tumor
3. Abscess of the psoas major muscle, the liver, the spleen, or intra-abdominal abscess
4. Fistulae enterocutaneous, entero-organic, enterovesical, interintestinal towards the retroperitoneum
5. Ileus, subileus
6. Toxic megacolon
7. Obstructive nephropathy/kidney stones
8. Free perforation
9. Cholelithiasis
10. Acute pancreatitis (caused by medication)
11. Primary sclerosing cholangitis (late stage)

Table 7

tigations. Ascites are a common and non-specific concomitant finding. Subileus, ileus, and more rarely, free perforation may also be detected, as well as cholelithiasis, which is more commonly found in Crohn's disease.

In the case of suspected perforation, it should be taken into account that due to inflammatory adhesions, free air cannot always rise to the region before the liver. In principle, it should be noted that sonography is a more sensitive option for detecting free air than examination by X-ray, however ultrasound examination is much more technically challenging. In the case of doubt, CT may be helpful.

If there is no response to medication treatment, extramural complications should be searched for if symptoms increase. Sometimes, an inflammatory conglomerate tumor is found as a precursor of an abscess or a fistula, in rare cases a toxic megacolon (Fig. 31). If there is a discrepancy between severe clinical symptoms and largely inconspicuous sonographic findings, it should be assumed that there is a significant finding that has not been caught in the sonography. This particularly applies to formation of fistulae or a loop abscess, for instance. In such cases, CT, MRI, or MR enteroclysis should be arranged accordingly at an early stage. Here, the rule is that no method is capable of visualizing everything, and none of them can generally be replaced by any of the others.

Visualization of fistulae (Fig. 32–37) used to be the preserve of radiological diagnostics. Nowadays, they are increasingly being detected by sonography.

Incomplete enterocutaneous fistulae and blind fistulae that end in parenchymatous organs or in the retroperitoneum are comparatively easy to detect. Unlike in conventional radiological imaging, sonography is capable of visualizing fistulae even when the fistula exit is covered by stool. The easiest fistulae to recognize are those between the gastrointestinal tract and the bladder; in these cases there is echogenic material in the urine and gas bubbles in the bladder. The most difficult fistulae to recognize are interintestinal fistulae.

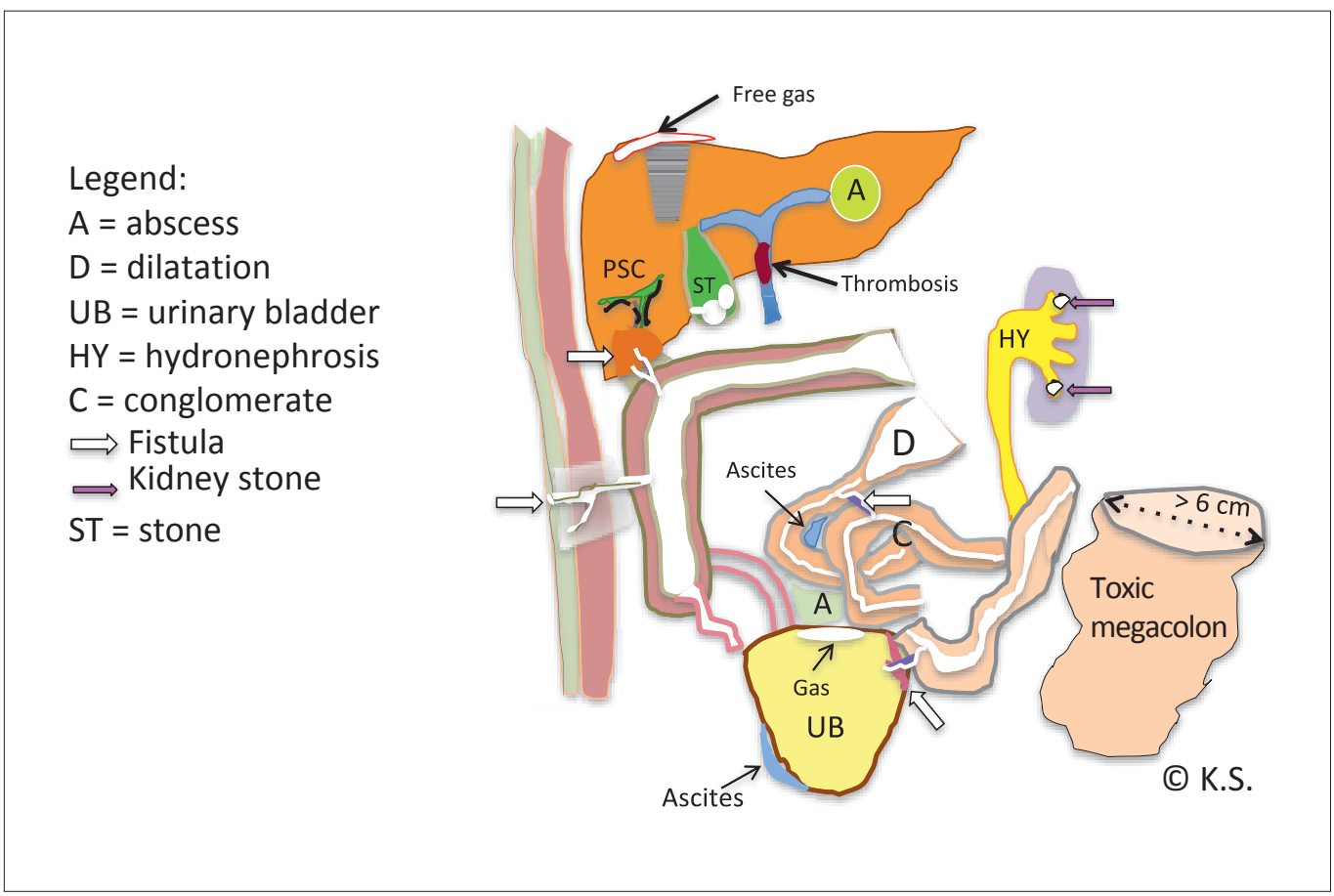
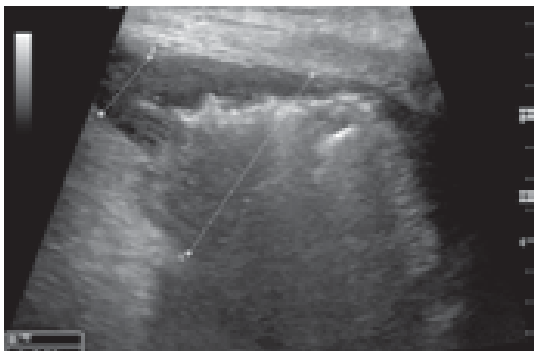


Fig. 21:
Diagram showing complications associated with Crohn's disease.

Crohn's disease: ileus

Fig. 22a

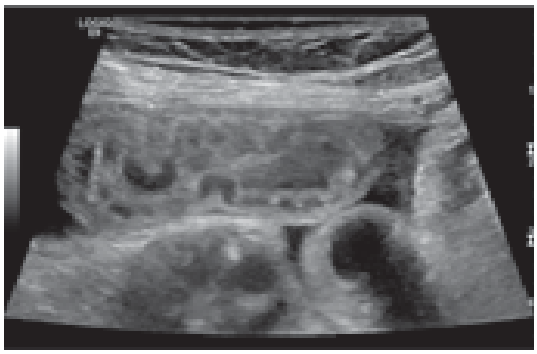


Visualization of cause of obstruction: inflammatory, stenosed terminal ileum with wall thickening (distance mark 2) and with prestenotic dilatation (distance mark 1).

Fig. 22b

Complete ileus of the small bowel: dilated neighboring jejunal and ileal loops (distance mark).

Fig. 22c



Mechanical ileus of the small bowel that has been present for a long period of time with jejunal loop exhibiting edema and wall thickening, plus ascites.

Fig. 22d

Mechanical ileus of the small bowel with distended jejunal loop (DüDa) and collapsed descending colon (arrow) in transverse slice above the psoas major muscle in the left lower abdomen.

Crohn's disease: ileus

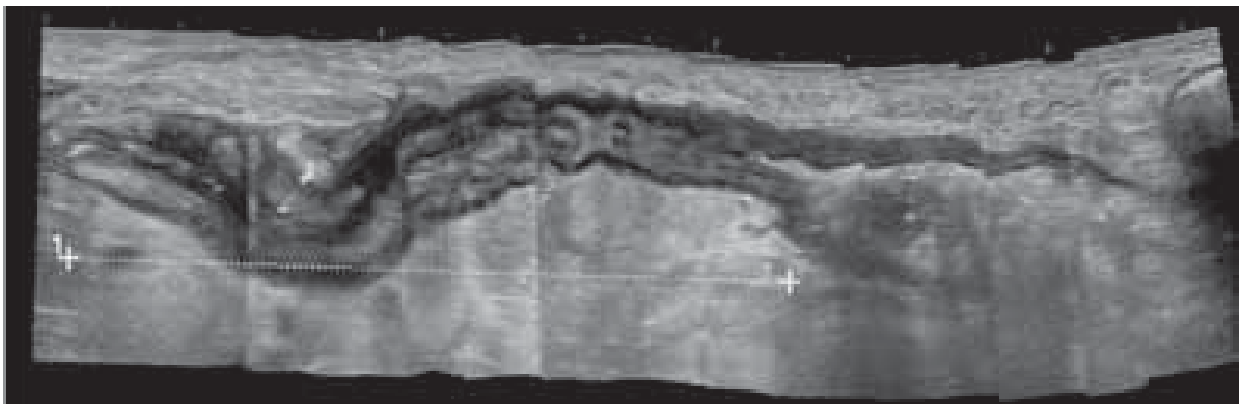


Fig. 23a

Crohn's terminal ileitis with long section of stenosis (distance mark 1; 19 cm) and prestenotic dilatation (right of image) in "panoramic view".

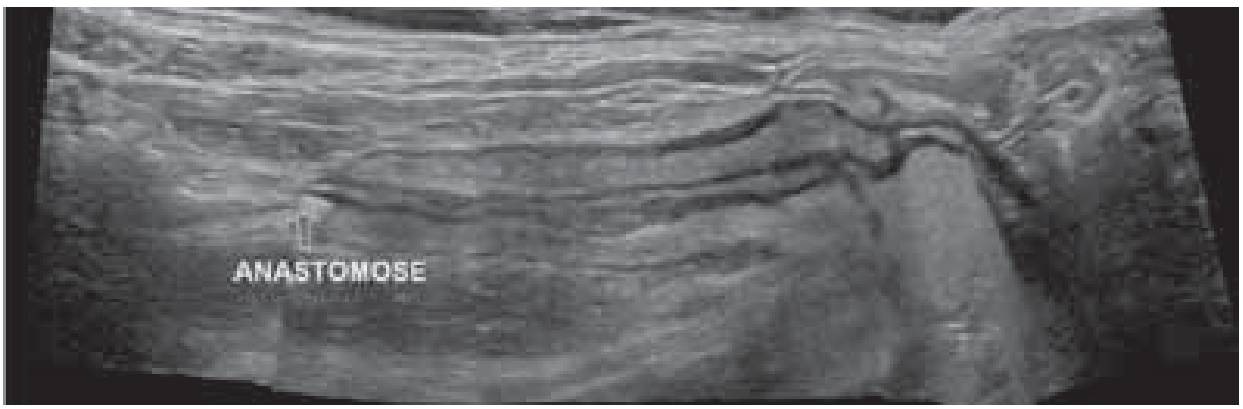


Fig. 23b

Ileocecal anastomotic stenosis in the presence of Crohn's disease; filiform stenosis caused by scarring (arrow) and long section of inflammation (hyperechoic thickened submucosa) in the neoterminal ileum with prestenotic dilatation.

Crohn's disease: liver abscess formation

Fig. 24a

Liver abscess in the presence of Crohn's disease under immunosuppression. Hypoechoic subphrenic mass of about 8 x 6 cm in size in the right hepatic lobe (distance marks).

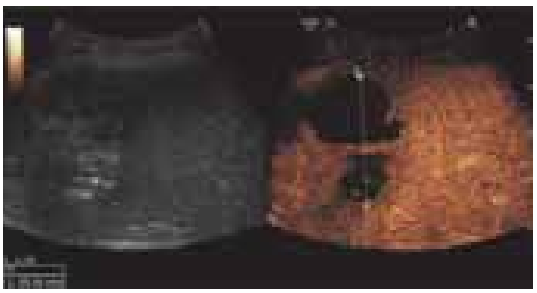


Fig. 24b

Same patient as in Figure 24a; Visualization of the liver in an intercostal slice on the right, contrast medium mode, late phase (1:39 min.): The entire extent of the abscess is demarcated by the lack of CM uptake.

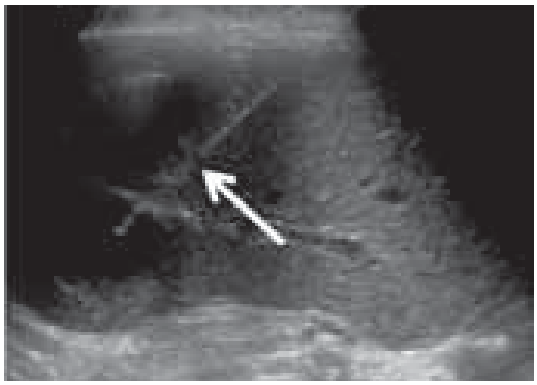


Fig. 24c

Ultrasound guided abscess drainage. Trocar reflection in the middle of the abscess (arrow).

Fig. 24d

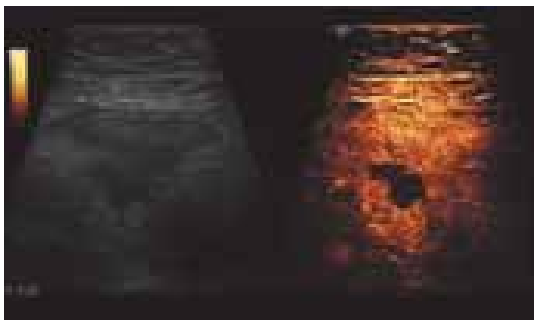
Contrast medium administration via drainage: Visualization of the drainage and the abscess cavity.

Crohn's abscess

Fig. 25a

Right lower abdomen; Crohn's terminal ileitis. "Immature" extramural abscess in the dorsal region of the wall of the ileum – cannot be delimited as separate from the wall.

Fig. 25b



Same slice and patient as in Figure 25a in CEUS mode. The abscess cavity is demarcated by the lack of CM uptake.

Fig. 26a

Small intraperitoneal abscess in Crohn's disease prior to treatment.

Fig. 26b

After draining by fine needle aspiration. Several punctures were needed before healing was achieved.

Crohn's abscess

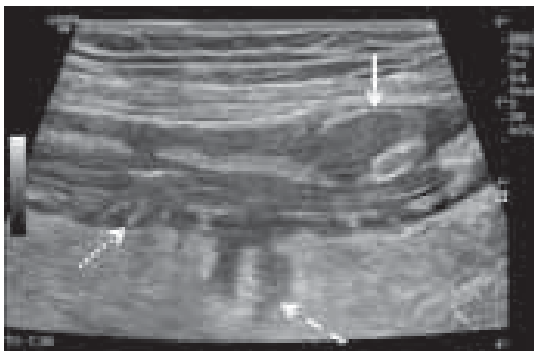


Fig. 27a Crohn's terminal ileitis with intramural abscess (arrow), fissures (dotted arrow) and dorsally located extramural abscess (arrow with dashes).

Fig. 27b Same patient as in Figure 27a. Terminal ileum in transverse slice at the level of the intramural abscess. It is located in the muscularis propria and measures 8 mm in the transverse slice.

Fig. 27c CEUS of the section of gastrointestinal tract from Figure 27a. The lumina of the abscesses are not contrasted and the abscess membrane of the extramural abscess is hyperperfused. The bowel wall also appears to be hypercontrasted.

Crohn's disease: psoas abscess, splenic abscess

Fig. 28a

Psoas abscess in Crohn's disease: Transverse slice.

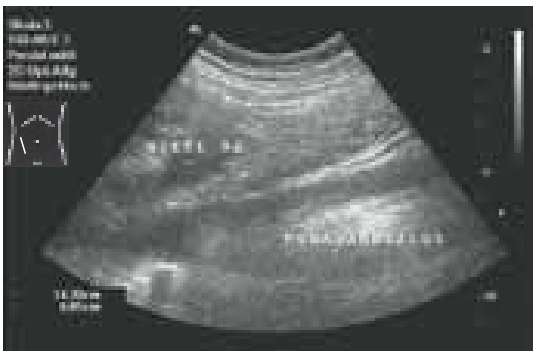


Fig. 28b

Psoas abscess in Crohn's disease: Longitudinal slice.

Fig. 29

Abscess shortly before perforation into the urinary bladder, visualization in a longitudinal slice above the symphysis.

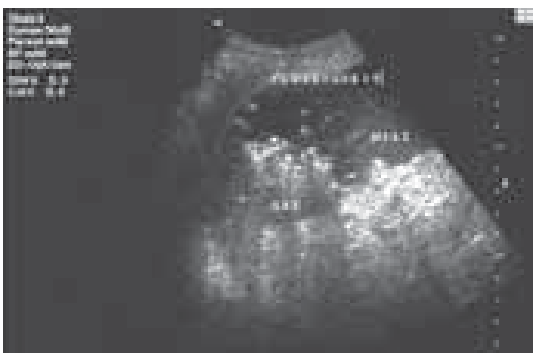


Fig. 30

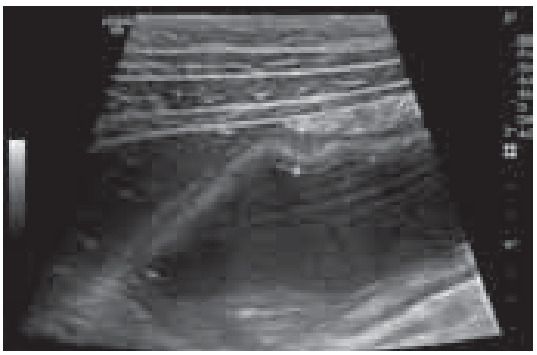
Large liquid splenic abscess in the case of a severe flare-up of Crohn's disease with pronounced involvement of the jejunum.

Crohn's disease: toxic megacolon

Fig. 31a

Toxic megacolon in Crohn's disease. Transverse slice of descending colon exhibiting distension (diameter 4.5 cm) and wall thickening. Initial diagnosis of Crohn's disease in a 27-year-old patient. High-dose cortisone treatment prevented the perforation.

Fig. 31b



Same patient as in Figure 31a; descending colon in longitudinal slice. Pronounced thickening of the bowel wall with preserved layers.

Crohn's disease: enterocutaneous fistula

Figures 32a and b: enterocutaneous fistula.

Fig. 32a

Radiological imaging of fistula: It is possible to follow the fistula until the point where it opens into the rectosigmoid junction by filling with contrast medium.

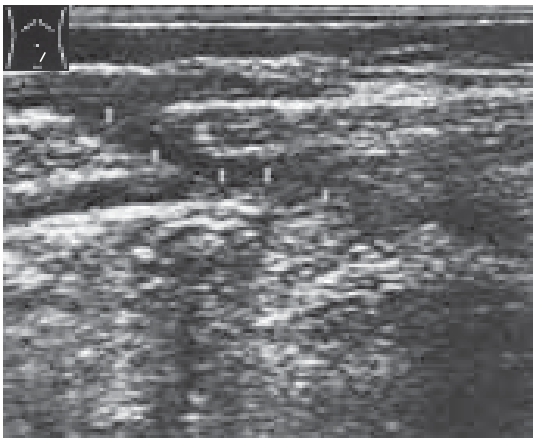


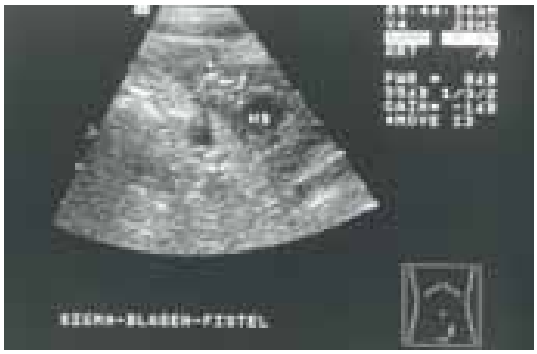
Fig. 32b

Enterocutaneous fistula, ultrasound image. In the image, the fistula is visualized as a hypo-echoic strand and is characterized by star shapes. The fistula is healing, which is why the "string of pearls"-shaped, strongly reflective gas bubbles are missing from the fistula track.

Crohn's disease: enterovesical fistula

Figures 33a and b: enterovesical fistula.

Fig. 33a



The fistula track can be easily recognized by the reflective gas bubbles (arrow).

Fig. 33b

Fistula track without gas bubbles. A complete fistula is evidenced by the detection of air in the urinary bladder (HB). Cave: The amount of air in the bladder is usually very low. It can escape detection in the sonography if it moves to the side along with the transducer, which pushes it out of the picture. Therefore, place the transducer with care!

Crohn's disease: interintestinal fistula/enteromesenteric fistula

Fig. 34a Several bowel loops are joined together by a crossroads-like system of fistulae. In the moving image, we can see the transport of gas in alternating directions due to the wide fistulae.

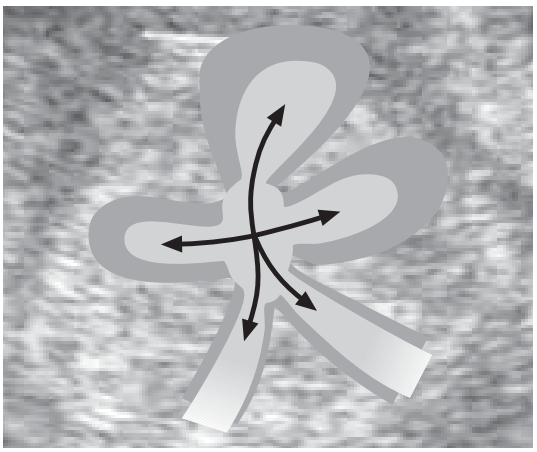


Fig. 34b Clover leaf-shaped small bowel loops exhibiting inflammatory adhesions with interintestinal fistula and gas transport in various directions. The arrows indicate the direction of gas transport.

Crohn's disease: interintestinal fistula/enteromesenteric fistula

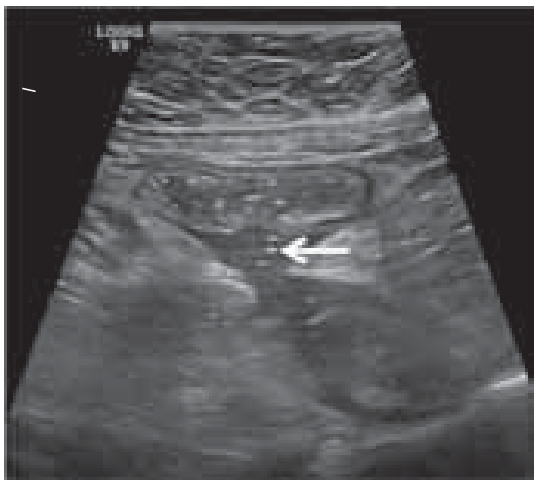


Fig. 34c

Crohn's disease. Hypoechoic fistula between two neighboring ileal loops. The dorsally located loop exhibits hypoechoic wall thickening and acute inflammation. Gas reflections can be seen in the fistula (arrow).

Fig. 35

Enteromesenteric fistula. Inflamed terminal ileum in transverse slice with two hypoechoic blind fistulae that end in the mesentery (arrows).

Fig. 36

◁ Crohn's disease with inflamed jejunal loop in the left middle abdomen. Formation of fistula in the mediocaudal direction in an abscess of 5 cm in size (distance marks).

Crohn's disease: interintestinal fistula – course

Fig. 37a

Female patient with Crohn's disease and acute abdominal symptoms. The sonography shows an oval-shaped, irregular, and poorly delimited lesion suspected to be an abscess. The stem-like connection to the hypoechoic small bowel loop that is exhibiting mild wall thickening strongly suggests a fistula.

Fig. 37b

Situation after ultrasound-guided abscess aspiration.

Differential diagnosis by sonography

Crohn's disease and ulcerative colitis are the most significant and most common types of inflammatory bowel disease (IBD). In clinical practice, there are many types of inflammatory bowel diseases that have a different genesis and require differential diagnosis using all of the available means (Table 8). In addition to the morphological methods, bacterial and immunological/serological examination methods are of particular importance. The fact that it is sometimes difficult to distinguish between different types of IBD even by histopathological examination of the resection specimen clearly demonstrates the limits of the ultrasound differentiation between Crohn's disease, ulcerative colitis and other types of IBD.

Although in the classic case, there are almost completely unambiguous findings, in reality these findings overlap in numerous cases (Fig. 38–46). In addition to the overlaps in the findings of the two main forms of IBD, there are those of the other, rarer inflammatory and tumorous forms, which cover every aspect of the entire spectrum of sonographic findings in Crohn's disease, and even those of ulcerative colitis, which are less conspicuous in the sonography (Fig. 47–62). All forms of infectious colitis can mimic ulcerative colitis, and some can mimic Crohn's disease. Therefore, it is important to perform differential diagnosis in order to distinguish between the main forms of IBD and other forms due to the different treatments required.

Differential diagnostics by ultrasound in Crohn's disease
Cardinal symptom: long sections of wall thickening with lumen constriction

Crohn's disease

Ulcerative colitis

Colitis and enteritis of other etiology
(antibiotics, Yersinia, radiation, amoebas, cytomegaly, ischemia, neutropenic colitis)

Intestinal tuberculosis

Actinomycosis

Amyloidosis (long type; short type: "napkin ring" stenoses, poorly visible)

Diverticulitis

Vasculitis of different etiology (e.g. Henoch–Schönlein purpura [IgA vasculitis])

IgG4-related disease with gastritis, duodenitis, or Crohn's ileitis

Bowel wall edema (ileus, radiation, toxic megacolon, mesenteric venous thrombosis, right heart insufficiency)

Graft-versus-host disease (GvHD) of the gastrointestinal tract

Tumor: primary/metastasis
lymphoma
carcinoid
(each only in the case of a long section of involvement)

Table 8

Ulcerative colitis

During acute flare-up, ulcerative colitis cannot be distinguished from Crohn's disease by sonography unless the small bowel is involved. In particular, it should be noted that contrary to pathological/anatomical knowledge of the exclusive involvement of the mucosa, the entire colon wall along with all its wall layers appears to be moderately thickened in the sonography. The individual bowel wall layers are difficult to distinguish, and in some cases they cannot be distinguished at all. In these cases, pronounced inflammatory hyperemia is often detectable, and in contrast to Crohn's disease, the reaction in the surrounding mesenteric tissue is missing. As with infectious colitis, the bowel lumen is narrowed and the haustration is often not detectable, or is absent in the case of a prolonged disease course. The colon looks like a narrow tube (Fig. 47–50).

Infectious enteritis, enterocolitis, and colitis

In the case of outpatient bowel infections, which are usually fleeting, sonography is of little diagnostic value. It is primarily used for differential diagnosis to exclude acute appendicitis, and to diagnose mesenteric lymphadenitis. In the case of enteritis, more mesenteric lymph nodes and fluid-filled small bowel loops with irregular peristalsis can be visualized, with the result that those with less experience in sonography sometimes mistakenly diagnose a subileus.

Severe enteritis cases, e.g. cases of salmonellosis or shigellosis, may exhibit marked wall thickening in the bowel loops, or even a full sonographic picture of terminal ileitis with prestenotic dilatation. Diagnosis becomes more difficult if enteritis persists for a long time and the etiology remains unclear. In these cases, using the combination of medical history, endoscopy with biopsy, and microbiological findings in addition to sonography provides further clarification.

Figures 51–62 show important differential diagnoses. It is not uncommon for a definitive diagnosis to be made immediately based on a combination of medical history, clinical signs, and sonography ("clinical sonography").

Acute diverticulitis

For years now, acute diverticulitis has been diagnosed by sonography with a very high level of reliability, and sonography has also been able to exclude diverticulitis with a high degree of certainty. Accordingly, sonography is recommended in the first German S2k guideline for diverticulitis as an essential diagnostic tool with a high recommendation grade.

Diagnosis of diverticulitis consists of palpation findings, sonographic findings, and detection of inflammatory parameters (CRP, leukocytosis). If there are no serious complications, treatment is conservative with follow-up monitoring of the aforementioned parameters soon after (initially on a daily basis). If the conservative treatment is successful and the patient is free of symptoms, then colonoscopy is performed 4–6 weeks later in order to rule out colorectal cancer or polyps.

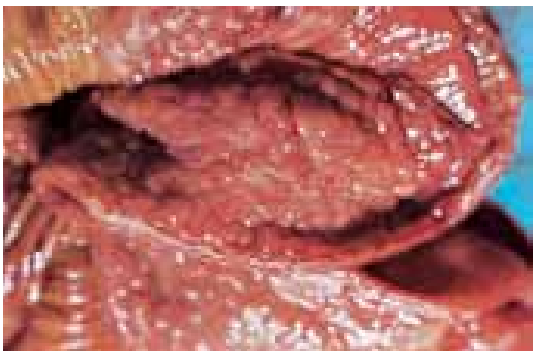
Of all the types of inflammatory bowel disease, acute diverticulitis (Fig. 56a–d) is the easiest to diagnose by sonography; the localized tenderness in the left lower abdomen is informative. The ultrasound finding is strikingly highlighted by the regular coverage with omentum ("echo-dense omental cap"). Often, sonography can detect smaller or more expansive abscesses, and the latter can usually be successfully treated using ultrasound-guided aspiration, or by drainage, which is less commonly used. If there is a discrepancy between clinical findings and ultrasound findings, a CT examination is indicated in order to avoid overlooking any more deeply located abscesses that cannot be visualized.

Example images for macropathology – the reference

Fig. 38

Crohn's disease of the small bowel with several garland-shaped stenoses.

Fig. 39



Resection specimen with cobblestone relief and a comparatively lower amount of wall thickening. The cobblestone relief cannot yet be visualized in the ultrasound (cf. Fig. 10).

Fig. 40*

Pronounced bowel wall edema with radiation colitis. It is not possible to differentiate between these types of wall changes using sonography. The ultrasound findings of Fig. 39 and 40 are identical.

* These images were kindly provided by Prof. Dr. G. Seitz, Pathological Institute of the Bamberg Hospital.

Fig. 41*

Crohn's disease of the small bowel. The macroscopic changes that make up the basic ultrasound findings can be seen clearly. In addition to the wall thickening with moderate lumen constriction, the mesenteric fat wrapping over the bowel loop can be visualized well.

Fig. 42*

Long section of infiltration in the terminal ileum due to a primary signet ring cell carcinoma in a 40-year-old patient. This finding cannot be distinguished from Crohn's disease by sonography.

Fig. 43*

Stenosis in Crohn's colitis. Moderate wall thickening and cobblestone relief in the prestenotic section.

* These images were kindly provided by Prof. Dr. G. Seitz, Pathological Institute of the Bamberg Hospital.

Fig. 44

Resection specimen in the case of segmental Crohn's colitis in the region of the cecum with stenosis.

Fig. 45*

Interintestinal proliferation of colorectal cancer with wall thickening and formation of a conglomerate. Guide rail-like outwards growth of the carcinoma in the region of the small bowel loops. This finding mimics the typical ultrasound findings of Crohn's disease with a long section of wall infiltration and lumen constriction.

Fig. 46*

Crohn's colitis with inflammatory wall thickening and tumorous pseudocystic changes.

* These images were kindly provided by Prof. Dr. G. Seitz, Pathological Institute of the Bamberg Hospital.

Ulcerative colitis

Figures 47a and b: florid ulcerative colitis. In the presence of ulcerative pancolitis, the entire colon exhibits mild to moderate wall thickening. The wall thickening is slightly more pronounced from the descending colon onwards.

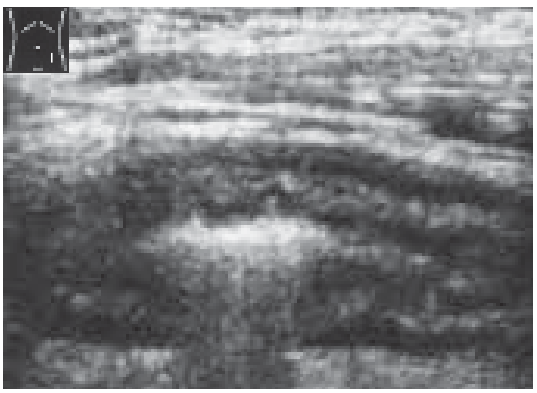


Fig. 47a

Fig. 47b

a and b) The wall layers are preserved.

Figures 47c and d: ulcerative colitis, acute flare-up

Fig. 47c

Sigmoid with wall thickening

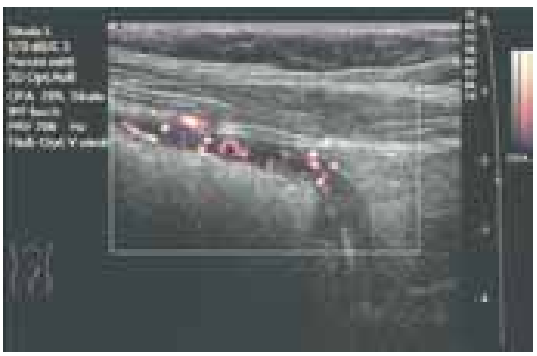


Fig. 47d

Inflammatory hyperemia

Doppler sonography

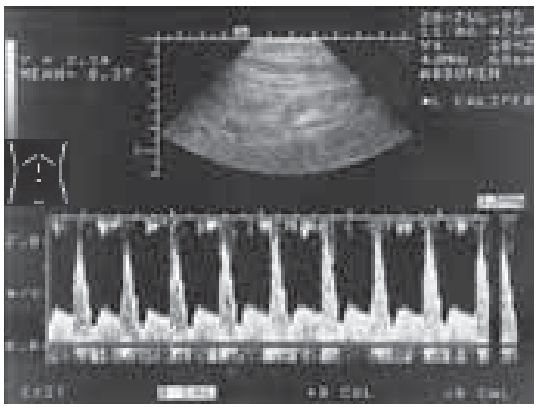


Fig. 47e Global inflammatory hyperemia with significant systolic and diastolic flow velocity acceleration in the superior mesenteric artery (flow direction towards the transducer, therefore Doppler spectrum above the 0 line)

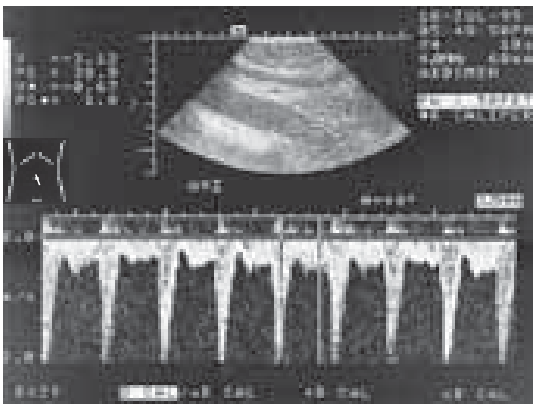


Fig. 47f Systolic flow in the inferior mesenteric artery is also increased fourfold. A particularly striking feature is the high diastolic flow with low vascular resistance (flow direction away from transducer, therefore Doppler spectrum below the 0 line).

Ulcerative colitis

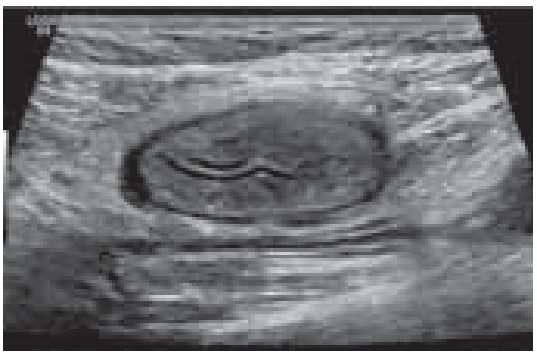


Fig. 48a Ulcerative colitis during an acute flare-up. Sigmoid in transverse slice, exhibiting wall thickening, prominent submucosa, hypoechoic muscularis propria.

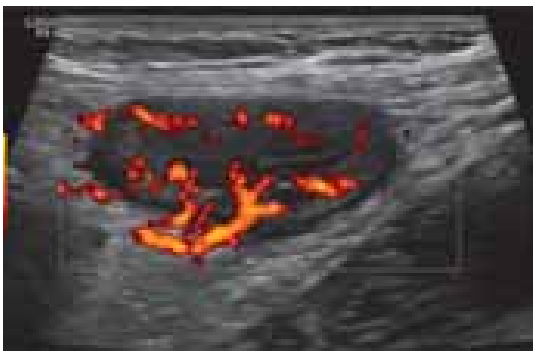


Fig. 48b Same patient and same slice as in Figure 48a. Increased vascularity in the power Doppler, consistent with inflammatory hyperemia.

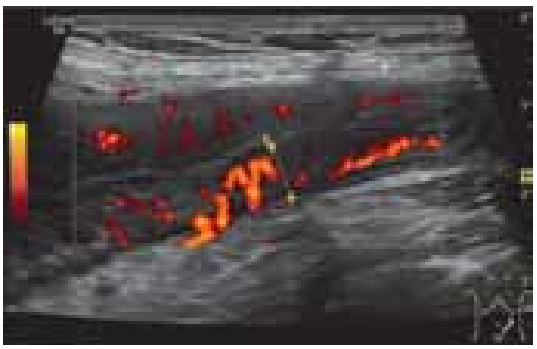


Fig. 48c Same patient. Sigmoid in longitudinal slice, hyperemia in the power Doppler.

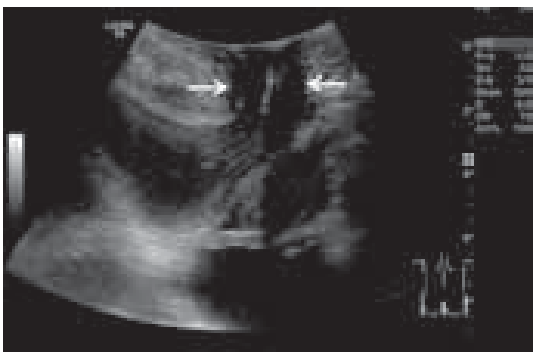


Fig. 48d Same patient. Ulcerative proctitis during an acute flare-up. Perineal transducer head position (curved array, 5 MHz). Circular, hypoechoic rectum with wall thickening (between the arrows).

Ulcerative colitis

Figures 49a and b: moderately active ulcerative colitis.

Fig. 49a Visualization of the rectum exhibiting wall thickening, dorsal to the uterus and vagina.

Fig. 49b Zoomed-in image of the rectum.

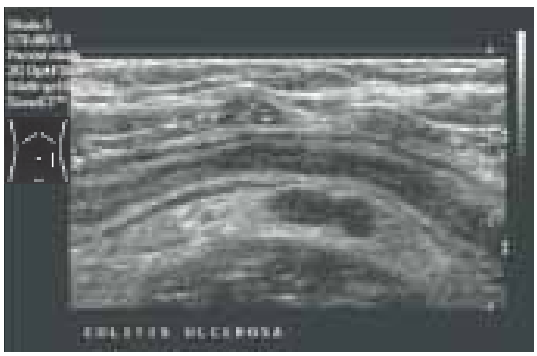


Fig. 50 ◁ "Garden hose phenomenon" in the descending colon, in the presence of ulcerative colitis in this case. In this female patient, the entire colon was found to be like this. Two small hypoechoic lymph nodes can be seen in the mesentery.

Ischemic colitis – course

Figure 51a–e: ischemic colitis.
76-year-old female patient. Several soft to watery stools per day for the last week approximately. At the start, there reportedly may have been blood in the stools.

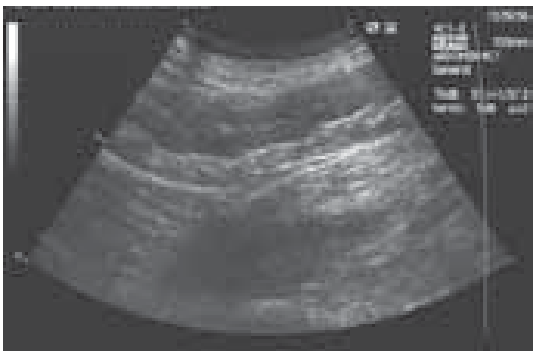


Fig. 51a

In the ultrasound, we can see pronounced, uneven wall thickening in the region of the descending colon. The wall layers are no longer detectable.

Fig. 51b

In contrast to the active phase of ulcerative colitis or Crohn's disease, no inflammatory hyperemia can be detected in the affected wall sections; however, color Doppler sonography is not specific for diagnosis.

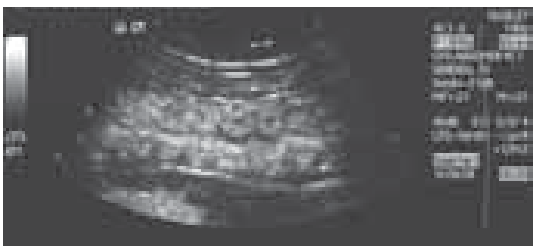


Fig. 51c

◁ When CEUS is performed with an intravenous bolus of 1.0 mL of CM, a striking perfusion of the thickened colon wall can be observed 20 seconds later. The finding fits with the repair phase of ischemic colitis, but it is not specific.

Ischemic colitis – course

Fig. 51d Four days later, the wall thickening has mostly cleared up.

Fig. 51e Precise ultrasound analysis shows an asymmetrical, eccentric cockade/bull's eye. In the endoscopy/biopsy, the "apple core" lesion is found to be a descending colon carcinoma, as expected.

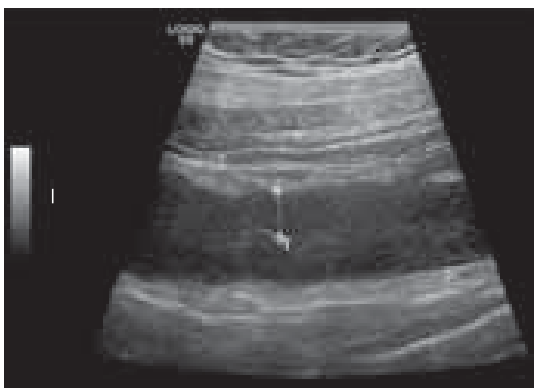


Fig. 52 ◁ 75-year-old female patient with severe left-sided abdominal pain since the previous day. Suspected ischemic colitis, confirmed by histology. Hypoechoic descending colon with circular wall thickening in longitudinal slice, layering absent. Conservative treatment and normalization of the finding after a week.

Infectious colitis

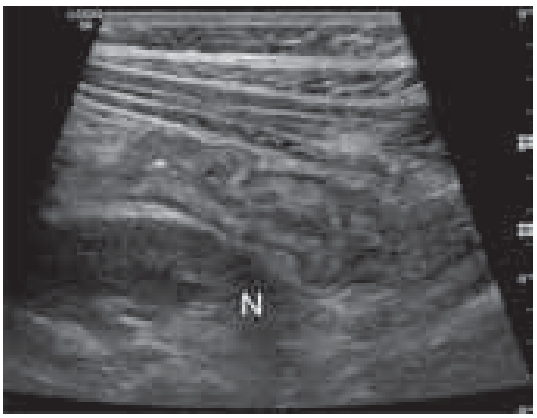


Fig. 53a 20-year-old female patient with headache, limb pain, abdominal pain, fever, and diarrhea. Proximal descending colon with irregular wall thickening and hyperechoic submucosa. Detection of campylobacter jejuni antigen in the stool. Left kidney lower pole (N).

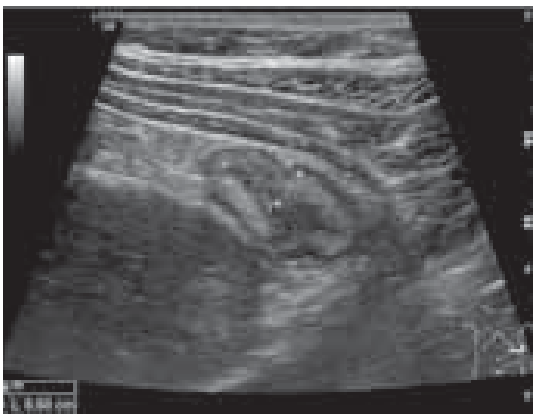


Fig. 53b Same patient as in Figure 53a. Descending colon in transverse slice.

Drug/antibiotic-associated colitis

Figures 54a and b: Drug-associated colitis.
There is a hypoechoic, pronounced thickening of the bowel wall. The wall layers can no longer be delimited. The decisive diagnostic indicator is the medical history (use of antibiotics). The diagnosis is verified by the detection of toxin in the stool, and/or by endoscopy. In severe cases, ascites are frequently also detected in the sonography.

Fig. 54a

Transverse colon.

Fig. 54b

Descending colon.

Fig. 54c

◁ NSAID-induced colitis.
When it can be visualized in the sonography, NSAID-induced colitis exhibits a rather uneven section of wall thickening that is not particularly long. In the case of involvement of the cecum – as in this longitudinal slice – Crohn's disease, cecum carcinoma, ascending colon carcinoma, and infectious cecitis are the most important differential diagnoses.
The medical history typically provides important indications for differential diagnosis.

Chronic diverticular disease

Figures 55a and b: chronic diverticular disease.

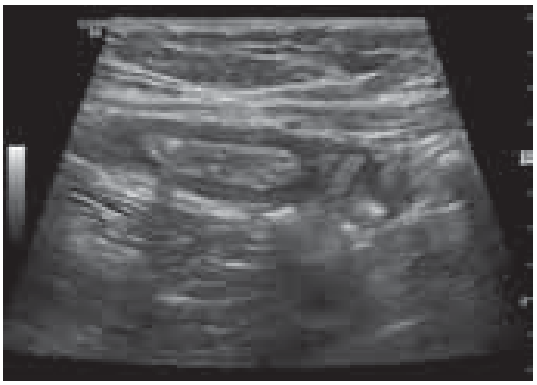


Fig. 55a

Sigmoid in transverse slice. Hypertrophied muscularis mucosa (hypoechoic layer) with non-inflamed diverticulum on the right side of the image (central gas reflection).

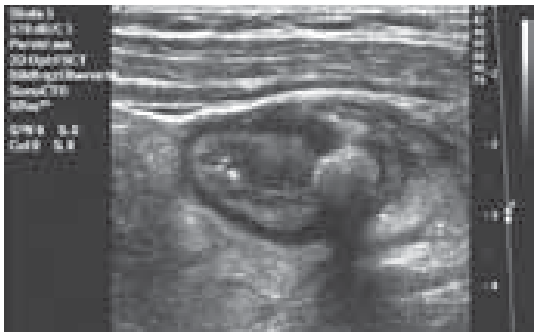
Fig. 55b

Medium-length wall thickening with lumen constriction; in the extraluminal region, the diverticulum can also be seen as an intense echo complex with connection to the bowel wall. Generally, either the sigmoid or the descending colon is affected (as shown in the image).

Acute diverticulitis

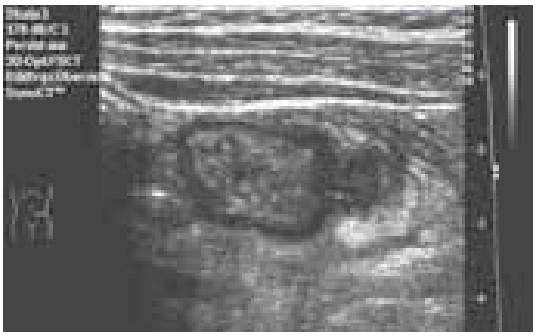
Figures 56a and b: acute diverticulitis – example of changes.

Fig. 56a



Acute diverticulitis with onion skin-like inflammatory thickening of the sigmoid wall and trapped fecalith.

Fig. 56b

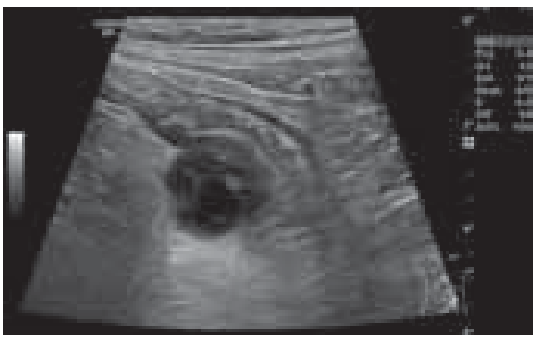


The same patient was free of symptoms the next day after passing the trapped fecalith. The diverticulum appears to be "pleated", and on the outside, it is surrounded by an echoic halo.

Fig. 56c

Acute diverticulitis with two small abscesses and echoic halo (omental cap).

Fig. 56d



Complicated acute diverticulitis type IIb. Sigmoid in longitudinal slice, wall thickening with a paracolic abscess of approx. 2 cm in size (macroabscess from > 1 cm).

Colon carcinoma

Figures 57a and b: carcinoma of the transverse colon with stenosis.
Carcinomas are characterized by bizarre, hypoechoic, irregular cockades (bull's eyes) with lumen constriction. Usually, it is possible to assign them to the colon, and frequently, liver metastases can already be found. Unfortunately, in the case of colon carcinoma, the initial diagnosis is quite often still established by sonography due to the advanced stage of the disease.

Fig. 57a
Longitudinal slice.

Fig. 57b
Transverse slice.

Lymphoma of ileum, case study

Figures 58a–e: 69-year-old male patient with Crohn's disease (initial diagnosis 9 years previously). Current medication: Azathioprine 2.5 mg/kg of body weight Last flare-up 3 years ago. Inpatient admission due to abdominal pain, massive weight loss, fever, and night sweats, with a suspicion of a Crohn's disease flare-up.

Fig. 58a

Terminal ileum in longitudinal slice: asymmetrical wall thickening, conspicuous hypoechoic distension of the dorsal bowel wall.

Fig. 58b

Terminal ileum in transverse slice: hypoechoic mass in the hyperechoic, thickened submucosa in the dorsal bowel wall.

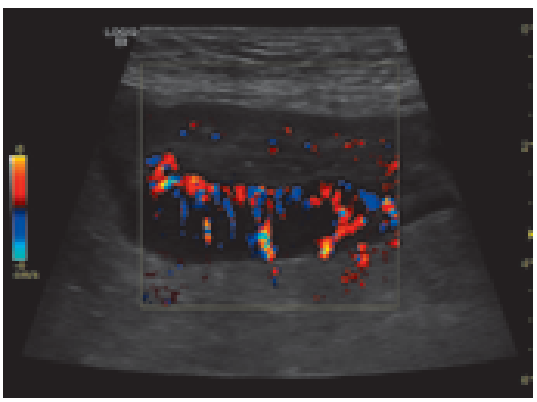


Fig. 58c

Same slice as in Figure 58a with color Doppler: local hypervascularization of the hypoechoic mass; histology sample harvested by endoscopy: highly active Crohn's disease.

Fig. 58d

Endoscopy: View of the ileocecal valve in the terminal ileum that is ulcerated, inflamed, stenosed, and coated with fibrin.

Fig. 58e

Percutaneous ultrasound-guided punch biopsy of the bowel wall; histology: plasmablastic, high-grade lymphoma. Initiation of a high-dose cyclophosphamide chemotherapy.

Summary:
– Structural differences in the bowel wall can be visualized well by sonography.
– Hypervascularization may also be associated with a tumor.
– Intramural lesions cannot be reached endoscopically by biopsy.

Vasculitis: intestinal involvement

Figures 59a–c: Vasculitis with small bowel involvement.
Two to three weeks after polychemotherapy, the 55-year-old patient developed an acute abdomen.

Fig. 59a

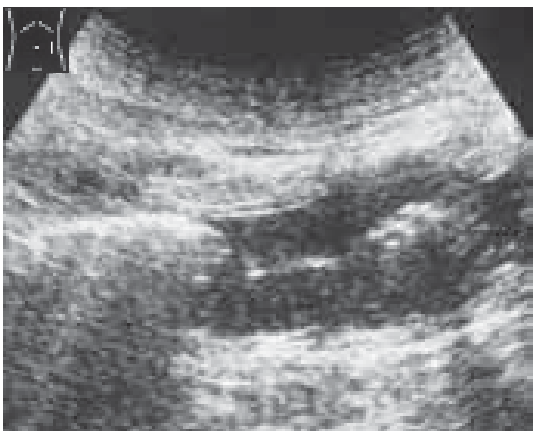


Fig. 59b

a and b) Small bowel loops with significant wall thickening were found.

Fig. 59c

◁ The blurred wall layers exhibited individual vessels in the color Doppler. The histology showed vasculitis of the smallest bowel wall vessels, along with a clinical picture consistent with leukocytoclastic vasculitis. The vasculitis was very likely to have been drug-induced. The wall changes and the patient's symptoms slowly and steadily regressed without treatment.

Radiogenic damage

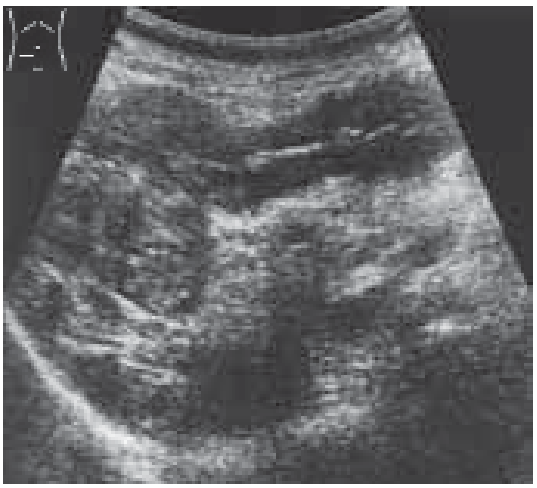


Fig. 60

◁ Radiogenic damage of the terminal ileum and the cecum. The above radiation damage was recorded by sonography several years after irradiation of a tumor of the lower abdomen. The female patient suffered from recurrent abdominal pain and diarrhea.
The finding is very similar to Crohn's ileocolitis with wall thickening in the region of the terminal ileum and cecum. The wall layers have not been preserved.

Actinomycosis

Figures 61a and b: Small bowel actinomycosis with connection to the abdominal wall that is exhibiting pseudo-tumorous infiltration.

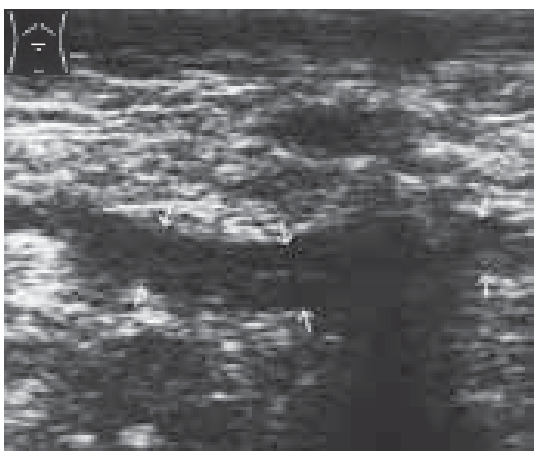


Fig. 61a

Small bowel loop with wall thickening (↑) and infiltrates between the bowel loop and the abdominal wall that appear hypoechoic (upper abdominal transverse slice).

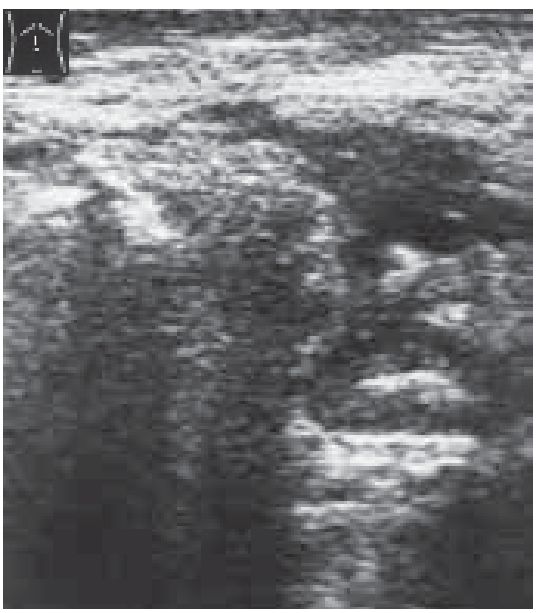


Fig. 61b

Cockade/bull's eye-shaped small bowel loop with wall thickening and canal-like connection to an almost oval region of infiltration of 3 x 2 cm in size with branching (upper abdominal longitudinal slice). The diagnosis was confirmed histologically with a transcutaneous punch biopsy. Within a few weeks, the finding healed completely under treatment with antibiotics. The patient did not have any recurrences. The sonographic findings equate to bowel wall infiltration with enterocutaneous fistula in Crohn's disease.

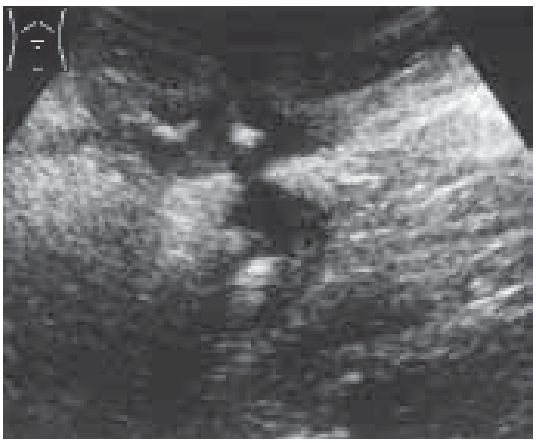


Fig. 62

Crohn's disease with ileocutaneous fistula.
In the center of the image, there is a bowel loop with wall thickening and a hypoechoic fistula canal towards the abdominal wall. Additionally, a fox den-like fistula tract can be seen and is easily recognizable thanks to the hypoechoic signs of inflammation. Cf. Fig. 61.

The value of sonography in initial diagnostics and follow-up monitoring

Given optimal examination conditions (5–12 MHz), the described sonographic changes in the gastrointestinal tract can be detected in the case of Crohn's disease in 80–90% of cases. In about 50% of cases, there are especially pronounced findings. The high sensitivity demonstrates that ultrasound diagnostics represent a suitable diagnostic method and not just when dealing with cases of advanced disease. The current guidelines for Crohn's disease state that in experienced hands, bowel wall sonography is a good and valid screening examination for inflammatory bowel disease. Furthermore, the guidelines see it as an excellent and readily available method for monitoring disease course in Crohn's disease without putting any relevant burden on the patient.

In the case of ulcerative colitis, pathological findings (main finding: mild to moderate wall thickening of the descending colon at 4–5 mm) are found in a little more than half of cases. The difference between this and Crohn's disease is the fact that the best diagnostic criterion that can be found by sonography, the thickening of the bowel wall, is less pronounced and less common. In addition, ulcerative colitis is often limited to the less visible areas of the sigmoid and rectum. The visualization of the five wall layers in the case of normal bowel wall thickness does not rule out Crohn's disease. In many cases, in the case of a characteristic medical history, appropriate age group, and typical ileocecal localization or in the case of a long section of wall thickening and fistula detection, a suspected diagnosis of Crohn's disease can be made. The diagnosis must then be evidenced using targeted endoscopic and histological diagnostics.

If a suspicious pathological sonography finding is present, diagnostic clarification using endoscopic procedures is required. An inconspicuous sonography finding cannot rule out a disease of the gastrointestinal tract, and especially not inflammatory bowel disease.

The extent of the disease shown in the sonography correlates very well with the findings of radiological and endoscopic diagnostics, but no complete agreement is possible due to the limited visibility of less affected bowel segments. Progression and regression of the disease should therefore only be assessed with caution. There is no correlation between the sonomorphology findings and the activity index according to Best. The detection of a hypoechoic wall thickening with wall layers that are difficult or impossible to distinguish, or detec-

tion of inflammatory hyperemia by color Doppler sonography, especially in the submucosa, is regarded as a very reliable sign of an active inflammatory process.

Only in some cases can the regression of the wall thickening be observed. The bowel wall changes caused by scarring in Crohn's disease are permanent. In ulcerative colitis, the wall thickening is more of an expression of the inflammatory wall edema in an acute flare-up. Good candidates for follow-up by sonography include antibiotic-associated colitis, especially diverticulitis, and generally speaking, left-sided ischemic colitis. Here, within a few days, there are pronounced changes in macromorphology that can be detected by sonography. Other examples of promising treatment follow-up by sonography include lymphoma, and the extremely rare actinomycosis.

The value of ultrasound diagnostics (Table 9) lies in their potential to uncover unexpected intestinal findings in inflammatory bowel disease and other diseases that involve wall infiltration. As an initial examination for abdominal complaints, sonography can initiate the clarifying diagnostics in the case of suspicious findings. In follow-up monitoring, the (often young) patients can be spared radiological examinations first and foremost, and also endoscopic interventions in some cases. Sonography complements endoscopy and radiological diagnostics because it primarily provides complementary findings; patients can also be examined repeatedly in the event of a dramatic worsening of their condition. In addition to pronounced intestinal changes, almost all significant abdominal and retroperitoneal complications can be detected without the need to use contrast media. The usefulness of sonography is not surprising when we compare the radiological and ultrasound diagnostic criteria (Table 10).

CT and MRI provide better results than sonography in very obese patients and patients with extreme meteorism when ultrasound examinations are limited or when high-frequency transducers cannot be used. It should also be noted that the investigator's experience is just as important for MR enteroclysis results as it is for bowel sonography results. Due to its low cost, the fact that it is readily available, and the often excellent or at least adequate examination results, sonography is the first method that should be used.

Importance of ultrasound diagnostics in inflammatory bowel disease

1. Initial detection of suspicious intestinal findings: further diagnostics required
2. Discovery of unexpected findings in Crohn's disease and other diseases that involve wall infiltration
3. Follow-up monitoring
   - Progression
   - Regression (not possible during the scarring stage)
   - Patient is spared radiological and endoscopic examinations
4. Complementary examinations, X-ray, and endoscopy (e.g. insurmountable stenosis, subileus, ileus)
5. Morphological diagnostics in the case of acute worsening
6. Detection of intramural and extramural complications in Crohn's disease
7. Future: may be helpful in detecting deep remission

Table 9

Comparison of ultrasound and radiological diagnostic criteria in Crohn's disease

	US	X-ray (Sellink)	MRI
Wall thickening	++	+	++
Lumen constriction	++	+	++
Fistulae	++	++	++(+)
Intermediary segment	++	++	++(+)
Mesenteric thickening (sclerolipomatosis)	++	+	++
Cobblestone relief, ulcers	*)	++	–
Deficient peristalsis	+	+	–
Deficient compressibility	+	+	–
Stenosis	++	++	++(+)
Subileus/ileus	+++	–	– (CT!)
Extramural complications	++	(+)	++(+)
Inflammatory hyperemia	++	–	–

*) Intramural fistulae can sometimes by visualized

Table 10

The value placed on sonography in the guidelines

Inflammatory bowel disease (IBD) is diagnosed and treated according to guidelines across the globe.
Even though there is international consensus regarding many aspects, there are still some differences in national and continental guidelines for diagnosis and therapy.
For example, various biologics such as natalizumab or certolizumab are not approved in some countries, so they cannot form part of the national algorithms in those countries.
The same applies to the use of sonography in the diagnosis and monitoring of IBD.
Historically, the use of sonography in gastroenterology was first established in Germany, Austria and Switzerland as an important diagnostic tool for IBD.
Based on many valid studies, ultrasound is highly valued in the current S3 guidelines of the German Society for Gastroenterology, Digestive and Metabolic Diseases (DGVS) for Crohn's disease, both for diagnosis and for assessment of disease activity over the course of the disease. Therefore, in addition to endoscopy, the German guideline calls for sonography for initial diagnosis with evidence level I.
In 2006, the European Crohn's and Colitis Organization (ECCO) set Europe-wide guidelines for the first time. In this first consensus paper, ultrasound did not play any relevant role either in the initial diagnosis or follow-up monitoring of Crohn's disease.
In addition to Sellink X-ray examination and CT, an important role was assigned to MR diagnostics at that time.
Intensive European-wide scientific work with ultrasound technology in IBD patients has since resulted in the generation of much valid data concerning the specificity and sensitivity of ultrasound as a diagnostic tool for inflammation of the bowel, including in comparison with MRI and CT diagnostics.
This data, some of which has been published at the highest level, led to a reevaluation of ultrasound by ECCO: The current guidelines now ascribe almost equal value to sonography as to CT and MRI. MRI remains the preferred method for complications of Crohn's disease in the pelvic region as well as for skip lesions and fistulae in the region of the upper small bowel.

The advantage of sonography as a diagnostic procedure that is readily available and places little burden on the patient has now also been communicated by the European guideline committee. Compared to the European guideline culture surrounding IBD, the American guidelines (first and foremost the guidelines of the American Gastroenterological Association [AGA]), and the Asian guidelines contain few or no recommendations for sonography, and in particular, they have little to say about sonography of the bowel wall as a diagnostic procedure for IBD.

The reasons for this are likely to lie not in doubts about the available data, but rather in the historically determined training of gastroenterologists as specialists. Ultrasound is not an integral part of specialist training in the USA or in many Asian countries, e.g. China. Gastroenterologists who are responsible for setting guidelines competence and have no knowledge of sonography likely explain the preference for radiological tomography in diagnostics and follow-up.

As long as there is no clear reflection of the value of sonography for endoscopic diagnostics in the specialist training curriculum of Asian and American countries, internationally recognized study data on the use of bowel wall sonography in IBD will only be taken into account to a limited extent. Therefore, a future rethinking of American and Asian guidelines is only likely if the curriculum for specialists is amended. In light of increasing globalization and the increasing economic pressure on all health care systems, the cost-effectiveness of sonography could potentially trigger a sensible rethink.

Outlook: value in mucosal healing and deep remission

Due to the improvement in treatment of IBD with immunosuppressants and biologics, the term "mucosal healing" has become an internationally established treatment aim. Despite the many possibilities that bowel wall sonography offers, the definition of mucosal healing has largely been defined endoscopically/macroscopically.

A histological specification for mucosal healing has not gained much traction in most studies.

Since sonography performed purely to assess the mucosal layer does not yield any valid data, its value should be exploited in the context of an

expanded concept of "deep remission". This term combines mucosal healing with clinical remission (patient free of symptoms, CDAI < 150). Due to the ability to evaluate the entire bowel wall in sonography (mucosa to muscularis mucosa) instead of just the mucosa as in endoscopy, sonography has the potential to classify deep remission as a remission through all wall layers in Crohn's disease. Since all of the data suggest that the absence of a recurrence of Crohn's disease even after medication is discontinued remains dependent on the "depth" (sustainability) of the remission that is detected (transmural and mucosal remission), it is essential to use all diagnostic tools available for Crohn's disease in order to assess the degree of remission.

Taking into account the expansion that has taken place in biologic-based treatment with integrin antibodies, interleukin-12/interleukin-23 antibodies, and the likely approval of further effective substances such as Janus kinase (JAK) inhibitors in the near term, the importance of detailed determination of disease activity in the course of treatment cannot be overestimated. A sustainable de-escalation strategy can only be implemented using all available diagnostic tools to establish that the patient is in deep remission.

Centers with highly qualified ultrasound units will be indispensable for ensuring excellence in IBD treatment.

Addendum: How sonography and inflammatory bowel disease are represented in the literature

Selected papers from the ultrasound (US) literature are presented below. The focus is on the beginnings and clinical applications of the various ultrasound techniques. The aim is to provide an overview of the current state of the art of sonography compared to the rival, equally competitive tomography methods. Due to the enormous amount of literature available, this overview must necessarily remain incomplete.

The beginnings of ultrasound diagnostics in the gastrointestinal tract

Initially, Lutz and Rettenmaier described the "cockade/bull's eye" as a sign of wall thickening in gastrointestinal tumors using the legendary Vidoson, the first real-time B-mode device with grayscale values [1]. Just 2 years later, the active Erlangen working group reported on 40 tumors of the stomach, small bowel and large bowel that were visualized by sonography [2]. The first report on ultrasound and Crohn's disease came in 1979 and was published in *Gut*. Using the adventurously poor images of a compound device, extensive findings of Crohn's disease were detected in 15 out of 20 cases [3]. The medical journal *Ultraschall in der Medizin*, which was established in 1980, contained articles on gastrointestinal diagnostics right from the first issue. The long section of bowel wall thickening as a characteristic sign [4] and its significance in the active phase of Crohn's disease [5] were described. The first prospective study which included 175 IBD patients (including 51 with Crohn's disease) was published by Sonnenberg et al. in 1982 [6]; in this study, the cockade/bull's eye sign (here named the target sign) achieves a sensitivity of 74% and a specificity of 88% for Crohn's disease. The prospective study by Worlicek et al. [7] represented a milestone for transabdominal ultrasound diagnostics in IBD (n = 241; Crohn's disease = 118, ulcerative colitis = 51, controls = 72). This paper described the marked wall thickening found in Crohn's disease compared to ulcerative colitis, and the significance of the location of the lesions for differential diagnosis, as well as the limitations of the procedure.

In 1986, a new age dawned for ultrasound. Lutz et al. successfully visualized the 5 wall layers of the stomach and their anatomical equivalents with a 5 MHz EUS prototype [8]. This, and the increasingly improved resolution of transabdominal

transducers enabled Meckler et al. [9, 10] to describe the different wall layers seen in Crohn's disease, and to determine their clinical significance. In the period from 1985 to 1995, bowel (wall) sonography came to be widely accepted by committed sonographers and was used for many clinical applications. Although the scientific evaluation of ultrasound diagnostics was initially hesitant, it was already widely accepted in sonography textbooks.

1. *Lutz H, Rettenmaier G. Sonographic patterns of tumors of the stomach and intestine. In: Proceedings of the Second World Congress on Ultrasonics in Medicine, Rotterdam. Excerpta Med. 1973:67.*
2. *Lutz HT, Petzoldt R. Ultrasonic patterns of space occupying lesions of the stomach and the intestine. Ultrasound Med Biol. 1976;2(2):129–32.*
3. *Holt S, Samuel E. Grey scale ultrasound in Crohn's disease. Gut. 1979;20(7):590–5.*
4. *Seitz K. Sonographische Diagnostik beim Morbus Crohn. Ultraschall Med. 1980;1(1):35–40.*
5. *Wellmann W, Gebel M, Freise J, Grote R. Sonographie in der Diagnostik der Ileitis terminalis Crohn. Rofo. 1980;133(2):146–8.*
6. *Sonnenberg A, Erckenbrecht J, Peter P, Niederau C. Detection of Crohn's disease by ultrasound. Gastroenterology. 1982;83(2):430–4.*
7. *Worlicek H, Lutz H, Thoma B. Sonographie chronisch entzündlicher Darmerkrankungen – eine prospektive Studie. Ultraschall Med. 1986;7(6):275–80.*
8. *Lutz H, Bauer U, Stolte M. Ultraschalldiagnostik der Magenwand – experimentelle Untersuchungen. Ultraschall Med. 1986;7(6):255–8.*
9. *Meckler U, Herzog P. Sonographischer Darmwandaufbau – Bedeutung für die Diagnose entzündlicher Darmerkrankungen. Ultraschall Med. 1989;10(3):152–7.*
10. *Meckler U, Caspary WF, Clement T, Herzog P, Lembcke B, Limberg B, et al. Sonografie beim M. Crohn – Stellungnahme einer Expertengruppe. Z Gastroenterol. 1991;29(7):355–9.*

Further scientific development among the German ultrasound community

Wile the use of ultrasound (US) diagnostics in IBD was predominantly shaped by the German community in the beginning, the Italian working groups

dominated in the following years. In the German-speaking countries, IBD was mainly worked on by B. Limberg in Heidelberg and by the working groups of M. Gebel in Hannover and W. Kratzer in Ulm. Their many publications can be easily found using PubMed.

Normal bowel wall and ultrasound imaging

The normal bowel wall is 2 mm thick throughout the entire gastrointestinal tract (GI tract). Knowledge of the bowel wall layers is essential and by no means optional!

In the past, the normal bowel wall thickness was overestimated due to poor resolution and poor measurement accuracy. The work of Nylund et al. once again proved this: The normal bowel wall thickness is a maximum of 2 mm in all sections of the GI tract [1]. A very illustrative depiction of the bowel wall layers using high-frequency ultrasound, along with information on the clinical applications of this can be found in Ødegaard et al. [2].

The current guideline of the EFSUMB (European Federation of Societies for Ultrasound in Medicine and Biology) regarding the examination technique and normal findings was thus published more than 25 years after gastrointestinal ultrasound became a part of German-language books on ultrasound [3].

1. *Nylund K, Hausken T, Odegaard S, Eide GE, Gilja OH. Gastrointestinal wall thickness measured with transabdominal ultrasonography and its relationship to demographic factors in healthy subjects. Ultraschall Med. 2012;33(7): E225–32.*
2. *Ødegaard S, Nesje LB, Lærum OD, Kimmey MB. High-frequency ultrasonographic imaging of the gastrointestinal wall. Expert Rev Med Devices. 2012;9(3):263–73.*
3. *Nylund K, Maconi G, Hollerweger A, Ripolles T, Pallotta N, Higginson A, et al. EFSUMB Recommendations and Guidelines for Gastrointestinal Ultrasound. Ultraschall Med. 2017;38(3):273–84.*

Ultrasound techniques

Transperineal ultrasound (TPUS) – simple and very much underused

Given that it is simple, uncomplicated, and above all pain-free, transperineal ultrasound (TPUS) is generally very much underused and its capabilities are underestimated. All one needs in order to do it is a condom or a disposable glove as a cover for the transducer, along with anatomical knowledge. TPUS should therefore be the very first diagnostic procedure [1–4]. The value of TPUS is almost equivalent to that of MRI when it comes to detecting fistulae and abscesses, and classifying perianal diseases [5]. In addition, perianal endosonography is also available as a further procedure. Both methods can be combined with the administration of ultrasound contrast medium (CM) in order to better depict fistulae (CM instillation, also possible using cheap hydrogen peroxide) and for better delimitation of abscesses (CEUS). The value of the method has been demonstrated in a recent literature review with meta-analysis [6].

1. *Maconi G, Tonolini M, Monteleone M, Bezzio C, Furfaro F, Villa C, et al. Transperineal perineal ultrasound versus magnetic resonance imaging in the assessment of perianal Crohn's disease. Inflamm Bowel Dis. 2013;19(13):2737–43.*
2. *Stewart LK, McGee J, Wilson SR. Transperineal and transvaginal sonography of perianal inflammatory disease. AJR Am J Roentgenol. 2001;177(3):627–32.*
3. *Plaikner M, Loizides A, Peer S, Aigner F, Pecival D, Zbar A, et al. Transperineal ultrasonography as a complementary diagnostic tool in identifying acute perianal sepsis. Tech Coloproctol. 2014;18(2):165–71.*
4. *Dietrich CF, Barreiros AP, Nuernberg D, Schreiber-Dietrich DG, Ignee A. Perinealer (perianaler) Ultraschall (PNUS). Z Gastroenterol. 2008;46(6):625–30.*
5. *Terracciano F, Scalisi G, Bossa F, Scimeca D, Biscaglia G, Mangiacotti M, et al. Transperineal ultrasonography: First level exam in IBD patients with perianal disease. Dig Liver Dis. 2016;48(8): 874–9.*

6. *Maconi G, Greco MT, Asthana AK. Transperineal ultrasound for perianal fistulas and abscesses – a systematic review and meta-analysis. Ultraschall Med. 2017;38(3):265–72.*

Doppler/duplex sonography

Only useful to those interested in the scientific aspect.

As early as the 1980s, we investigated flow velocities and flow volumes in both mesenteric arteries in healthy individuals and in patients with Crohn's disease and ulcerative colitis, and we demonstrated the presence of inflammatory hyperemia, but the method was abandoned because of the high level of effort required to achieve reliable measurements.

From 1992 to 2004, several papers were published in which Doppler techniques were used as activity parameters, and in some cases they demonstrated a very close correlation with endoscopic and clinical activity indices. As expected, quantitative duplex measurements did not gain much traction.

Some of these studies are quoted here for those interested in the science:

1. *Bolondi L, Gaiani S, Brignola C, Campieri M, Rigamonti A, Zironi G, et al. Changes in splanchnic hemodynamics in inflammatory bowel disease. Non-invasive assessment by Doppler ultrasound flowmetry. Scand J Gastroenterol. 1992;27(6):501–7.*
2. *Maconi G, Imbesi V, Bianchi Porro G. Doppler ultrasound measurement of intestinal blood flow in inflammatory bowel disease. Scand J Gastroenterol. 1996;31(6):590–3.*
3. *Mirk P, Palazzoni G, Gimondo P. Doppler sonography of hemodynamic changes of the inferior mesenteric artery in inflammatory bowel disease: preliminary data. AJR Am J Roentgenol. 1999;173(2):381–7.*
4. *Kalantzis N, Rouvella P, Tarazis S, Mourikis D, Kalantzis C, Kourkoutsakis N, et al. Doppler US of superior mesenteric artery in the assessment of ulcerative colitis. A prospective study. Hepatogastroenterology. 2002;49(43):168–71.*
5. *Ludwig D, Wiener S, Brüning A, Schwarting K, Jantschek G, Fellermann K, et al. Mesenteric blood flow is related to disease activity and risk of relapse in ulcerative colitis: a prospective follow up study. Gut. 1999;45(4):546–52.*

Color Doppler sonography

Color Doppler sonography is part of any routine sonography of the GI tract.
In addition, the easy-to-use activity score introduced by Limberg [1] has proved its worth – and rightly so. Ultimately, all subsequent works refer to Limberg ([2] and many more, see later).
However, the semi-quantitative assessment using the number of color spots and vessels should be adapted to the sensitivity of today's devices. Nowadays, the more sensitive color mode can be used in the same way as the power mode.

1. *Limberg B. Diagnostik von chronisch entzündlichen Darmerkrankungen durch Sonographie. Z Gastroenterol. 1999;37(6):495–508.*
2. *Heyne R, Rickes S, Bock P, Schreiber S, Wermke W, Lochs H. Non-invasive evaluation of activity in inflammatory bowel disease by power Doppler sonography. Z Gastroenterol. 2002;40(3):171–5.*

Hydrocolonic sonography – a glimpse into the past

Hydrocolonic sonography is far too complex, and was therefore abandoned.
As ultrasound devices improved, the procedure of hydrocolonic sonography [1–4] that was introduced by Limberg and published in high quality publications could not stand up against native sonography without the need for any preparations due to the practicalities (need for purge + water enema).
Limberg was only imitated by a few [5].

1. *Limberg B. Diagnosis and staging of colonic tumors by conventional abdominal sonography as compared with hydrocolonic sonography. N Engl J Med. 1992;327(2):65–9.*
2. *Limberg B, Osswald B. Diagnosis and differential diagnosis of ulcerative colitis and Crohn's disease by hydrocolonic sonography. Am J Gastroenterol. 1994;89(7):1051–7.*
3. *Limberg B. Hydrocolonic ultrasonography. N Engl J Med. 1995;332(23):1581–2.*
4. *Limberg B. Diagnosis of acute ulcerative colitis and colonic Crohn's disease by colonic sonography. J Clin Ultrasound. 1989;17(1):25–31.*

5. *Bru C, Sans M, Defelitto MM, Gilabert R, Fuster D, Llach J, et al. Hydrocolonic sonography for evaluating inflammatory bowel disease. AJR Am J Roentgenol. 2001;177(1):99–105.*

Oral contrast medium administration – has its potential been underestimated?

These days, oral contrast medium should no longer be administered with water (preferably still), milk or orange juice. Instead, 500–1000 mL of polyethylene glycol (PEG) administered orally can not only achieve contrast enhancement in the stomach, but also in the small bowel [1]. According to recent experience, an even better method is administration of water with just a few drops of ultrasound CM mixed in. The patient does not need to remain fasted for this. This CM filler reaches the terminal ileum in approximately 30 minutes.

It is likely that this technique can detect Crohn's disease lesions of the small bowel slightly more frequently (sensitivity with oral contrast 96% vs. 91% without). In any case, the sensitivity of this method in the case of strictures is significantly better than routine ultrasound (89% vs. 74% without) [1, 2]. A study by Kumar et al. [3] provides results that support this, and a recent systematic review by Mocci et al. is also available [4].

1. *Parente F, Greco S, Molteni M, Cucino C, Maconi G, Sampietro GM, et al. Role of early ultrasound in detecting inflammatory intestinal disorders and identifying their anatomical location within the bowel. Aliment Pharmacol Ther. 2003;18(10):1009–16.*
2. *Parente F, Greco S, Molteni M, Anderloni A, Sampietro GM, Danelli PG, et al. Oral contrast enhanced bowel ultrasonography in the assessment of small intestine Crohn's disease. A prospective comparison with conventional ultrasound, x ray studies, and ileocolonoscopy. Gut. 2004;53(11):1652–7.*
3. *Kumar S, Hakim A, Alexakis C, Chhaya V, Tzias D, Pilcher J, et al. Small intestinal contrast ultrasonography for the detection of small bowel complications in Crohn's disease: correlation with intraoperative findings and magnetic resonance enterography. J Gastroenterol Hepatol. 2015;30(1):86–91.*

4. *Mocci G, Migaleddu V, Cabras F, Sirigu D, Scanu D, Virgilio G, et al. SICUS and CEUS imaging in Crohn's disease: an update. J Ultrasound. 2017;20(1):1–9.*

CEUS (contrast-enhanced ultrasound)

CEUS is currently the most in-demand new ultrasound technique.
CEUS and DE-CEUS (digital-enhanced CEUS) are the rising stars of ultrasound diagnostics for IBD today. Numerous studies (of widely varying quality) have been published on examination technique, assessment of disease activity, and therapy monitoring. CEUS is useful in the case of IBD complications with a special indication (better delimitation of abscesses, differential diagnosis of stenosis caused by scarring versus stenosis caused by inflammation). DE-CEUS is currently a "work in progress", and it does not yet play any part in routine diagnostics. The technique is complex, its benefit is undetermined, and the method is not sufficiently standardized. Two meta-analyses are already available in addition to systematic reviews [1–8].

With 8 evaluated or evaluable publications with a total of 428 patients, the pooled sensitivity for an active Crohn's disease was 93%, the specificity was 87%, and the area under the curve was 0.96. The diagnostic standard is high compared to endoscopy and final clinical diagnosis, and the method is excellent when it comes to distinguishing between active and inactive Crohn's disease [9].
The second meta-analysis with 8 out of 51 evaluated publications and 338 patients shows a good sensitivity and moderate specificity with regard to CEUS and active Crohn's disease. CEUS showed higher accuracy compared to a thickened bowel wall plus/or increased color Doppler signals. Enhancement of the entire bowel wall as well as the mucosa and submucosa was evaluated as indicative of active Crohn's disease.
The technical complexity and quality of CEUS examinations are the predominant limiting factors; further studies and objectively defined measurement parameters are required in order to establish clinical applications of CEUS [10].
Performing meta-analyses with the current low amount of available data is bold and must be evaluated as preliminary at best, but DE-CEUS nevertheless has enormous potential.

1. *Ma X, Li Y, Jia H, Zhang J, Wang G, Liu X, et al. Contrast-enhanced ultrasound in the diagnosis of patients suspected of having active Crohn's disease: meta-analysis. Ultrasound Med Biol. 2015;41(3):659–68.*
2. *Serafin Z, Białecki M, Białecka A, Sconfienza LM, Kłopocka M. Contrast-enhanced ultrasound for detection of Crohn's disease activity: systematic review and meta-analysis. J Crohns Colitis. 2016;10(3):354–62.*
3. *Quaia E. Contrast-enhanced ultrasound of the small bowel in Crohn's disease. Abdom Imaging. 2013;38(5):1005–13.*
4. *Girlich C, Jung EM, Huber E, Ott C, Iesalnieks I, Schreyer A, et al. Comparison between preoperative quantitative assessment of bowel wall vascularization by contrast-enhanced ultrasound and operative macroscopic findings and results of histopathological scoring in Crohn's disease. Ultraschall Med. 2011;32(2):154–9.*
5. *Zink F, Kratzer W, Schmidt S, Oeztuerk S, Mason RA, Porzner M, et al. Comparison of two high-end ultrasound systems for contrast-enhanced ultrasound quantification of mural microvascularity in Crohn's disease. Ultraschall Med. 2016;37(1):74–81.*
6. *Quaia E, Migaleddu V, Baratella E, Pizzolato R, Rossi A, Grotto M, et al. The diagnostic value of small bowel wall vascularity after sulfur hexafluoride-filled microbubble injection in patients with Crohn's disease. Correlation with the therapeutic effectiveness of specific anti-inflammatory treatment. Eur J Radiol. 2009;69(3):438–44.*
7. *Wilkens R, Peters DA, Nielsen AH, Hovgaard VP, Glerup H, Krogh K. Dynamic contrast-enhanced magnetic resonance enterography and dynamic contrast-enhanced ultrasonography in Crohn's disease: an observational comparison study. Ultrasound Int Open. 2017;3(1):E13–24.*
8. *Socaciu M, Ciobanu L, Diaconu B, Hagiu C, Seicean A, Badea R. Non-invasive assessment of inflammation and treatment response in patients with Crohn's disease and ulcerative colitis using contrast-enhanced ultrasonography quantification. J Gastrointestin Liver Dis. 2015;24(4):457–65.*
9. *Ripollés T, Rausell N, Paredes JM, Grau E, Martínez MJ, Vizuete J. Effectiveness of contrast-enhanced ultrasound for characterisation of intestinal inflammation in Crohn's disease: a comparison with surgical histopathology analysis. J Crohns Colitis. 2013;7(2):120–8.*

10. *De Franco A, Marzo M, Felice C, Pugliese D, Veronica AD, Bonomo L, et al. Ileal Crohn's disease: CEUS determination of activity. Abdom Imaging. 2012;37(3):359–68.*

Elastography

Elastography is an interesting new ultrasound technique that has developed very quickly. At the moment, it has no clinical relevance for IBD, and its future potential is likely limited.

Elastography only became established a short time ago; it determines tissue elasticity partly in two dimensions and real time, either qualitatively or quantitatively. The EFSUMB has published guidelines, fundamental principles, and information on experience gained with the technique [1, 2]. This information can be found at www.efsumb.org.

The rationale behind the method is that a bowel wall that is affected by inflammatory or tumorous infiltrates has a stiffer consistency than a healthy intestine. The method is suitable for determining the elasticity of parenchymatous tissue, however its use in examinations of the GI tract and in the case of IBD is still in the preliminary stage. There can be no question that further research (especially research with larger sample sizes) is required in order to evaluate the diagnostic significance of the method in IBD. In studies using surgical specimens of the GI tract, adenocarcinomas and tissues affected by adenomyomatosis exhibited a higher "strain ratio" than surrounding tissues. However, the method was not capable of distinguishing between tissues affected by Crohn's disease, adenoma, and carcinoma with sufficient certainty. The inter-observer reliability was found to be good [3]. According to another study in 37 patients with ulcerative colitis, tissue elasticity (strain) appears to correlate with disease activity [4].

The most clinically interesting work is a prospective proof-of-concept study of Crohn's disease strictures. In 10 patients, elastography proved to be suitable for the detection of fibrosis, and the method therefore appears useful as an aid for decisions on stricture management [5].

1. *Bamber J, Cosgrove D, Dietrich CF, Fromageau J, Bojunga J, Calliada F, et al. EFSUMB guidelines and recommendations on the clinical use of ultrasound elastography. Part 1: Basic principles and technology. Ultraschall Med. 2013;34(2):169–84.*

2. *Cosgrove D, Piscaglia F, Bamber J, Bojunga J, Correas JM, Gilja OH, et al. EFSUMB guidelines and recommendations on the clinical use of ultrasound elastography. Part 2: Clinical applications. Ultraschall Med. 2013;34(3):238–53.*
3. *Havre RF, Leh S, Gilja OH, Ødegaard S, Waage JE, Baatrup G, et al. Strain assessment in surgically resected inflammatory and neoplastic bowel lesions. Ultraschall Med. 2014;35(2):149–58.*
4. *Ishikawa D, Ando T, Watanabe O, Ishiguro K, Maeda O, Miyake N, et al. Images of colonic real-time tissue sonoelastography correlate with those of colonoscopy and may predict response to therapy in patients with ulcerative colitis. BMC Gastroenterol. 2011;11:29.*
5. *Baumgart DC, Müller HP, Grittner U, Metzke D, Fischer A, Guckelberger O, et al. US-based real-time elastography for the detection of fibrotic gut tissue in patients with stricturing Crohn disease. Radiology. 2015;275(3):889–99.*

A glimpse into the future

Molecular imaging with CM enhanced ultrasound, and maybe more…

From a scientific point of view, MRI and sonography are the most interesting imaging techniques in terms of potential for future development. Here, animal tests with "targeted CEUS" highlight the new possibilities of molecular imaging in the long term, which could greatly improve diagnostics and treatment monitoring [1–3].

1. *Wang H, Machtaler S, Bettinger T, Lutz AM, Luong R, Bussat P, et al. Molecular imaging of inflammation in inflammatory bowel disease with a clinically translatable dual-selectin-targeted US contrast agent: comparison with FDG PET/CT in a mouse model. Radiology. 2013;267(3):818–29.*
2. *Machtaler S, Knieling F, Luong R, Tian L, Willmann JK. Assessment of inflammation in an acute on chronic model of inflammatory bowel disease with ultrasound molecular imaging. Theranostics. 2015;5(11):1175–86.*

3. *Knieling F, Waldner MJ. Light and sound – emerging imaging techniques for inflammatory bowel disease. World J Gastroenterol. 2016;22(25):5642–54.*

Sonography – clinical value in IBD

Meta-analyses
Ultrasound on a par with CT and MRI, so sonography first

The first meta-analysis of 2008 [1] showed no significant difference in sensitivity for ultrasound, MRI, CT and scintigraphy (89.7%, 93%, 84.3% and 87.8% respectively) in the method comparison (per patient). The specificity was 95.6% for ultrasound (MRI 92.8%, CT 95.1%, scintigraphy 84.5%) and only the specificity of ultrasound was statistically confirmed to be above that of scintigraphy. With regard to the affected segments, the sensitivity for all methods was lower (67.4–77.3%), but the specificity was similarly high (90.2–94%). However, the CT was significantly less sensitive and specific than scintigraphy and MRI, making ultrasound and MRI the preferred examination methods.

The second meta-analysis of sonography in diagnostics of the small bowel that was published in 2016, and which investigated detection and proliferation and included 13 studies, arrived at similar results (sensitivity 88%, specificity 86%, diagnostic odds ratio = 39.1); comparable values were found for strictures, dilated sections, abscesses and fistulae [2]. It was concluded that sonography is an accurate method for determining the location, extent, and number of most complications of small bowel lesions.

Systematic reviews

Scientifically reliable data have been available since the paper by Sonnenberg et al. in 1982 (see page 97): They mainly refer to Crohn's disease. The results naturally depend on patient selection, prevalence, the ultrasound parameters used, the inclusion of different clinical information, and the physical resolution of the respective device generation.

In 2016, Greenup et al. [3] produced a paper that attempted to answer the question "which one is the best for what?" (ultrasound, CT or MRI) in Crohn's disease of the small bowel, with the question forming part of the title of the paper. It concluded that all three procedures can play an important role, with the specific clinical question, the locally available resources, and the patient's wishes representing important factors.

The current systematic review by Conti et al. [4] reports a sensitivity of 75-94%, with specificities and positive predictive value (PPV) of 70–100% and negative predictive value (NPV) of 73–96%. These figures support the case for giving sonography a very high priority.

Further recent and excellent systematic reviews have been published by Deepak et al. [5], Kucharzik et al. [6], and Calabrese et al. [7]: In these, all clinically important aspects of MRI and ultrasound are presented, and the equivalent value of sonography is confirmed thanks to the convincing data. There is also a current systematic review of the use of sonography in therapy monitoring by Kucharzik et al. [6] that is particularly noteworthy. An overview of IBD in children and adolescents can be found in Chiorean et al. [8].

The systematic reviews that have been published in rapid succession in recent years reflect the high level of interest and increasing importance of sonography in IBD.

1. *Horsthuis K, Bipat S, Bennink RJ, Stoker J. Inflammatory bowel disease diagnosed with US, MR, scintigraphy, and CT: meta-analysis of prospective studies. Radiology. 2008;247(1): 64–79.*
2. *Zhu C, Ma X, Xue L, Xu J, Li Q, Wang Y, et al. Small intestine contrast ultrasonography for the detection and assessment of Crohn disease: A meta-analysis. Medicine (Baltimore). 2016;95(31):e4235.*
3. *Greenup AJ, Bressler B, Rosenfeld G. Medical imaging in small bowel Crohn's disease – computer tomography enterography, magnetic resonance enterography, and ultrasound: "Which one is the best for what?". Inflamm Bowel Dis. 2016;22(5):1246–61.*
4. *Conti CB, Giunta M, Gridavilla D, Conte D, Fraquelli M. Role of bowel ultrasound in the diagnosis and follow-up of patients with Crohn's disease. Ultrasound Med Biol. 2017;43(4): 725–34.*

5. *Deepak P, Kolbe AB, Fidler JL, Fletcher JG, Knudsen JM, Bruining DH. Update on magnetic resonance imaging and ultrasound evaluation of Crohn's disease. Gastroenterol Hepatol (NY). 2016;12(4):226–36.*
6. *Kucharzik T, Kannengiesser K, Petersen F. The use of ultrasound in inflammatory bowel disease. Ann Gastroenterol. 2017;30(2):135–44.*
7. *Calabrese E, Zorzi F, Lolli E, Pallone F. Positioning ultrasonography into clinical practice for the management of Crohn's disease. Gastroenterol Hepatol (NY). 2015;11(6):384–90.*
8. *Chiorean L, Schreiber-Dietrich D, Braden B, Cui XW, Buchhorn R, Chang JM, et al. Ultrasonographic imaging of inflammatory bowel disease in pediatric patients. World J Gastroenterol. 2015;21(17):5231–41.*

Original papers

Important prospective studies and comparison of methods

A study in 277 patients with suspected gastrointestinal disease and 168 pathological findings showed a sensitivity of 76% with 95% specificity and 98% PPV; sensitivity for Crohn's disease and ulcerative colitis was 84% and 66%, respectively. The weak points were in the duodenum, upper jejunum, and rectum [1].

In 487 patients with suspected disease of the GI tract (336 of them with pathological findings), sonography proved to be extremely reliable as an initial examination when combined with oral contrast in comparison to endoscopy, clinical diagnosis and surgical findings (sensitivity 85%, specificity 95%, PPV 95%, NPV 75%) [2]. Diagnostics in the region of the terminal ileum and sigmoid were more reliable than diagnostics using X-ray procedures and endoscopy (sensitivity 92%, specificity 87%). The weaknesses of sonography were once again in the rectum, duodenum and proximal jejunum.

The tomography methods use almost the same criteria for findings, which is why in theory, the results should be very similar given the same quality of methods.

In a study in 61 patients with Crohn's disease and ulcerative colitis (ultrasound: wall thickness > 3 mm, Doppler signals stronger or with increased enhancement under CEUS vs. MRI and ileocolonoscopy), sonography identified more active bowel segments for both diseases than MRI (sensitivity 89% vs. 73%); in addition, the inflammatory activity in the ultrasound correlated better with the endoscopy [3].

Publications that deal exclusively with ulcerative colitis are much rarer than those focused solely on Crohn's disease. In a retrospective study in 51 patients who had moderate to severe ulcerative colitis, endoscopy findings, sonographic findings, and C-reactive protein (CRP) values were analyzed over the course of three years. All patients exhibited a bowel wall thickness > 4 mm, and bowel wall thickness correlated very closely with CRP, endoscopy, and an endoscopic score [4].

1. *Hollerbach S, Geissler A, Schiegl H, Kullmann F, Lock G, Schmidt J, et al. The accuracy of abdominal ultrasound in the assessment of bowel disorders. Scand J Gastroenterol. 1998;33(11): 1201–8.*
2. *Parente F, Greco S, Molteni M, Anderloni A, Sampietro GM, Danelli PG, et al. Oral contrast enhanced bowel ultrasonography in the assessment of small intestine Crohn's disease. A prospective comparison with conventional ultrasound, x ray studies, and ileocolonoscopy. Gut. 2004;53(11):1652–7.*
3. *Pascu M, Roznowski AB, Müller HP, Adler A, Wiedenmann B, Dignass AU. Clinical relevance of transabdominal ultrasonography and magnetic resonance imaging in patients with inflammatory bowel disease of the terminal ileum and large bowel. Inflamm Bowel Dis. 2004;10(4):373–82.*
4. *Antonelli E, Giuliano V, Casella G, Villanacci V, Baldini V, Baldoni M, et al. Ultrasonographic assessment of colonic wall in moderate-severe ulcerative colitis: comparison with endoscopic findings. Dig Liver Dis. 2011;43(9):703–6.*

On the objection of subjectivity and the influence of examiner experience

There are no reliable data that could shed light on the objection of the subjectivity of the method. The same applies to any procedure that is not based on a measurement methodology. Furthermore, the results of ultrasound diagnostics depend more on the quality of examiner training than on experience as determined by the number of examinations performed. In the USA, ultrasound diagnostics enjoyed little or no acceptance because they were seen as being highly dependent on experience.

In a study on the reproducibility of ultrasound findings in Crohn's disease [1], 8 parameters (wall thickness, wall layering, color Doppler, enlarged lymph nodes, mesenteric hypertrophy, ascites, stenosis and fistula) were compared across 6 experienced examiners. Overall, the reproducibility proved to be very good: it was best for the most important parameter – wall thickness – and the only area where agreement was weak was in the assessment of the wall structure.

There is a North American research paper that is of particular interest in this context [2]. Diagnostic reliability in a low volume center and in a non-expert examination proved to be extraordinarily high (inflammatory wall thickening: sensitivity 87.8%, specificity 92.6%).

1. *Fraquelli M, Sarno A, Girelli C, Laudi C, Buscarini E, Villa C, et al. Reproducibility of bowel ultrasonography in the evaluation of Crohn's disease. Dig Liver Dis. 2008;40(11):860–6.*
2. *Sey MS, Gregor J, Chande N, Ponich T, Bhaduri M, Lum A, et al. Transcutaneous bowel sonography for inflammatory bowel disease is sensitive and specific when performed in a nonexpert low-volume North American center. J Ultrasound Med. 2013;32(8):1413–7.*

IBD and CT – radiation exposure is a serious problem

Only sonography and MRI are non-invasive. Despite improvements, CT still involves a relatively high level of radiation exposure, which is particularly important in light of the fact that most of the patients are young and the examinations are often repeated during the further course. Zakeri and

Pollok [1] provide an overview of further publications.

1. *Zakeri N, Pollok RC. Diagnostic imaging and radiation exposure in inflammatory bowel disease. World J Gastroenterol. 2016;22(7): 2165–78.*

Extent of findings

Generally speaking, in differential diagnosis, clinical data and the medical history are the decisive factors. Only complications associated with Crohn's disease or involvement of the small bowel are helpful in distinguishing between Crohn's disease and ulcerative colitis or infectious enteritis. The evaluation of the extent of the findings is an important aspect: although there was originally a stubborn bias against CT and MR enterography as very expensive procedures, these days they are frequently relied upon more. Therefore, improved sonography training is urgently needed as part of the further training required to become a gastroenterologist.

The etiology of inflammatory colitis cannot be determined using ultrasound procedures alone. For example, the rare condition of amoebic colitis does not differ from ulcerative colitis in the ultrasound [1].

In 30 patients with 53 out of 119 altered bowel segments examined using ultrasound and MRI on the same day, sonography was not significantly superior (sensitivity: ultrasound 91%, MRI 83%); the same applied to transmural complications (sensitivity: ultrasound 91%, MRI 83%) [2].

Ultrasound was found to be accurate in a prospective study [3] in 296 patients with Crohn's disease (sensitivity 93%, specificity 97%), and the extent of findings correlated with the results of X-ray diagnostics and endoscopy, and also with the resected bowel segments of patients who had undergone surgery. For 75 radiologically evidenced strictures, ultrasound sensitivity, specificity and PPV were 79%, 98%, and 95% respectively for patients who had not undergone surgery and 90%, 90%, and 100% for the patients who had undergone surgery.

1. *Hussain S, Dinshaw H. Ultrasonography in amebic colitis. J Ultrasound Med. 1990;9(7):385–8.*

2. *Martínez MJ, Ripollés T, Paredes JM, Blanc E, Martí-Bonmatí L. Assessment of the extension and the inflammatory activity in Crohn's disease: comparison of ultrasound and MRI. Abdom Imaging. 2009;34(2):141–8.*
3. *Parente F, Maconi G, Bollani S, Anderloni A, Sampietro G, Cristaldi M, et al. Bowel ultrasound in assessment of Crohn's disease and detection of related small bowel strictures: a prospective comparative study versus x ray and intraoperative findings. Gut. 2002;50(4):490–5.*

Disease activity and detection of complications

Evaluating IBD disease activity is very important, particularly in the case of Crohn's disease. Various methods with various diagnostic criteria are used, including the gold standard of endoscopy with histology and clinical scores. Generally speaking, in the small bowel, endoscopy is limited to the terminal ileum. CT should be used as little as possible due to the radiation exposure involved. The most easily comparable methods are ultrasound and MRI – both non-invasive methods. This also applies to complications of Crohn's disease and ulcerative colitis.

In a systematic review of diagnostics, detection of activity, and complications in Crohn's disease, 68 publications were evaluated with a comparison of methods [1]. In the detection of Crohn's disease, ultrasound was found to have a sensitivity of 84% and a specificity of 92%. The figures for MRI were 90% and 93% respectively, and the results were less dependent on the examiner and the localization of the disease. CT, MRI, and ultrasound were found to be equally accurate with regard to activity and extent of findings. For fistulae, stenoses, and abscesses, there was a very high level of equivalence between the three procedures (sensitivity and specificity > 80%).

In 10 out of > 1700 selected patients with Crohn's disease without fistulae or abscesses in Limberg stage 1 ("hypo-flow"), 3, and 4 ("hyper-flow"), 12 defined segments of the small bowel were surgically removed. In the histopathology, the hyper-flow segments showed significantly increased vascularization and inflammatory cell infiltration, including increased CD163 macrophages, CD3-T lymphocytes, and CD79-B cells ($p = 0.043$), as opposed to the hypo-flow lesions [2]. This can be

regarded as good evidence of the clinical usefulness of the Limberg stages. (Because of the much higher sensitivity of the color Doppler devices, we use an "adapted" Limberg scale in the clinic, which has proven itself in practice).

Although Mayer et al. [3] did not find a sufficient correlation between the extent of segments of wall thickening and the activity indices or laboratory chemistry inflammation parameters in patients with Crohn's disease (n = 137) and ulcerative colitis (n = 32), Calabrese et al. [4] tried to develop a sonography score based on a prospective ultrasound study with oral contrast medium administration in Crohn's disease. The parameters were wall thickness, lumen width, length and number of affected segments, fistulae, abscesses, fibrous-fatty mesenteric thickening, and mesenteric lymphadenopathy. The 5-stage index (A–E) showed a significantly higher value for a CDAI > 150 and for a CRP > 5 mg/L. Patients in classes D and E underwent surgery significantly more frequently than patients in classes A–C during the following year, and this result was highly significant. In a clinical study, this score proved helpful for treatment monitoring [5].

1. *Panés J, Bouzas R, Chaparro M, García-Sánchez V, Gisbert JP, Martínez de Guereñu B, et al. Systematic review: the use of ultrasonography, computed tomography and magnetic resonance imaging for the diagnosis, assessment of activity and abdominal complications of Crohn's disease. Aliment Pharmacol Ther. 2011;34(2):125–45.*
2. *Sasaki T, Kunisaki R, Kinoshita H, Kimura H, Kodera T, Nozawa A, et al. Doppler ultrasound findings correlate with tissue vascularity and inflammation in surgical pathology specimens from patients with small intestinal Crohn's disease. BMC Res Notes. 2014;7:363.*
3. *Mayer D, Reinshagen M, Mason RA, Muche R, von Tirpitz C, Eckelt D, et al. Sonographic measurement of thickened bowel wall segments as a quantitative parameter for activity in inflammatory bowel disease. Z Gastroenterol. 2000;38(4):295–300.*
4. *Calabrese E, Zorzi F, Zuzzi S, Ooka S, Onali S, Petruzziello C, et al. Development of a numerical index quantitating small bowel damage as detected by ultrasonography in Crohn's disease. J Crohns Colitis. 2012;6(8):852–60.*

5. *Zorzi F, Stasi E, Bevivino G, Scarozza P, Biancone L, Zuzzi S, et al. A sonographic lesion index for Crohn's disease helps monitor changes in transmural bowel damage during therapy. Clin Gastroenterol Hepatol. 2014;12(12): 2071–7.*

Detection of fistulae and strictures

Only case reports were initially available regarding detection of fistulae by sonography [1]. In systematic examinations in larger patient populations, sonography proved to be effective in detecting Crohn's-typical complications.

Gasche et al. [2] succeeded in detecting strictures using sonography in 22 out of 22 cases and in excluding them in 10 out of 11 cases. Fistulae were detected in 20 out of 23 cases, and correctly ruled out in 9 out of 10 cases. Intra-abdominal abscesses were correctly identified in 20 out of 22 patients. The sensitivities were all at least 87%, and the specificities were all at least 90%.

A careful study in which 211 Crohn's disease patients received conservative treatment and 85 received surgical treatment found a sensitivity of 93% and a specificity of 97% [3] with regard to the extent of the findings in the ultrasound. Correlation with radiological and surgical findings was good. In the group that received conservative treatment, one or more stenoses were detected by radiology in 75 patients (35.5%), compared to 70 patients (82%) in the surgical treatment group. The study confirms the high diagnostic value of sonography, especially in the case of severe progression of Crohn's disease, but also indicates that the method has a high degree of operator dependency.

A prospective study [4] in a large patient population (n = 625) yielded equivalent results for internal fistulae with both sonography and X-ray (barium contrast). Furthermore, there were no significant differences in the detection of abscesses when ultrasound was compared to CT.

Another monocentric study [5] in 58 patients with follow-up by CT, MRI, endoscopy, or surgical colon resection showed comparably good results (sensitivity and specificity for stenosis 86% and 90%, for fistulae 78% and 95%, for abscesses 90% and 99%).

The power Doppler also proved helpful in the diagnosis of fistulae. It improves the detection of fistulae and does not correlate with the disease activity [6].

1. *Seitz K, Reuss J. Sonographische Fisteldarstellung bei Morbus Crohn. Ultraschall Med. 1986;7(6):281–3.*
2. *Gasche C, Moser G, Turetschek K, Schober E, Moeschl P, Oberhuber G. Transabdominal bowel sonography for the detection of intestinal complications in Crohn's disease. Gut. 1999;44(1): 112–7.*
3. *Parente F, Maconi G, Bollani S, Anderloni A, Sampietro G, Cristaldi M, et al. Bowel ultrasound in assessment of Crohn's disease and detection of related small bowel strictures: a prospective comparative study versus x ray and intraoperative findings. Gut. 2002;50(4):490–5.*
4. *Maconi G, Sampietro GM, Parente F, Pompili G, Russo A, Cristaldi M, et al. Contrast radiology, computed tomography and ultrasonography in detecting internal fistulas and intra-abdominal abscesses in Crohn's disease: a prospective comparative study. Am J Gastroenterol. 2003;98(7):1545–55.*
5. *Neye H, Ensberg D, Rauh P, Peitz U, Mönkemüller K, Treiber G, et al. Impact of high-resolution transabdominal ultrasound in the diagnosis of complications of Crohn's disease. Scand J Gastroenterol. 2010;45(6):690–5.*
6. *Maconi G, Sampietro GM, Russo A, Bollani S, Cristaldi M, Parente F, et al. The vascularity of internal fistulae in Crohn's disease: an in vivo power Doppler ultrasonography assessment. Gut. 2002;50(4):496–500.*

Fibrolipomatosis of the mesentery – a diagnostic criterion that receives too little attention

Fibrolipomatosis of the mesentery is regarded as a newer sign in Crohn's disease. It was initially observed by CT, especially in the upper right quadrant [1, 2]. In a larger study [3], mesenteric hypertrophy (the wrapping of mesenteric fat over the bowel loops) was detectable in almost half of cases, and it was also associated with disease activity. In inactive Crohn's disease, mesenteric hypertrophy was only detectable in about 20% of cases.

1. *Herlinger H, Furth EE, Rubesin SE. Fibrofatty proliferation of the mesentery in Crohn disease. Abdom Imaging. 1998;23(4):446–8.*

2. *Golder WA. The "creeping fat sign" – really diagnostic for Crohn's disease? Int J Colorectal Dis. 2009;24(1):1–4.*
3. *Maconi G, Greco S, Duca P, Ardizzone S, Massari A, Cassinotti A, et al. Prevalence and clinical significance of sonographic evidence of mesenteric fat alterations in Crohn's disease. Inflamm Bowel Dis. 2008;14(11):1555–61.*

Fibrosis or inflammatory stenosis?

A current systematic review of all ultrasound techniques, which includes the current literature on CEUS and elastography is available from Coelho et al. [1].

Summary: Sonography with color Doppler, CEUS, and elastography (with some limitations) are helpful for differentiation, but a reliable distinction is not possible.

In a study by Lenze et al. [2], which compared ^{18}F-FDG-PET/CT, MRI and transabdominal ultrasound with endoscopic/histological findings in 30 patients with 37 strictures, PET/CT and MRI performed slightly better than ultrasound (81%, 81%, and 68% respectively) when it came to detecting strictures; correct differentiation between fibrous, inflammatory or mixed was achieved in 57%, 53% and 40% of cases respectively. The differentiation between strictures caused by inflammation and those caused by scarring remains equally insufficient across all methods.

The combinations of PET/CT + ultrasound and MRI + ultrasound proved successful in the detection of strictures regardless of genesis in all cases.

1. *Coelho R, Ribeiro H, Maconi G. Bowel thickening in Crohn's disease: fibrosis or inflammation? Diagnostic ultrasound imaging tools. Inflamm Bowel Dis. 2017;23(1):23–34.*
2. *Lenze F, Wessling J, Bremer J, Ullerich H, Spieker T, Weckesser M, et al. Detection and differentiation of inflammatory versus fibromatous Crohn's disease strictures: prospective comparison of 18F-FDG-PET/CT, MR-enteroclysis, and transabdominal ultrasound versus endoscopic/histologic evaluation. Inflamm Bowel Dis. 2012;18(12):2252–60.*

Follow-up monitoring

The efficacy of ultrasound follow-up monitoring, which was in clinical use at an early stage, has now been documented in publications several times, and may be used as an alternative to colonoscopy in IBD. In the sonography, wall thickness and Doppler signals are used to assess disease activity [1, 2]. Calabrese et al. [3] have emphasized the important role of ultrasound both with and without CEUS. A warning against use by inexperienced examiners is given (note: it would be more accurate to say poorly trained or untrained examiners) in the case of POCUS (point of care ultrasound). Ultrasound is recommended for monitoring patients with known Crohn's disease, especially with regard to complications (stenosis, ileus).

Kucharzik et al. [4] recently published a careful, prospective multicenter study on follow-up monitoring in Crohn's disease. They used bowel wall thickness, fibrous/fatty mesenteric proliferation, detection of lymphadenopathy, fistulae, strictures, and the Limberg score as parameters for disease activity. These gastroenterologists and sonography users found that sonography is an ideal method for follow-up monitoring if the diagnostic criteria are taken as a whole.

In severe ulcerative colitis requiring high-dose steroid therapy [1, 2], the endoscopic and sonographic severity (wall thickness, color Doppler) were investigated using clinical scores over the course of 15 months.

Higher endoscopic and sonographic scores were associated with a high risk of active ulcerative colitis after 15 months.

According to the authors, sonography can be used by experienced examiners as a replacement for colonoscopy or as a follow-up monitoring method [5].

In a pilot study [6] using DE-CEUS in 14 Crohn's disease patients, one month after initiation of treatment, 8 patients with treatment response and 6 patients in which treatment had no effect showed significant differences in peak contrast enhancement ($p = 0.013$), rate of wash-in ($p = 0.020$) and wash-out ($p = 0.008$), and time-intensity AUC in the wash-in phase. The authors believe that it is possible to predict the therapeutic effect with DE-CEUS.

In 30 patients with Crohn's disease [7], Crohn's Disease Endoscopic Inflammatory Index of Severity

(CDEIS) and transabdominal ultrasound (wall thickness, color Doppler, CEUS) showed a good correlation after 1 year of treatment with biologics or immunomodulators. Out of 18 patients with a CDEIS < 6 points, 15 patients had inconspicuous ultrasound findings; the bowel wall thickness was the most reliable parameter.

It remains doubtful whether the introduction of a quantitative ultrasound score for oral small bowel contrast imaging can be accepted in practice in light of the excellent results achieved by Kucharzik et al. [4].

1. *Parente F, Molteni M, Marino B, Colli A, Ardizzone S, Greco S, et al. Bowel ultrasound and mucosal healing in ulcerative colitis. Dig Dis. 2009;27(3):285–90.*
2. *Maconi G, Ardizzone S, Parente F, Bianchi Porro G. Ultrasonography in the evaluation of extension, activity, and follow-up of ulcerative colitis. Scand J Gastroenterol. 1999;34(11): 1103–7.*
3. *Calabrese E, Zorzi F, Lolli E, Pallone F. Positioning ultrasonography into clinical practice for the management of Crohn's disease. Gastroenterol Hepatol (NY). 2015;11(6):384–90.*
4. *Kucharzik T, Wittig BM, Helwig U, Börner N, Rössler A, Rath S, et al. Use of intestinal ultrasound to monitor Crohn's disease activity. Clin Gastroenterol Hepatol. 2017;15(4):535–42.e2.*
5. *Parente F, Molteni M, Marino B, Colli A, Ardizzone S, Greco S, et al. Are colonoscopy and bowel ultrasound useful for assessing response to short-term therapy and predicting disease outcome of moderate-to-severe forms of ulcerative colitis?: a prospective study. Am J Gastroenterol. 2010;105(5):1150–7.*
6. *Saevik F, Nylund K, Hausken T, Ødegaard S, Gilja OH. Bowel perfusion measured with dynamic contrast-enhanced ultrasound predicts treatment outcome in patients with Crohn's disease. Inflamm Bowel Dis. 2014;20(11): 2029–37.*
7. *Moreno N, Ripollés T, Paredes JM, Ortiz I, Martínez MJ, López A, et al. Usefulness of abdominal ultrasonography in the analysis of endoscopic activity in patients with Crohn's disease: changes following treatment with immunomodulators and/or anti-TNF antibodies. J Crohns Colitis. 2014;8(9):1079–87.*

Sonography and surgical treatment

In the case of involvement of the small bowel in Crohn's disease, endoscopic diagnostics are limited. However, in this same region, stenoses, fistulae, and loop abscesses requiring repeated surgical interventions often occur. Since ultrasound can detect these complications in a non-invasive manner and with a high degree of sensitivity and specificity, sonography is a valuable tool for surgeons [1] in terms of establishing an indication and choosing the most targeted surgical procedures possible.

Preoperative ultrasound findings using orally-administered contrast for imaging of the small bowel were compared with the resection findings in 49 patients [2]. In this study, 39 out of 40 solitary strictures were correctly detected and solitary strictures were correctly excluded in 9 cases; 32 or more strictures were correctly identified in 9 out of 12 patients, fistulae were correctly identified in 27 out of 28 cases and correctly excluded in 19 out of 21 cases, and all 10 abscesses were correctly identified.

A resection study [3] showed good agreement with regard to stenosis and sonographic and pathological inflammatory scores in Crohn's disease. Similarly, transmural complications, color Doppler grading, and the increase in contrast enhancement correlated with the pathological inflammation score.

A study in 60 Crohn's disease patients [4] using sonography (wall thickness, transmural complications, color Doppler, and CEUS) for the detection of a recurrence of disease after surgical treatment provided excellent results that agreed with the endoscopy results for recurrence after surgical treatment.

1. *Botti F, Caprioli F, Pettinari D, Carrara A, Magarotto A, Contessini Avesani E. Surgery and diagnostic imaging in abdominal Crohn's disease. J Ultrasound. 2013;18(1):3–17.*
2. *Pallotta N, Vincoli G, Montesani C, Chirletti P, Pronio A, Caronna R, et al. Small intestine contrast ultrasonography (SICUS) for the detection of small bowel complications in Crohn's disease: a prospective comparative study versus intraoperative findings. Inflamm Bowel Dis. 2012;18(1):74–84.*

3. *Ripollés T, Rausell N, Paredes JM, Grau E, Martínez MJ, Vizuete J. Effectiveness of contrast-enhanced ultrasound for characterisation of intestinal inflammation in Crohn's disease: a comparison with surgical histopathology analysis. J Crohns Colitis. 2013;7(2):120–8.*
4. *Paredes JM, Ripollés T, Cortés X, Moreno N, Martínez MJ, Bustamante-Balén M, et al. Contrast-enhanced ultrasonography: usefulness in the assessment of postoperative recurrence of Crohn's disease. J Crohns Colitis. 2013;7(3): 192–201.*

Sonography in the IBD guidelines

Sonography has become an established part of German and European guidelines. Naturally, ultrasound diagnostics are of more value in Crohn's disease than in ulcerative colitis. Under the somewhat older guidelines of the American Gastroenterological Association (AGA), sonography does not play any role in the management of Crohn's disease and ulcerative colitis.

The EFSUMB is preparing guidelines on sonography of the GI tract and these will soon be freely available on the Internet (www.efsumb.org).

The German guidelines [1] basically favor MR enterography among the tomography imaging methods because it does not involve radiation exposure; its use is recommended for initial diagnostics in the small bowel (Key recommendation 1–9: An MRI of the small bowel [enterography or enteroclysis] should be used for the initial small bowel diagnostics [I, ↑, strong consensus]; Key recommendation 1–10: In the further course of the disease, sonography can be used as a primary imaging method for the assessment of disease activity. If assessment is difficult, endoscopy and MRI can be used depending on the primary localization [I, ↑, strong consensus]).

However, the following section places great importance on sonography:

"The sensitivity and specificity of sonography compared to a gold standard consisting of clinical signs, endoscopy, X-ray, and surgical inspection were evaluated in a non-consecutive cohort study at 87% (95% CI: 65–97%) and 100% (56–100%) respectively [2]. In a second study for the evaluation of wall layering only, in comparison to endo-

scopic activity as the gold standard, sonography achieved a sensitivity of 90% (95% CI: 80–100%) and a specificity of 100% (95% CI: 100–100%) and for the evaluation of wall thickness, it achieved a sensitivity of 90% (95% CI: 80–100%) and a specificity of 94% (95% CI: 82–100%). The correlation between these two parameters and the CDAI was found to be good (r = 0.60 or r = 0.67) [3]. Transabdominal sonography should therefore be carried out as an initial basic examination performed by experienced examiners during the course of the disease."

The main statement of the current European recommendation [4] is as follows:

"Cross-sectional imaging (MRI and CT enterography) and transabdominal ultrasonography (US) are complementary to endoscopy and offer the opportunity to detect and stage inflammatory, obstructive and fistulising CD (EL1).

Radiation exposure should be considered when selecting techniques, especially to monitor follow-up (EL4).

A meta-analysis comparing the accuracies of US, MRI, scintigraphy, CT and positron emission tomography (PET) for diagnosis in patients with suspected or known IBD, mainly CD, showed that mean sensitivity estimates for the diagnosis of IBD on a per-patient basis were high and not significantly different among the imaging modalities. CT and MRI are the current standards for assessing the small intestine.

Cross-sectional imaging techniques are needed after endoscopy to allow a complete and sensitive staging of the small bowel and perineum with the unique advantage to assess mural and extramural disease (ESGAR evidence-based consensus guideline)," and [...] "US, CT and MRI have a high accuracy for the assessment of penetrating complications (i.e. abscess, fistulae). In a systematic review, using surgery as a reference standard for fistulizing lesions, US demonstrated a sensitivity of 74% and specificity of 95%, CT 79% and 97%, and MRI 76% and 96%, respectively."

1. *Preiß JC, Bokemeyer B, Buhr HJ, Dignaß A, Häuser W, Hartmann F, et al. Aktualisierte S3-Leitlinie –„Diagnostik und Therapie des Morbus Crohn" 2014. AWMF-Registriernummer: 021–004. Z Gastroenterol. 2014;52(12): 1431–84.*

2. *Miao YM, Koh DM, Amin Z, Healy JC, Chinn RJ, Zeegen R, et al. Ultrasound and magnetic resonance imaging assessment of active bowel segments in Crohn's disease. Clin Radiol. 2002;57(10):913–8.*
3. *Migaleddu V, Scanu AM, Quaia E, Rocca PC, Dore MP, Scanu D, et al. Contrast-enhanced ultrasonographic evaluation of inflammatory activity in Crohn's disease. Gastroenterology. 2009;137(1):43–52.*
4. *Gomollón F, Dignass A, Annese V, Tilg H, Van Assche G, Lindsay JO, et al. 3rd European Evidence-based Consensus on the Diagnosis and Management of Crohn's Disease 2016: Part 1: Diagnosis and Medical Management. J Crohns Colitis. 2017;11(1):3–25.*

FALK FOUNDATION e.V.

Leinenweberstr. 5
79108 Freiburg
Germany

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