Mistakes in gastrointestinal ultrasound and how to avoid them

Andreas J. Gjengstø, Kim Nylund, Hilde L. von Volkmann and Odd H. Gilja

Ultrasound is a routine diagnostic procedure widely used in gastroenterology departments worldwide, and gastrointestinal ultrasound (GIUS) has become increasingly important in diagnosing and following gastrointestinal disorders.[1-4] Being a real-time imaging modality, it has some advantages over static imaging modalities such as CT and MRI, and it allows the examiner to perform various techniques and methods to enhance visualisation. GIUS requires more than essential ultrasound experience, and acquiring good images for correct interpretation can be challenging even for the experienced examiner. As such, there are several pitfalls that clinicians should be aware of. Based on our clinical experience with an evidence-based approach, we present the ten most common mistakes made in gastrointestinal ultrasound and how to avoid them.

Mistake 1 Using the wrong ultrasound equipment

Ultrasound technology has dramatically progressed and there are multiple types of ultrasound machines with different applications installed. The scanners range from low-end hand-held portable devices to high-end machines with highly advanced functionalities. The hand-held devices have revolutionised the use of ultrasound in the clinic and are well-suited for point-of-care ultrasound (POCUS) examinations. However, they have lower-resolution images and smaller screens, and it can be challenging to find a suitable position for the device while using it.[5] Examining the intestinal tract with suboptimal image quality can be frustrating, so using the correct ultrasound equipment is essential. For GIUS, a medium range to high-end machine with high-resolution images and a large screen size is recommended. The scanner should also be equipped with Doppler modes to assess the vascularity of intestinal segments and basic measurement tools to assess intestinal wall thickness. For documentation and communication with colleagues, it is important that the scanner can label and store images and videos. The curvilinear probe uses longer wavelengths (2-5 MHz) than the linear probe and has better depth penetration, so we recommend using a curvilinear probe for an overall assessment of the abdominal anatomy. However, we recommend using a linear probe with a frequency range of 7-12MHz for a detailed examination of intestinal segments and wall layers. It is crucial that the investigator can visually separate the intestinal wall layers, which the linear probe enables. Accordingly, a suitable scanner with the optimal ultrasound probe and frequency is paramount.

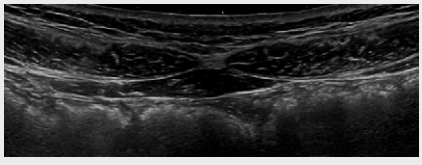

Figure 1 | Rectus muscles and linea alba anteriorly and the transverse colon with visible haustrations. Only the anterior wall of the colon is visible because of air and faecal contents in the colon.

Mistake 2 Failure to distinguish between the large and small intestine

The large and small intestine have distinct features that differentiate them physiologically and anatomically. We can therefore use these features to our advantage. Physiologically the colon is filled with air and slow-moving faecal content, and the colonic wall has visible haustrations with sparse motility (Figure 1). On the contrary, the small intestine has frequently visible contractions, visible mucosal folds (valvula conniventes in the jejunum) and soft-moving contents. The size and number of the mucosal folds in the small intestine decrease significantly towards the distal portion of the ileum. This feature can be used to distinguish the jejunum from the ileum.[2] (Figure 2)

As a general anatomical guide, the duodenum is in the epigastrium, and particularly the duodenal bulb can be identified by scanning the pylorus from the antrum. The jejunum is often seen in the left upper quadrant and the ileum in the right lower quadrant. However, due to intra- and inter-individual variability, loops of the ileum and jejunum can be found in all quadrants, while the terminal ileum is visualised in the right iliac fossa.

The ascending and descending colon have fixed positions and are in the abdominal flanks. However, the transverse colon is not firmly fixed to the abdominal wall, so that it can lie in the epigastric or the periumbilical region. In contrast, the sigmoid colon is found in the left iliac fossa and the rectum in the suprapubic region behind the bladder.

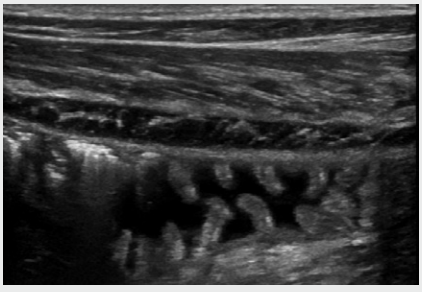

Figure 2 | Valvula conniventes of the jejunum depicted with a high-frequency ultrasound probe (15 MHz).

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Andreas J. Gjengstø is a Consultant at Department of Medicine, Haukeland University Hospital, Haukelandsbakken 22, 5021 Bergen, Norway and currently working on his Ph.D at the University of Bergen, Norway. **Kim Nylund** is an Associate Professor at the Department of Clinical Medicine, University of Bergen and a Consultant and Clinical Researcher, Department of Medicine, Haukeland University Hospital, Bergen, Norway· **Hilde L. von Volkmann** is a Consultant gastroenterologist, Head of the IBD-group Section of Gastroenterology, Department of Medicine, Haukeland University Hospital, Norway. **Odd H. Gilja** is a Professor at the Department of Clinical Medicine, University of Bergen; Senior Consultant and Director at National Centre for Ultrasound in Gastroenterology, Haukeland University Hospital, Bergen, Norway.
Illustrations: J. Shadwell

Correspondence to: andreas.jessen.gjengsto@helse-bergen.no
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Mistake 3 Not using appropriate preparation or techniques for optimal visibility

Visibility depends on many factors; the examiner may improve some of them with the proper technique. In general, no preparation is required to perform GIUS.[2] Fluid installation, laxatives and anti-flatulent preparations do not improve results markedly. [6,7] To reduce the amount of food and air in the small bowel, a four-hour fasting period is recommended. However, this may only significantly improve visibility in some cases.[8,9]

The scanning technique depends on the bowel segment you want to examine. The investigator should have a systematic strategy for an overall scanning of the intestines with the linear probe. 'Mowing the lawn' is a strategy where you examine the small intestine while moving the probe in parallel overlapping lanes caudally to cranially from right to left while applying sufficient probe pressure. The small intestine in the upper part of the abdomen usually moves with respiration, so asking the patient to take a deep breath and hold it will allow for better pathology identification. A full bladder is also an advantage as it pushes the small intestine into the abdomen and makes it accessible for scanning. To improve the investigators' confidence in excluding pathology, care should be taken to identify the dorsal wall of the abdominal cavity if possible. Intestinal gas reduces visibility distally to the gas but helps delineate the intestinal wall from the lumen. If air, intestinal contents, or intraabdominal fat occludes the view, graded compression with the ultrasound probe may improve the image quality and assessment of the intestinal wall. In other cases, the intraluminal gas can be avoided entirely by using an oblique viewing angle in relation to the abdominal wall.

A different approach is recommended for the colon. Although graded compression can sometimes enable the examiner to see through the colon, it is challenging and impossible in deeper-lying segments such as the left flexure and distal sigmoid. Scanning the colon in the longitudinal axis is recommended for identifying the outline of the haustra, which is used to identify the colon. The ascending and descending colon can be found by starting in both flanks with a longitudinal section and moving the probe medially. The transverse colon can be found by starting at the level of the epigastrium with a transverse section and moving caudally. The proximal sigmoid colon can be found in the left fossa in a transverse section by starting over the iliopsoas muscle and moving cranially. A filled bladder helps inspect the rectum in the suprapubic region, as it acts as an acoustic window and improves visibility beyond the bladder. Identifying the iliopsoas muscle and ileum should be the primary strategy when trying to locate the appendix. The appendix can be found by scanning between these two structures. If the cecum is deep in the pelvis or the direction of the appendix is retrocecal, the task is complex. However, the cecum usually rests in the lower right flank just over the iliopsoas, so a steady hand combined with graded compression can help identify the appendix as a small tubular structure typically 3-4 mm in diameter.

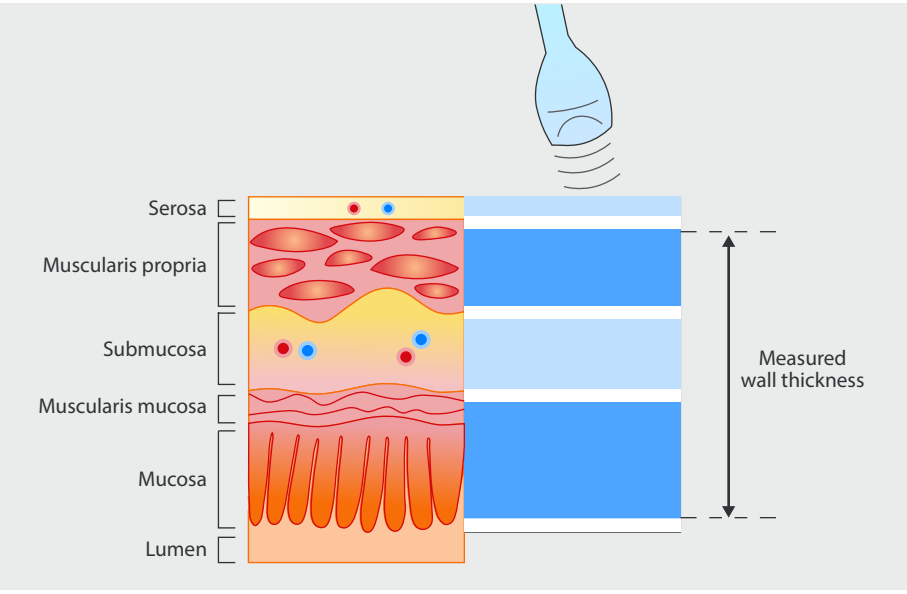

Figure 3 | An illustration with a histological section of the intestinal wall (left) and the corresponding sonographic layers (right). The bright white layers in between are the interface echoes which signify the transition from one wall layer to the next. The thickness of the anterior GI wall is measured from the start of the hypoechoic layer corresponding to the muscularis propria to the end of the hypoechoic area corresponding to the mucosa. The thickness of the anterior wall is slightly reduced compared to histology since the interface echo between the serosa and the muscularis propria is not included in the measurement.

Mistake 4 Failure to change strategy when visibility is poor

Failure to obtain the intended images can be frustrating, so have a strategy when visibility is poor before the examination ends. First, return to an identified reference point proximally or distally and follow that structure to the area of interest as far as possible. Segments that are easy to use as reference points are the terminal ileum as it crosses the right iliopsoas muscle, the ascending and descending colon in the flanks and the proximal sigmoid colon as it crosses the left iliopsoas muscle.[2] However, some patients have undergone gastrointestinal surgery. Thus, it is essential to be aware of changes in their anatomy. The investigator should therefore have a basic understanding of the main types of gastrointestinal surgery with its respective anatomical changes. Sometimes, you will not complete an overview of the area of interest. Accordingly, the investigator should use all the various techniques and piece together the findings to make a clinical judgement.

Mistake 5 Incorrect measurement of intestinal wall thickness

Bowel wall thickness is an instrumental measurement and is frequently used in GIUS. Increased thickness can indicate inflammation or oedema, as seen in inflammatory bowel disease or gastrointestinal infections. The overall thickness should be measured under mild compression from just above an air-mucosal interface in the lumen to the outside of the outer muscular propria layer border.[10] However, as the bowel is a dynamic structure, performing a correct measurement can be challenging.

Gas-filled bubbles in the intestine will help with the measurement as they float within the lumen and lie along the mucosal surface. On ultrasound, these bright white gas bubbles act as the border between the lumen and mucosa. To measure the thickness of the intestinal wall, the first cursor is set at this transition echo. The transition echo between the muscular propria and serosa is also bright white and will act as the outer border of the intestinal wall. Here, the second cursor is set. You get the correct measurement by measuring the distance between these two cursors (Figure 3). An incorrect measurement will often lead to overestimating the bowel wall thickness.[11]

A collapsed bowel without luminal content or a contracting bowel segment will appear thicker. Thus, avoid measuring mid-contraction or over haustra and mucosal folds. However, measuring in collapsed bowel segments is sometimes unavoidable. In these cases, the wall layers tend to blend, so separating the mucosal folds from the wall can be difficult. The examiner can even out the mucosal folds by compressing the bowel

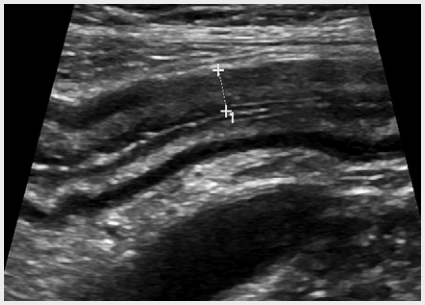

Figure 4 | Thickened wall in the sigmoideum of a patient with Ulcerative Colitis. Note the partial loss of wall layers (partial loss of stratification) and position of the cursors for accurate measurement.

with the probe to reduce overestimation (Figure 4). A lack of colour Doppler signal in these segments could help with the decision-making and clinical judgement, but repeating the examination later could also solve this issue.

The examiner needs to be aware that the wall will appear thicker if the ultrasound section through the bowel wall is oblique, so the imaging plane should be perpendicular to the surface of the bowel.

The normal thickness of the stomach wall is 3-5 mm; the normal small intestinal wall is between 1-3 mm, and the colon is 0.5-2 mm.[11]

Measuring the intestinal wall thickness can also be beneficial in addition to endoscopy. Some patients with inflammatory bowel disease are unable to undergo a full ileocolonoscopy due to technical or patient related factors. To identify the severity and full extent of inflammation in these patients, ultrasound can be used to examine the remaining area of interest.

Mistake 6 Using inadequate colour Doppler technique

Colour Doppler (and Power Doppler) ultrasound measures the vascularity in the mesentery close to the bowel and the smaller vessels in the bowel wall. Due to improvements in Doppler technology, Colour Doppler is the dominant feature. Colour Doppler can aid in deciding whether a pathological bowel segment is inflamed, which gives an increased Doppler signal, or fibrous, which contains mostly scar tissue and has no or few Colour Doppler signals. The Colour Doppler sector should be adapted to the bowel region of interest and include the adjacent mesentery. Respiration can also affect the Doppler results, so the patient should hold their breath while measuring the Doppler signal. A high pass filter of 100-200 kHz should eliminate low frequencies related to vessel wall movement, and the Doppler gain should be turned down until flash artefacts disappear before assessing vascularity.[12, 13] (Figure 5)

A practical advice for setting correct Doppler gain is to use the gallbladder as a reference. With the colour Doppler sector covering the gallbladder, turn the Doppler gain to max and then turn it down until there is no more Doppler noise within the gallbladder. This confirms the correct gain level.

Colour Doppler is considered present when the signal persists throughout the observation period and/or reoccurs in the exact location. Suppose a Doppler signal is not detected in a pathologically thickened intestinal wall. In that case, this might be due to insensitivity of the equipment, inadequate Doppler parameters, high body mass index or depth of >40mm from the skin to the bowel, which results in loss of sensitivity. Bowel wall vascularity is graded according to the number of vessels detected, and various scoring systems are available to quantify these findings.[14-17]

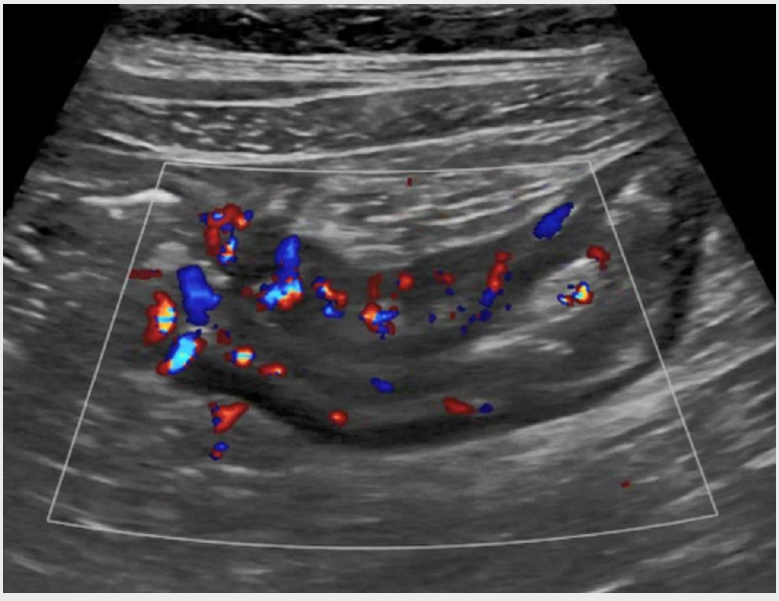

Figure 5 | Colour Doppler image of ileal wall thickening with increased Doppler signals in the anterior and posterior wall.

Mistake 7 Failure to assess intestinal motility

The ability to assess intestinal motility is one of the advantages of real-time ultrasound. However, it is often overlooked and rarely documented. There are many reasons for this, and there needs to be more consensus on what defines normal intestinal motility on ultrasound. Motility can be studied directly by documenting peristaltic contractions or indirectly by studying transit times. Peristaltic contractions are divided into occlusive/non-occlusive and propagating/non-propagating contractions. Occlusive contractions fully contract so the opposing intestinal walls close the lumen, while non-occlusive contractions do not. Propagating contractions start from point A and move along the bowel wall to point B continuously, while non-propagating contractions stay in one place. The implications of these findings are not fully understood to date, but it is still helpful to detect gross deviation of motility. A thickened stiff bowel wall with reduced or no motility, a narrow lumen <1cm and proximal dilatation >2,5cm with hyperperistalsis of the prestenotic gut is characteristic of a stenosis.[18, 19] (Figure 6). Hyperperistalsis can also be seen in some patients with coeliac disease, where there is an abnormal increase in intestinal fluid in the fasting state with active peristalsis. This causes slow-moving luminal air and chyme to whirl quickly back and forth (washing-machine phenomenon).[20] Mechanical obstruction can also present either with hyperperistalsis or hypoperistalsis. In acute small bowel obstruction, hyperperistalsis is common, but this may shift to hypoperistalsis in the later stages.[21]

Mistake 8 Failure to look outside the bowel

Pathological sonographic findings outside the bowel often accompany pathology in the intestine. Looking outside the bowel is, therefore, an essential part of GIUS.

Pathologically enlarged mesenteric lymph nodes are hypoechoic oval-shaped structures with a short axis diameter > 5mm.[22] They are often regional and adjacent to the pathology in the bowel and are found in many intestinal diseases.[23] Colour Doppler can also differentiate between a blood vessel and a lymph node (Figure 7).

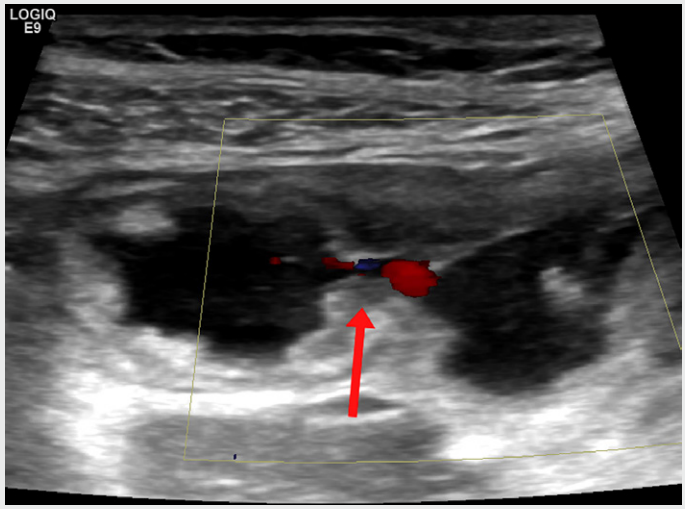

Figure 6 | A short stenosis (< 1 cm) (red arrow) with compromised flow through the stricture and no Doppler signals in the wall indicating less inflammatory activity and more fibrosis.

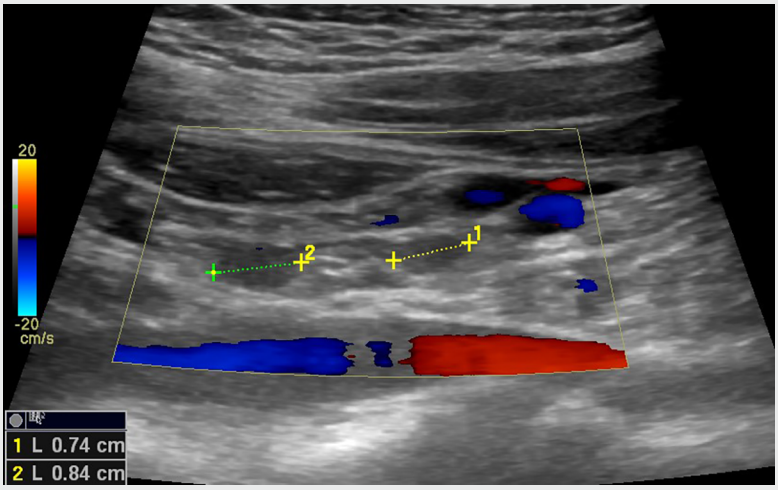

Figure 7 | Two lymph nodes (marked 1 and 2) in the mesentery of a patient with Crohn's disease. Colour Doppler is applied to distinguish lymph nodes from blood vessels.

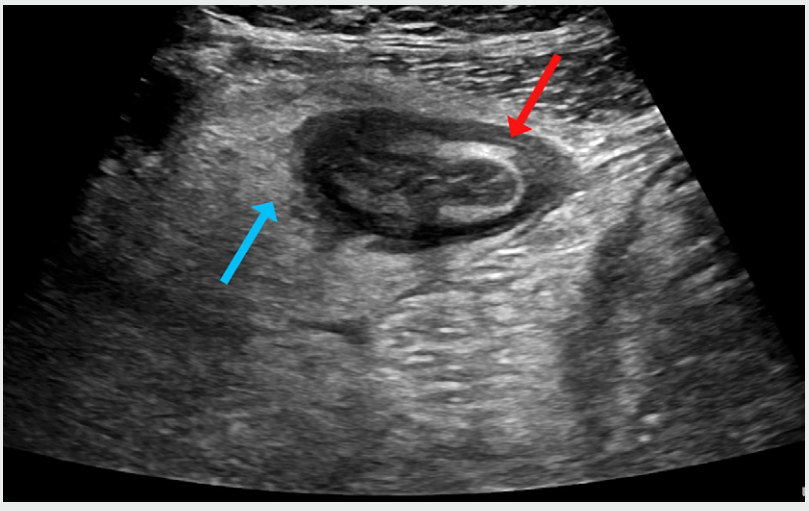

Figure 8 | Thickened bowel wall in Crohn's disease resembling a target lesion (red arrow) with transmural activity and fatty wrapping (blue arrow).

Mesenteric fat hypertrophy (fatty wrapping) is another extra-intestinal finding associated with transmural inflammation, fibrosis, muscular hypertrophy, and strictures. It is visualised as a hyperechoic mass encircling the affected bowel (Figure 8).[24, 25] Mesenteric fat hypertrophy is associated with clinical and biochemical disease activity in Crohn's disease and may improve in patients who respond to medical treatment.[26, 27]

Abscesses are pus-filled cavitations characterised as hypo/anechoic lesions containing fluid and sometimes gaseous artefacts with posterior enhancement[1] (Figure 9). They can lie deep in the pelvis and may be missed on ultrasound or mistaken for inflammatory masses or phlegmons. Ultrasound is also helpful to visualise fistulas and sinus tracts. Their diagnostic criteria are similar to hypoechoic areas or tracts with or without gas, sometimes originating from a visible defect in the bowel wall. With ultrasound, these tracts can be followed until their end, where abscesses or inflammatory masses can occasionally be identified.[12, 28]

Furthermore, if the cause of patients' complaints is not detected during GIUS, the operator should look for extra-intestinal pathology. Visualising the pancreas is relevant in patients under investigation for GI symptoms such as diarrhoea. However, if the pain is a dominating symptom, a brief look at the gallbladder, kidney, or ovaries could reveal the pathology.

Mistake 9 Misinterpreting the image

There are both patient and practitioner-related factors that can affect image interpretation. Some patient-related factors have been mentioned above, while some of the practitioner-related errors that can lead to misinterpretation in sonography are: [29, 30]

- Complacency and faulty reasoning: Errors of over-reading and misinterpretation. Where a finding is appreciated but is attributed to the wrong cause or erroneous classification of the finding.
- Lack of knowledge: The finding is seen but is attributed to the wrong cause because of lack of knowledge on the part of the viewer.
- Under-reading: The finding is missed.

As ultrasound is operator dependent, it is important to continuously improve the skills and knowledge required to achieve diagnostic reliability comparable to published guidelines. [31] It is also essential to have enough time to complete a thorough examination and to interpret and review the images with a second expert if needed. At the same time, the equipment needs to be regularly maintained to meet the accepted manufacturer standards for optimal diagnostic reliability.

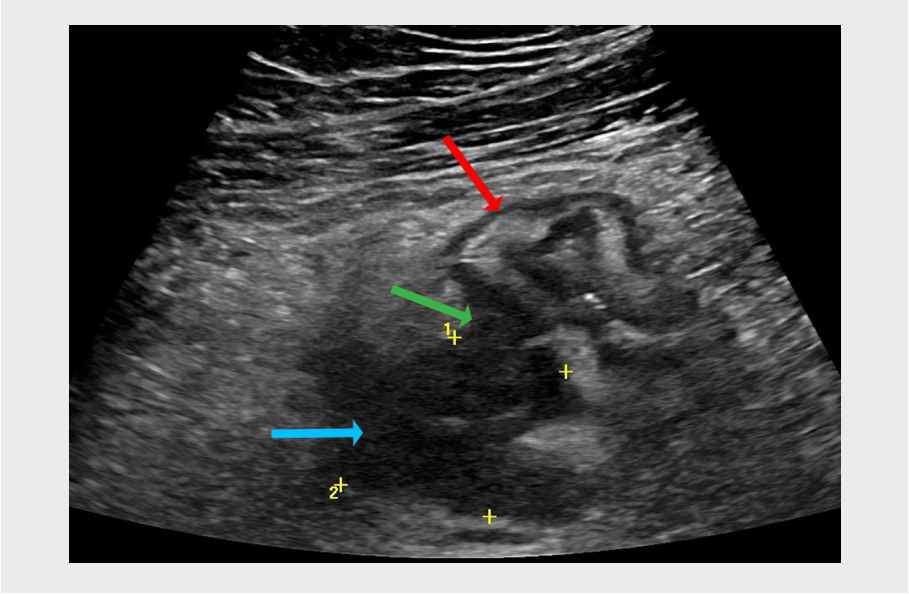

Figure 9 | Peri-intestinal abscess (blue arow) adjacent to an inflamed and thickened bowel segment in Crohn's disease (red arrow). The abscess is hypoechoic and communication with the bowel wall can be observed as a hypoechoic sinus tract (green arrow).

Mistake 10 Failure to document the examination

With improper documentation, it is not easy, both medically and legally, to act on that information. The examination documentation should include both a written report and saved images/video loops with relevant measurements and annotations. Different parts of the intestine can appear very similar, and thus, the segments in question should be named. Adding the probe's orientation to the media files is also helpful, especially with challenging examinations.

It is important to document the degree of visibility as it indicates the examination's overall quality and the findings' sensitivity and specificity. Relevant structures that are not visible should also be reported as such. Documenting the thickness, length, and distribution of bowel wall thickening and assessing the preservation of intestinal wall layers is essential.[2] Other findings suggesting inflammation are lymphadenopathy and free fluid, while fatty wrapping is a particular finding in Crohn's disease and should be reported as such. Complications from inflammatory bowel disease, such as fistulas, abscesses, strictures, and bowel dilatation, are relevant findings that characterise the severity of the disease and must be documented. Using appropriate scoring systems for individual diseases is also helpful in standardising the measurements taken. The ultrasound machines should preferably be connected to a digital media archive, allowing images to be stored and accessed through the patient journal for future reference while maintaining data safety. For the written report, it is, in our experience, both helpful and efficient to use a standardised ultrasound template where the examiner makes changes depending on the documented findings.

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Your gastrointestinal ultrasound briefing

UEG week

- 'Intestinal Ultrasound at IBD diagnosis predicts major disease events – A Copenhagen IBD cohort study' session at UEG Week 2022 [https://ueg.eu/library/intestinal-ultrasound-at-ibd-diagnosis-predicts-major-disease-events-a-copenhagen-ibd-cohort-study/65733a70-9363-11ed-9eff-0242ac140004]
- 'Prognostic value of intestinal ultrasound parameters for long-term outcomes in IBD patients – One year interim results of the TRUST BEYOND study' session at UEG Week Virtual 2021 [https://ueg.eu/library/prognostic-value-of-intestinal-ultrasound-parameters-for-long-term-outcomes-in-ibd-patients-one-year-interim-results-of-the-trust-beyond-study/093732a8-9362-11ed-be47-0242ac140004]
- 'Intestinal ultrasound response and transmural healing after 48 weeks of treatment with ustekinumab in Crohn's disease: STARDUST trial substudy' session at UEG Week Virtual 2020 [https://ueg.eu/library/intestinal-ultrasound-response-and-transmural-healing-after-48-weeks-of-treatment-with-ustekinumab-in-crohns-disease-stardust-trial-substudy/dbb08320-9361-11ed-9084-0242ac140004]

Standards and Guidelines

- Dietrich CF, et al. EFSUMB Gastrointestinal Ultrasound (GIUS) Task Force Group: Celiac sprue and other rare gastrointestinal diseases ultrasound features. *Med Ultrason* 2019; 21 (3), 299–315. [https://doi.org/10.11152/mu-2162 [https://ueg.eu/library/efsumb-recommendations-and-guidelines-for-gastrointestinal-ultrasound-part-5-efsumb-gastrointestinal-ultrasound-gius-task-force-group-celiac-sprue-and--other-rare-gastrointestinal-diseases-ultrasound-features/e9361934-9360-11ed-acdb-0242ac140004]
- Maconi G, et al. Gastrointestinal ultrasound in functional Disorders of the gastrointestinal Tract - EFSUMB Consensus Statement. *Ultrasound Int Open* 07(01), E14–E24. 2021; (1): E14-E24. doi: 10.1055/a-1474-8013. Epub 2021 May 28. PMID: 34104853; PMCID: PMC8163523
- Hollerweger A, et al. Gastrointestinal Ultrasound (GIUS) in Intestinal Emergencies – An EFSUMB Position Paper. *Ultraschall Med* 2020; 41 (06), 646–657. https://doi.org/10.1055/a-1147-1295 [https://ueg.eu/library/efsumb-recommendations-and-guidelines-for-gastrointestinal-ultrasound-part-6-efsumb-guidelines-gius-intestinal-emergencies-position-paper/e9416faa-9360-11ed-b764-0242ac140004]