Review Article

Point-of-care Ultrasound of the Gastrointestinal Tract

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Abstract

The widespread use of portable ultrasound scanners has promoted the concept of point of care ultrasound (POCUS), namely "ultrasound performed bedside and interpreted directly by the clinician." The purpose of this short review is to outline how POCUS can be used in patients with diseases of the gastrointestinal (GI) tract. POCUS is not a replacement for comprehensive ultrasound, but rather allows physicians immediate access to clinical imaging for rapid diagnosis and efficient work-up and treatment of the patients. There are many indications for doing POCUS of the GI tract, including abdominal pain, diarrhea, palpable masses, and to detect fluid or free air in the abdominal cavity. To improve the visibility of deeper parts of the abdomen, the graded compression technique with the scan head is useful. During POCUS, the operator should look for signs of severe pathology including target lesions, the pseudo-kidney sign, the onion sign, dilated bowel loops, gastric retention, free fluid, and free air, depending on the actual clinical problem. We conclude that POCUS of the GI tract is very useful to provide a rapid diagnosis in many clinical scenarios.

Keywords: Abdominal diseases, gastrointestinal ultrasound, inflammatory bowel disease (IBD), point of care ultrasound, ultrasonography

Introduction

The utilization of portable scanners has paved the way for bedside scanning and the use of ultrasound in emergency settings,[1-3] leading up to the concept of point-of-care ultrasound (POCUS).[4] POCUS examinations differ from ordinary, more comprehensive examinations.[5,6] Ordinary abdominal ultrasound examinations cover several anatomical regions performed in a systematic way, for example, "6+" #15930[7] and result in a full report of the examination. On the contrary, the focus of POCUS examinations is to answer specific questions rapidly (e.g., does my patient have dilated bowels?), and the findings are often included in the general patient report.

Ultrasound of the gastrointestinal (GI) tract requires an experienced operator as systematic scanning of tiny details is often necessary to detect pathological changes and reach the correct diagnosis. Furthermore, pattern recognition of well-known clinical ultrasound signs of severe pathology is important to identify during scanning. Therefore, seven guidelines were published to establish a sound scientific and clinical foundation for the use of GI ultrasound (GIUS).[8-14] There are numerous indications for doing POCUS of the GI tract, including abdominal pain, diarrhea, palpable masses, and also to detect fluid or free air in the abdominal cavity.[15] In these cases, POCUS is often indicated as a first diagnostic procedure to guide further work-up and treatment.[10,16]

The aim of this short review paper is to present how POCUS can be applied in patients which have signs of diseases of the GI tract.

Examination Techniques and Normal Findings

Ultrasound B-mode and Doppler

The thickness of the bowel wall is usually <2 mm in a healthy subject,[17,18] Accordingly, the frequency of the transducer should be at least 5 megahertz (MHz) for wall layers to be well discriminated,[18,19] A low-frequency transducer is preferred to obtain a good overview of the bowels, whereas a high-frequency linear scan head (9–12 MHz) is recommended for detailed studies of the GI wall layers and its pathology.

Doppler US can assess the flow velocity of visceral vessels that supply the GI tract and evaluate the vascularity of smaller

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vessels in the intestinal wall.[20] Color Doppler can be used to determine the direction of flow and to semi-quantitatively estimate bowel wall vascularity,[21] as shown in Figure 1. It is important to optimize the color Doppler parameters to increase the sensitivity for low-velocity flow in the bowel wall to avoid false-negative results.[22]

Scanning procedure

To improve the visibility of deeper parts of the intestines, graded compression is performed by using the US probe much in the same way as when performing palpation with the fingertips.[23] Manual force onto the scan head is used to compress the abdominal wall to push away overlying bowel segments with gas or intra-abdominal fat and in this way enable the examiner to reach deeper, for example, in the pelvic region.[24-26]

The rectum can be scanned with a low-frequency probe using a well-filled urinary bladder as an acoustic window. The cecum, ileocecal valve, and terminal ileum can be identified lying over the iliopsoas muscle in the right iliac region using a high-frequency linear probe. Furthermore, this is a convenient location to start a systematic scan of both the large and small intestines.[6] The hallmark of the large bowel is the haustrations, which are best viewed with the probe oriented in the bowel's longitudinal direction. After the cecum has been identified in the right iliac fossa, the large bowel is followed in the distal direction through the ascending colon, transverse colon, descending colon, sigmoid colon, and finally the rectum.[27]

Scanning of the small bowel can start by returning the probe to the right iliac fossa and identifying the terminal ileum. The examiner should then follow the terminal ileum as far as possible in a proximal direction. The rest of the small bowel should be scanned in parallel overlapping lanes cranially and caudally almost like "mowing the lawn" searching for signs of pathology. If the dorsal wall of the abdominal cavity can be seen clearly throughout the scanning, it could reduce the risk of missing pathology and increase the examiner's confidence in the examination.

Figure 1: The image shows multiple color Doppler signals inside the intestinal wall of a patient with Crohn's disease, indicating increased vascularity, dilated vessels, and inflammatory activity

Bowel wall thickness and layers

The GI wall consists of five sonographic layers, which correlate well with histological sections,[28,29] Bowel wall thickness (BWT) is measured from the outer border of the hypoechoic proper muscle layer and into the lumen interface shown as a bright line between the mucosa and the lumen, often with small air bubbles [Figure 2]. Typically, both the normal small and large intestine is <2 mm when distended,[30,31] The exceptions are the gastric antrum, the duodenal bulb, sigmoid colon (thicker proper muscle layer), and rectum which normally have BWT <3–4 mm.[18]

Signs of gastrointestinal pathology

When performing POCUS of the GI tract, the operator should look for signs of severe pathology, which includes the following: Target lesions, the pseudo-kidney sign, the onion sign, dilated bowel loops, gastric retention, free fluid, and free air.

Target lesion and pseudo-kidney sign

A target lesion or the pseudo-kidney sign are sign of significant pathology, most often inflammation or malignancy in a short segment of the GI tract.[32]

In a patient with Crohn's disease, a target lesion, where the bowel is scanned in a transverse section, most commonly represents a stenosis [Figure 3]. In a longitudinal section of the bowel, a stenosis may appear more like a pseudo-kidney lesion [Figure 4]. However, a pseudo-kidney lesion or a target lesion may also indicate colonic cancer, acute appendicitis or diverticulitis, but also other conditions can induce a significant BWT. If the operator has access to a high-end scanner with a high-frequency transducer more subtle changes in the GI-wall can be detected, for example, discerning between normal and slightly thickened intestinal wall.

Findings in inflammatory bowel disease

Typical complications of Crohn's disease are fistulas, phlegmons, and abscesses. Fistulas from the GI tract are seen

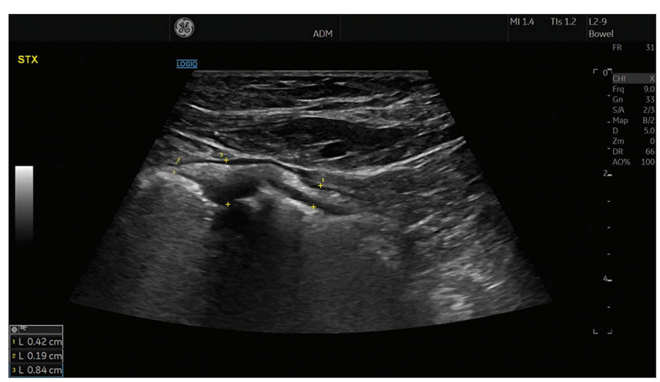

Figure 2: Measurement of BWT is performed by locating the cursor at the outer point of the proper muscle layer and moving through the wall layers to the interface echo between the mucosa and lumen, see yellow markers. The ultrasonogram demonstrates three different measurements in a pathological segment in a patient with Crohn's disease. BWT: Bowel wall thickness

as hypoechoic tract connecting with the bowel lumen and its endpoint. Sometimes the lumen is gas-filled and identified as a hyperechoic tract within. An abscess is a rounded, hypoechoic lesion sometimes with hyperechoic gas contents floating to the top [Figure 5]. It can be confused with a phlegmon but a phlegmon does not contain gas and often vessels are detected within using color Doppler.[33,34]

Although there is so far less evidence indicating the accuracy of POCUS for detecting these lesions, it appears useful.[35,36]

Patients with inflammatory bowel diseases require frequent follow up to evaluate and adjust medical treatment. GIUS in a point-of-care setting has been shown to be accurate,[37] and the inclusion of POCUS in the decision-making leads to significant changes in disease management.[35,38,39] Evidence also suggests that the introduction of POCUS reduces the need for magnetic resonance (MR) enterography and colonoscopy.[40]

The onion sign

The onion sign denotes the classical finding of bowel invagination, most often observed in children using ultrasound.[41] The characteristic pattern arises when the proximal part of a bowel segment is feeding into the bowel distally located, thus generating multiple layers resembling a section through an onion [Figure 6]. If both the anterior and posterior walls are seen in a section through the bowel invagination, then 20 layers may be observed. Furthermore, one may also observe mesentery inside the lumen, as well as a polyp or tumor, which is often the cause of the invagination in adults.[42]

Dilated bowel loops

Dilated bowel loops are a marker of intestinal obstruction, which in turn may have several causes.[43] POCUS can easily demonstrate dilated fluid-filled loops of the intestines [Figure 7], changes in peristaltic activity, and often a collapsed distal bowel.[44] Furthermore, POCUS may confirm or exclude bowel obstruction, decide whether small bowel dilatation is mechanical or functional, identify the site of obstruction, and point toward the cause of the obstruction.[13] Small bowel

Figure 3: A target lesion with concentric rings is observed when the wall layers are markedly thickened and projected in a transverse section, like in this patient with inflammatory bowel disease

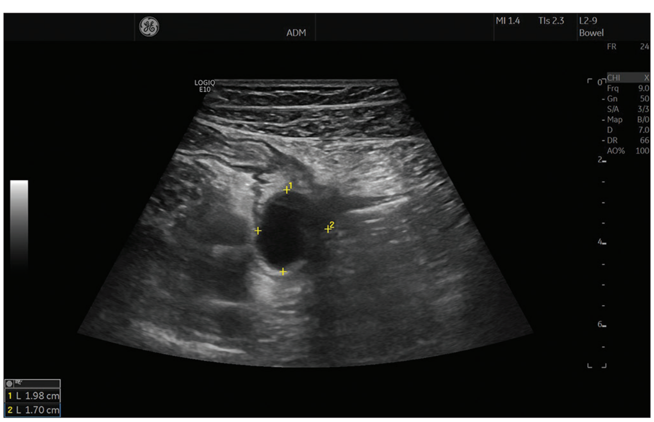

Figure 5: An abscess cavity is depicted between the four markers in a patient with Crohn's disease. Note the bowel segment to the upper left of the abscess with a twisted fistula leading down into the left side of the abscess cavity

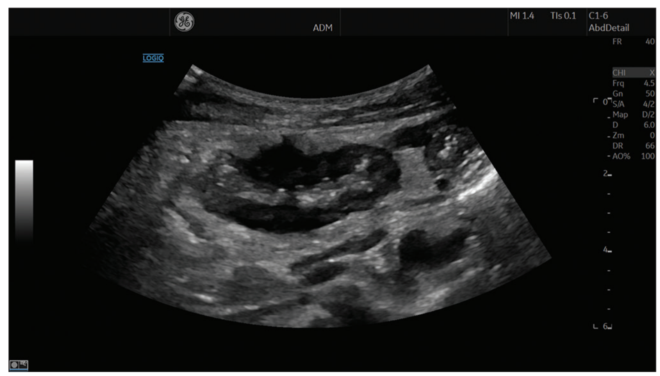

Figure 4: This image shows a pseudo-kidney lesion, depicting a longitudinal section of the intestine in a patient with Crohn's disease. Note in the central upper part of image that the transmural inflammatory activity is creeping out through the proper muscle layer into the surrounding bright fatty tissue

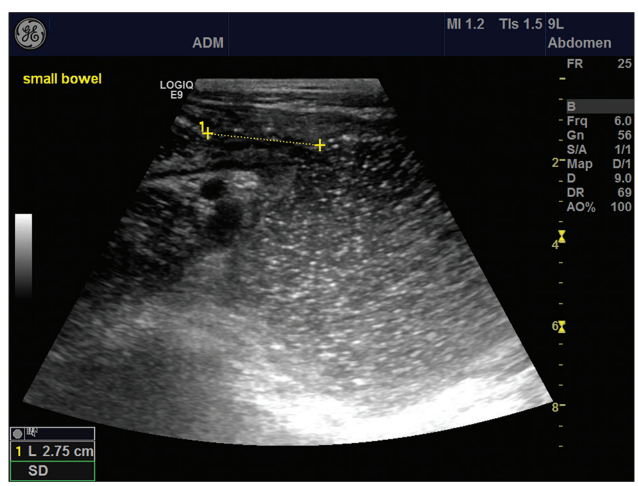

Figure 6: A marked dilatation (7 cm) of the small bowel is observed in this image of a young boy with chronic abdominal pain, weight loss and diarrhea. The yellow cursors depict the length of the narrow stenosis giving rise to the dilatation caused by Crohn's disease

obstruction is usually diagnosed if the dilatation exceeds 2.5–3 cm over a length of at least 2–3 loops or more than 10 cm. Passage of the bowel content may be absent, normal or increased with to-and-fro motion, depending on the cause of occlusion.

Initially, mechanical obstruction is evident by increased peristaltic activity that may diminish later with potential progression toward a chronic condition. Looking for collapsed bowel loops distally to a stenosis is important to locate the exact position of the obstruction. Typically, the site is detected by observing a contracted descending colon or terminal ileum.

For a systematic scanning approach, a 3-step examination technique was developed: 1st step scanning of epigastrium (stomach); 2nd step scanning of the left mid abdomen (jejunum and descending colon); 3rd step right lower abdomen (ileocecal junction). Particularly for inexperienced operators, this method may help to get a first overview whether bowel obstruction is present or not, and which segments are involved.[45] Moreover, using POCUS to diagnose bowel obstruction may save lives and reduce costs significantly.[46]

Gastric retention – dilated stomach

Severe delayed gastric emptying may result in the retention of food and fluids in the gastric compartment. The distal part of the stomach is readily available for ultrasound scanning both in vertical and horizontal sections in the epigastrium.[47,48] Depending on the body habitus of the patient, the antrum may be located at various positions in the craniocaudal direction. Classically, a tall, slim female will have the antrum located in the caudal part of the epigastrium whereas a corpulent male will tend to have the antrum in the uppermost part of the abdomen. The proximal part of the stomach is more difficult to scan but is easier to obtain in a fluid-filled stomach,[49,50] By positioning the probe in the upper epigastrium and tilting it cranially, the proximal stomach can be scanned. Alternatively, in a left lateral, intercostal approach, the spleen can be used as an acoustic window to allow for scanning of the proximal gastric compartment.[51]

The etiology of gastric retention is manifold, ranging from severe dysmotility of the antro-pyloric segment to malignancies of the upper GI tract giving rise to stenosis, as shown in Figure 8. Pyloric stenosis often result is severe gastric retention and both the thickened muscle layer of the pylorus and the dilatation of the stomach can be observed by POCUS. In patients with clinical signs of small bowel obstruction, the presence of a dilated and fluid-filled stomach gives further evidence to the correct diagnosis. Moreover, POCUS of the stomach may also be useful to assess the need of prompt placement of a nasogastric tube to prevent lung aspiration of gastric content.

Free fluid in the peritoneal space

Free fluid in the abdominal cavity is typically detected in peritoneal spaces such as the perihepatic space

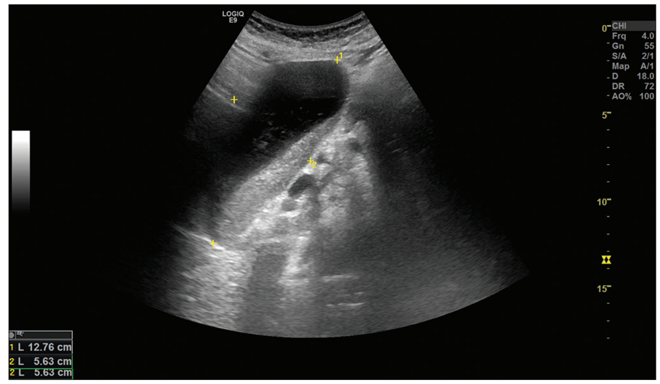

Figure 7: The ultrasonogram shows a major expansion of the gastric antrum in a patient with a stricturing tumor in the proximal small intestine. The content of the stomach has both liquid and solid components and represent significant gastris retention

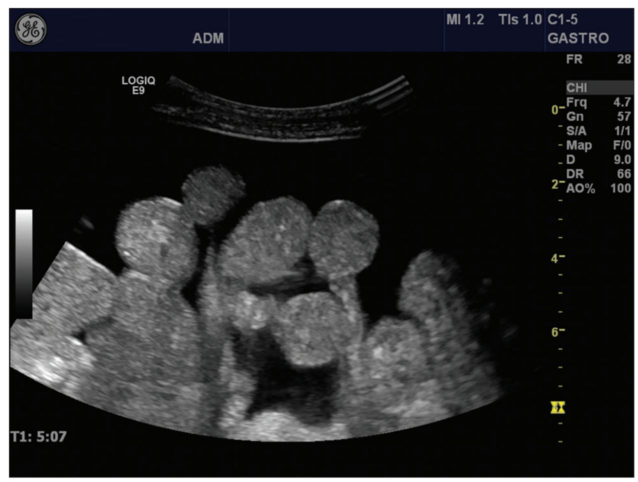

Figure 8: Many small bowel loops with mesenteric attachment can be observed in the abdominal cavity surrounded by ascites. POCUS is highly sensitive to detect even the smallest amount of free abdominal fluid. POCUS: Point of care ultrasound

Figure 9: The onion sign is depicted in this ultraonogram of a patient with invagination due to a large polyp in the small intestine. The onion sign refers to the similarity between all the visible bowel wall layers and a section through an onion. Note that the polyp and parts of the mesentery can be seen on the luminal side of the lesion

(Morrison's pouch), the perisplenic space (Koller's pouch), and the deep pelvic space (pouch of Douglas),[52] as shown in Figure 9. Ultrasonography is highly sensitive to detect even the smallest amount of liquid. Accordingly, examination for free fluid is used by POCUS, for example, with the focused assessment with sonography in trauma (FAST) protocol.[53-57] Furthermore, to scan for ascites, for example, in chronic liver diseases or abdominal malignancies, is highly feasible by applying POCUS.[3,58] Moreover, POCUS is used to guide the aspiration of intraperitoneal fluid by needle drainage or catheter placement.[59]

Free air in the abdominal cavity

Pneumoperitoneum is a rare cause of acute abdominal pain and its etiology encompasses perforation of peptic ulcer, diverticulitis, ischemic bowel disease, trauma, or neoplasm.[60] The classical symptom is a sudden onset of severe abdominal pain. Free abdominal air is the main sign of GI perforation and rapid diagnosis is very important due to its high mortality. Ultrasound can be used as the initial diagnostic tool for the evaluation of patients with acute GI perforation.[61] Although the presence of gas sometimes may limit the ultrasonic field of view, detection of gas collections is an important element of ultrasound imaging in acute abdominal conditions.[62]

Examination protocols may include scanning of the epigastrium and the right hypochondrium.[63,64] Pneumoperitoneum is often described as an accentuation of the peritoneal stripe, similar to a sharp echogenic line, and as hyperechoic foci with reverberations and so-called "dirty shadowing."[65,66] This phenomenon is usually best visible between the abdominal wall and the anterior surface of the liver [Figure 10]. Typically, free gas is easily moved around by pressure of the scan head or movement of the patient (the shifting phenomenon) and this indicates free intraperitoneal air. Furthermore, simple application and release of probe pressure can displace free gas in the epigastrium and subsequently the liver appears and disappears (like opening and closing of a curtain).[67] However, note that detection of pneumoperitoneum is a difficult task because free intraperitoneal air is easily confused with intraluminal air of the bowels.

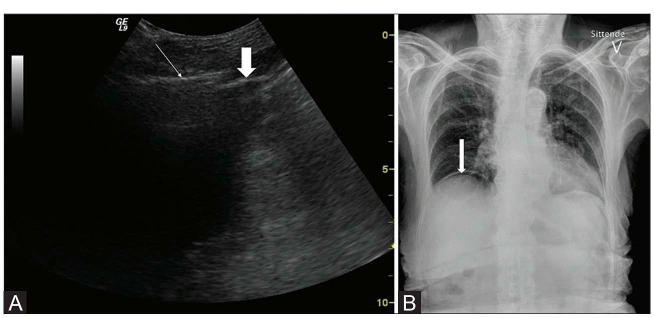

Figure 10: A 100-year-old female was admitted to the hospital with nausea and acute abdominal pain in the upper epigastrium. Panel A shows an ultrasonogram with free air (white thin arrow) above the liver as a bright line with a dirty shadow, and the thick arrow depicts the liver capsule. In panel B, the X-ray image demonstrates free air between the liver and the diaphragm (white arrow)

Discussion/Conclusion

In this review paper, we have elaborated on the use of POCUS to diagnose acute and severe diseases of the GI tract. The great advantage of POCUS compared to computed tomography and MR is the immediate availability, inexpensive cost, and high level of safety. Accordingly, the use of POCUS at first glance when the patient meets the doctor has a great potential to streamline further work-up and treatment. Patients with symptoms like acute abdominal pain, diarrhea or findings like palpable masses or distended abdomen may all profit by the application of POCUS. However, scanning of the GI tract and particularly if looking for pneumoperitoneum requires an experienced operator. Therefore, education of doctors in ultrasonography and providing hands-on training is key to enable the efficient use of POCUS.[68,69] We conclude that POCUS of the GI tract is very useful to provide a rapid diagnosis in many clinical scenarios.

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Nil.

Conflicts of interest

Odd Helge Gilja has received speaker honoraria from the following companies: AbbVie, Bracco, Almirall, GE Healthcare, Takeda AS, Meda AS, Ferring AS, Allergan, and Janssen-Cilag. He has served as a consultant for Bracco, GE Healthcare, Takeda and Samsung, but not during the past 3 years.

Kim Nylund has received speaker honoraria from Takeda and Janssen Cilag AS.

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