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Frontiers in Gastroenterology & Hepatology

REVIEW ARTICLE

ISSN: 2771-0157

Point of care ultrasound of the digestive tract (“Echoenterogram”)—Current evidence and the need for training

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Abstract

Background: Point-of-care ultrasound (PoCUS) is used in multiple fields of medicine to aid in diagnosis and treatment. However, gastroenterology focused PoCUS examinations (we named it “Echoenterogram”: a sound-based scanning of the digestive tract) are not routinely performed.

Aims: The primary objective of this review is to highlight PoCUS examinations related to common gastroenterology (GI) pathologies, such as inflammatory bowel disease, non-alcoholic fatty liver disease, diverticulitis, small bowel obstruction, and assessment of gastric contents to help determine a nil per os status. **Methods:** We performed a search of the literature related to gastrointestinal PoCUS in PubMed, without publication type or study design limitations, and used snowballing to identify further papers from the reference lists of the identified papers. Two independent reviewers screened titles, followed by abstracts and full-text articles for eligibility.

Results and Conclusions: We show that the PoCUS examination is a good diagnostic bedside tool for several common gastrointestinal diagnoses. In this comparison of GI PoCUS examinations to the current standard of care practices, we conclude that, with appropriate training of gastroenterologists, the echoenterogram can be incorporated into routine medical practice.

Keywords*: gastric ultrasound, gastroenterology ultrasound, intestinal ultrasound, liver ultrasound, point-of-care ultrasound (PoCUS), gastroenterology point-of-care ultrasound (GI PoCUS).*

Abbreviations: *BWT: Bowel Wall Thickness; CSA: Cross-Sectional Area; CT: Computed Tomography; EFSUMB: European Federation of Societies for Ultrasound in Medicine and Biology; GI: Gastrointestinal; IBD: Inflammatory Bowel Disease; IBS: Irritable Bowel Syndrome; IUS: Intestinal Ultrasound; NAFLD: Non-Alcoholic Fatty Liver Disease; NPO: Nil per Os; PoCUS: Point-Of-Care Ultrasound; RLD: Right Lateral Decubitus; SBO: Small Bowel Obstruction; US: Ultrasound*

Introduction

Ultrasound was first utilized in medicine in the 1940s and has since evolved into a ubiquitous, non-invasive, and radiation-free imaging modality [1-3]. Today, point-of-care ultrasound (PoCUS) has become a popular method to enhance physical examination and guide diagnostic and treatment plans in real-time. Smaller, portable, and hand-held ultrasound devices have become more affordable and accessible for use in daily practice [1-3]. Bedside ultrasonography has been popularized globally in the fields of cardiology, pulmonology, critical care, emergency medicine, rheumatology, obstetrics/gynecology, and others [1]. Gastrointestinal (GI) PoCUS examinations are performed in many European countries, in both the acute and outpatient settings [1-3]. However, gastroenterology focused PoCUS examinations have not been universally incorporated into the clinical practice of gastroenterology, despite a mounting body of literature showing its efficacy.

This review aims to outline the evidence for utility and optimal techniques of using GI PoCUS. We focus this review on the differentiation of irritable bowel syndrome (IBS) from inflammatory bowel disease (IBD), monitoring of IBD and non-alcoholic fatty liver disease (NAFLD), assessing stomach contents to determine nil per os (NPO) status, assessing small bowel obstruction (SBO), and diagnosing diverticulitis.

Methods

Prior to review, search terms, inclusion/exclusion criteria, and an extraction protocol were defined based on the *a priori* question, “How is PoCUS used for common GI pathologies, including: IBD, non-alcoholic fatty liver disease NAFLD, diverticulitis, and SBO; and how is it used to assess NPO status?” We defined GI PoCUS as ultrasound that had the potential to be performed and interpreted at the bedside in order for it to be used for real-time diagnostic and treatment enhancement. It was not limited to the type or size of the machine, nor the experience or specialty of the sonographer.

We performed a search of the National Library of Medicine database MEDLINE using the PubMed interface. The search was not restricted by publication type or study design but was restricted to English language publications of adult human participants. Studies related to endoscopic ultrasound, contrast-enhanced ultrasound, the pediatric population, and procedural applications (e.g., paracentesis) were excluded. The exact search terms can be found in (Table 1). We also checked the reference lists of reviewed literature for additional articles that fit the inclusion/exclusion criteria.

A systematic review of titles, abstracts, and full-text articles was performed up to and including March 2022. Studies were excluded if they did not relate specifically to ultrasound of the GI pathologies listed above. Two independent reviewers screened titles, followed by abstracts and full-text articles for eligibility. Discrepancies were resolved by consensus. Information was extracted from the included studies based on relevance to the *a priori* question. If overlapping studies were found, we only included the latest or most suitable publication (based on consensus). A summary of the review process is found in (Figure 1).

The initial query yielded 7,845 results (including 9 snowballed/recommended articles), which were narrowed down to 54 results based on title and abstract. From those, a total of 48 articles were included after full text review.

Table 1: Search terms used in PubMed database on 4/10/2020. Note that each topic was searched individually along with the ultrasound query. Results were limited to human studies

Topic	Search Terms	No. of articles
Ultrasound	"point-of-care ultrasound" OR "point-of-care" OR " point of care" OR "POCUS" OR "POC ultrasound" OR "POC" OR "bedside ultrasound" OR ultras* OR sono* OR "US"	-
IBD	"inflammatory bowel" OR "inflammatory intestinal" OR "IBD" OR "ulcerative colitis" OR "crohn's" OR "crohns"	2,702
NAFLD	"NAFLD" OR "NAFL" OR "NASH" OR "fatty liver" OR "steatohepatitis"	3,725
NPO Status	"gastric content" OR "gastric volume" OR "stomach volume" OR "stomach content" OR "NPO" OR "aspiration"	458
Diverticulitis	"diverticulitis"	403
SBO	"small bowel obstruction" OR "SBO" OR "bowel obstruction"	548
Total:		7,836

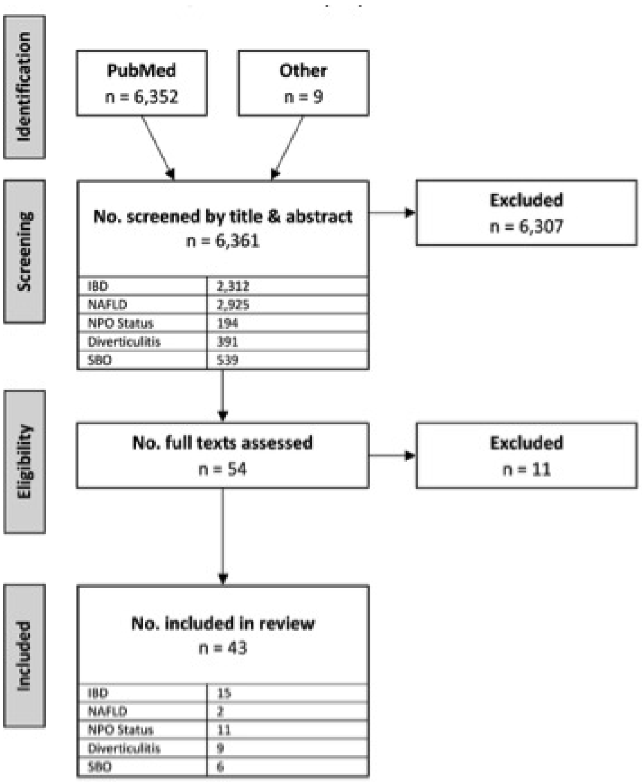

Figure 1: Search Process. Other refers to references that were cited by the PubMed search (i.e., snowball references, or identified by expert recommendation.

Results

Inflammatory Bowel Disease

Background

Endoscopy is considered the gold-standard diagnostic tool for IBD. However, the number of patients diagnosed with IBD is low compared to the number of patients with IBS who undergo endoscopy [4]. Ultrasound has long been used in Europe to aid in the diagnosis of IBD [5]. Furthermore, modern disease management concepts (i.e. “treat to target”) stress the importance of objective monitoring of disease activity (i.e. mucosal healing) for treatment optimization, improving long-term outcomes, and prevention of complications [6,7]. Several studies have compared intestinal ultrasound (IUS) to other cross-sectional imaging modalities, such as magnetic resonance enterography (MRE) or computed tomography (CT) [8,9]. Intestinal ultrasound(we will call intestinal ultrasound GI PoCUS as it fits the GI PoCUS definition stated in the methods section) has been found to be accurate in diagnosing IBD, identifying penetrating disease, and monitoring disease activity in IBD [2,8]. GI PoCUS has an advantage over other non-invasive testing modalities such as fecal calprotectin (FC) levels, as GI PoCUS can be performed at the point-of-care, providing information while the patient is in clinic, and helping immediately inform treatment decisions. In contrast, a stool sample collection and follow up time for test results is necessary for FC. Furthermore, a nationwide survey was performed in patients with IBD in France in which GI PoCUS was the patients’ preferred modality for Crohn’s disease as it relates to the patient experience [10].

Probes

The provider should have a low frequency (1–6 MHz) and a high frequency (2–12 MHz) transducer available. Low frequency curvilinear transducers have increased depth and can identify the area of interest, while high frequency linear transducers are preferred in lean patients and where higher definition is needed [2,11,12].

Scanning technique:

The transabdominal ultrasound examination begins in the left lower quadrant to assess the proximal rectum and sigmoid colon, and then progresses proximally to evaluate the entire large bowel. The ileocecal valve and the terminal ileum are then examined. Lastly, all four quadrants are evaluated, completing the examination of the small bowel [2,4].

Diagnosis

Active IBD is diagnosed on GI PoCUS if inflammation is present, which is defined as an increase in bowel wall thickness (BWT) (> 3 mm in the small bowel or > 4 mm in the large bowel) and at least one of the following: mesenteric hypertrophy, mesenteric lymphadenopathy, or hyperemia, as measured by Doppler ultrasound [4]. The current literature favors the diagnosis of Crohn’s disease over ulcerative colitis, given its transmural involvement, but GI PoCUS is gaining traction in the evaluation of ulcerative colitis as well [2,12,13].

In the setting of IBD diagnosis, Novak et al. [4] compared PoCUS to endoscopy in 58 patients. Ten of the 58 patients had inflammation confirmed on both endoscopy and histology, while the PoCUS examination correctly identified eight of these ten patients. PoCUS had an 80% sensitivity and a 97.8% specificity, with a PPV of 88.9////5 and a NPF of 95.7%, when compared to endoscopy [4]. The authors proposed that a gastroenterologist-performed bedside PoCUS could accurately distinguish inflammatory from non-inflammatory disease in patients presenting with abdominal pain and diarrhea. Even though Novak’s analysis was small, Parente et al. [5] confirmed these findings in a more extensive study of 487 patients with similar sensitivity, specificity, PPV, and NPV of 85%, 95%, 98%, and 75% respectively. However, it should be noted that Parente et al. utilized an experienced sonographer to perform and interpret the PoCUS, rather than a trained gastroenterologist [4,5].

GI PoCUS not only aids in the diagnosis of IBD, but it can also help monitor disease activity. Mucosal healing is now considered the treatment goal in patients with IBD, as it decreases complications associated with IBD [2,6,7,11,14]. However, monitoring the luminal mucosa via endoscopy is invasive, expensive, and requires bowel preparation, among many other considerations; thus, GI PoCUS has obvious advantages over endoscopy.

Sathananthan et al. compared PoCUS examination to ileocolonoscopy to evaluate disease activity in IBD [2,11]. PoCUS had a sensitivity, specificity, PPV, and NPV of 87%, 81%, 85%, and 83%, respectively, when compared to ileocolonoscopy [11]. The authors suggested that PoCUS examination is an accurate and non-invasive approach to monitor disease activity when endoscopy is not otherwise indicated (i.e. endoscopy is needed for colorectal cancer screening) [14].

The TRUST initiative (TRansabdominal Ultrasonography of the bowel in Subjects with IBD To monitor disease activity) has conducted studies to promote IUS as a first-line, non-invasive modality in IBD. Maaser et al. [13] noted that in patients with clinical relapse of ulcerative colitis, increased bowel wall thickness (BWT) decreased significantly at the start of treatment, even within the first 2 weeks of the study, and remained low at weeks 6 and 12. After 12 weeks of treatment, there was a strong correlation between normalization of BWT and clinical response. In the TRUST initiative study for Crohn's disease, it was shown that IUS is a useful method for monitoring disease activity [15]. Novak et al. proposed a "Simple Sonographic Score" for Crohn's disease that incorporates bowel wall thickness and color Doppler ultrasound which demonstrated 92% sensitivity and 82% specificity compared with endoscopy [2,16]. These studies are part of the mounting body of evidence that GI PoCUS is an effective modality for monitoring disease activity and for assessing response to therapy in IBD. The European Federation of Societies for Ultrasound in Medicine and Biology (EFSUMB) has endorsed GI PoCUS for IBD in its 2018 recommendations [12].

Advantages of PoCUS

Using GI PoCUS to identify signs of inflammation in the bowel can reduce the time to performing endoscopy, as reported by Novak et al. [4] where there was a trend toward expedited endoscopy based on input from GI PoCUS. Performing a GI PoCUS examination may not eliminate the need for endoscopy; however, it provides objective, immediately available data to guide treatment decisions. Additionally, this diagnostic modality may help reduce radiation exposure, contrast administration, and the financial burden associated with cross-sectional imaging [8]. GI PoCUS has the additional advantage of allowing transmural disease monitoring in Crohn's, compared to mucosal disease monitoring only via endoscopic evaluation. Recent evidence suggests that transmural healing in Crohn's disease has better outcomes than mucosal healing alone [7].

Limitations

A limitation of incorporating GI PoCUS in IBD management is the significant amount of time required for each PoCUS assessment. The examination generally takes 10-20 minutes, so patients may have to schedule a separate appointment for a PoCUS examination [2,11]. Diagnosing and monitoring IBD in obese patients and patients with pelvic disease is challenging as ultrasound images may lack adequate clarity. Furthermore, there are concerns about subjective differences in interpretation; although this can be reduced by using similar protocols/ scoring systems for diagnosis and monitoring of disease [2,8].

Non-alcoholic fatty liver disease

Background

With a high prevalence in the United States, NAFLD is becoming the most common cause of elevated liver chemistries [17]. When NAFLD is suspected, guidelines suggest using abdominal ultrasound as the first-line imaging modality due to its low cost and widespread availability. Studies have shown that PoCUS of the liver has similar diagnostic accuracy as the conventional abdominal ultrasound [19].

Probes

A curvilinear probe (2–5 MHz, preferred) or a phased array probe (1–5 MHz) is typically used.

Scanning Technique

Patients are positioned supine with their right arm lifted above their head and the probe is placed on the right mid-axillary line between the 8th and 11th ribs [18,19].

Diagnosis

Miles et al. [18] studied 100 patients and compared liver echogenicity to that of the right renal cortex. Fatty infiltrate was considered present in the liver if the echogenicity of the liver was hyperechoic as compared to that of the renal cortex. There were 40 individuals that were diagnosed by both GI PoCUS and conventional ultrasound, and discrepancy between GI PoCUS and conventional ultrasound was observed in only 11 of 100 (11%) study participants [18].

Riley et al. [20] proposed a prototype image with the following criteria:

1. Attenuation of the image within 4-5 cm depth
2. Diffuse echogenicity
3. Uniform heterogeneity of the liver
4. Thick subcutaneous tissue greater than 2 cm
5. Liver fills the entire field, with no visible edges

For NAFLD to be considered, four of the five above criteria must be met. The criteria were based on a small study, which assessed 20 patients with NAFLD. Sixteen of the 20 patients were correctly identified with GI PoCUS as they met four of the five criteria [19].

Even though the diagnostic criteria of Miles et al. [19] and Riley et al. [20] differ, they have comparable sensitivity (91% and 80%, respectively) and specificity (80% and 99%, respectively). In a quick GI PoCUS examination, assessing for all five criteria is not always feasible. Since assessing for the single criterion of comparing hepatic echogenicity to that of the renal cortex is comparable to the diagnostic accuracy of a conventional abdominal ultrasound, the criteria proposed by Miles et al. hold greater promise for integration into clinical practice [18].

Advantages of PoCUS

GI PoCUS can be used to screen for hepatic fat infiltration. If fatty infiltrates are found on GI PoCUS, a conventional abdominal US may not be needed. This technique aims to streamline patient care.

Limitations

As with PoCUS for other indications, assessing NAFLD is often limited by body habitus, particularly class III obesity, with body mass index (BMI) > 40 kg/m^2. Another limitation is the relatively small sample size in both previous studies by Miles et al. and Riley et al., with a combined 120 patients in these studies. Additionally, patients with chronic kidney disease may have increased echogenicity of the renal cortex at baseline, limiting the applicability of the criteria proposed by Miles et al.

NPO status

Background

Pulmonary aspiration of stomach contents, particularly in patients with altered gastric motility [20], is a serious anesthetic complication, with significant implications for patient outcomes. Therefore, it is important to consider gastric contents prior to procedures requiring anesthesia. Most of the evidence related to the assessment of gastric contents has been garnered from the anesthesia literature, but this information is vital to gastroenterologists performing endoscopy.

Probes

A curvilinear probe (2–5 MHz) is typically used for assessing NPO status, but a high-frequency linear probe (2–12 MHz) can be used in lean patients.

Scanning technique

Perlas et al. [21,22] has published original research as well as review articles discussing the use of ultrasound methodology to assess gastric contents. They found that the antrum was most amenable to sonographic examination [23,24], and that antral evaluation accurately reflects the content of the entire organ. They also concluded that the antrum is better evaluated in a semi-sitting or right lateral decubitus (RLD) position, with the RLD position being the most sensitive [23-25].

The probe is placed in a sagittal plane in the epigastric area, immediately inferior to the xiphoid process and superior to the umbilicus. On imaging, the antrum is surrounded by the left lobe of the liver anteriorly and superiorly, and the head or neck of the pancreas posteriorly. The inferior vena cava or aorta lies posterior to the pancreas. If a volume assessment is to be carried out, an imaging plane at the level of the aorta is preferred, as this is the plane used in the development of the volume model [25]. The direction of the probe marker is toward the head [21,23,24].

Several factors are to be considered while scanning. First, for quantitative assessment of gastric contents using calculations proposed by Perlas et al. [25], the scan should be conducted in the RLD position. Second, the cross-sectional area measurements are taken from serosa to serosa between peristaltic contractions, so that the full thickness of the gastric wall is included.

Although initial studies were conducted on adult, non-pregnant subjects with BMI < 40 kg/m^2, subsequent investigations have validated gastric PoCUS in pediatric, obese, and obstetric patients [22,26].

Diagnosis

In the empty stomach, the antrum appears round to ovoid, similar to a "target" or "bull's eye" [23,27]. After ingestion of liquids, the antrum becomes distended with a mixture of liquid (anechoic) and air bubbles (hyperechoic), leading to the appearance of a "starry night" (Figure 2) [23]. Solid food gives the appearance of "frosted glass" [23,27], as immediately after eating a solid meal, air is still mixed with the food, causing multiple ring-down artifacts that blur the posterior wall of the antrum. Eventually, the air is displaced and the mixed echogenicity of the solid content can be better appreciated [23,27].

Quantitative assessment

Several studies have demonstrated a linear relationship between ultrasound-determined antral CSA and the total volume of gastric fluid [25,28]. One such study performed by Perlas et al. [25] suggested a straightforward formula for calculating gastric fluid volume using antral CSA and age. The formula [25] is:

Gastric Volume (mL) = 27.0 + 14.6*right – lateral CSA – 1.28*age

This formula can predict volumes of up to 500 mL with a mean difference of 6 mL between the predicted and measured volumes.

Perlas et al. [21,22] also provided suggestions on how to use this information in clinical decision-making: an empty stomach on ultrasound implies a low aspiration risk. Solid or particulate matter in the stomach indicates a high aspiration risk. Therefore, it is not mandatory to calculate gastric fluid volume in patients with an empty stomach or those who have had solid food. However, if clear fluid is found, a volume assessment can be performed to determine if the fluid is ≤ 1.5 mL/kg (baseline gastric secretions), indicating a low aspiration risk. If the fluid volume is ≥ 1.5 mL/kg, this implies a higher aspiration risk. If quantitative calculations cannot be made, a semi-quantitative way to assess the aspiration risk can be used [24].

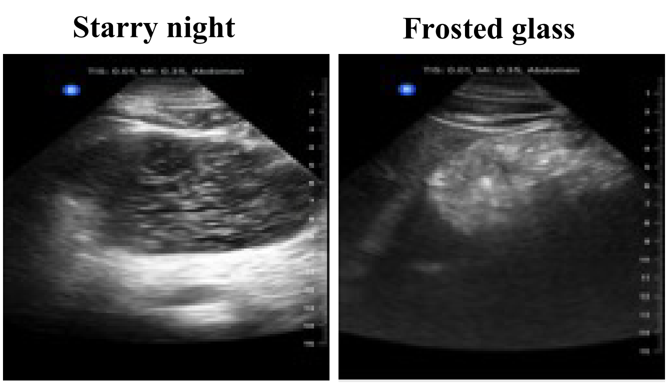

Figure 2. Comparing the starry night appearance of the stomach after liquid ingestion to the frosted glass appearance after solid food ingestion.

The antrum is scanned in both the supine and the RLD positions. If the antrum appears empty in the supine position, but clear fluid is visible in RLD, it indicates a small amount of gastric fluid and a low risk of aspiration. Perlas et al. suggested that, among subjects with fluid visible in the RLD position only, 23% had a gastric volume > 100 mL, and none of them had a volume > 250 mL [25]. In contrast, if clear fluid was visible in both positions (semi-sitting and RLD), 75% of subjects had a volume > 100 mL, and more than 50% had volumes > 250 mL, indicating a high risk for aspiration [25]. The 100 mL threshold is important, as it generally reflects the baseline gastric secretions.

Advantages of PoCUS

Assessing NPO status with ultrasound could expedite the performance of urgent procedures or inform the need for endotracheal intubation [29]. This may have an impact on patient outcomes, such as procedural complications related to empiric nil-per-os recommendations and reducing risk of unexpected aspiration.

Limitations

Several areas related to NPO assessment require further investigation. These include defining the minimum training requirements to ensure accurate assessment, as well as establishing sensitivity, specificity, and positive- and negative-predictive values in larger groups of practitioners [30]. In one study, participants practiced both gastric content and volume identification on healthy volunteers with the help of a radiologist for the first 20 cases [20]. Other studies have found that approximately 33 practice examinations, followed by expert feedback, are needed for anesthesia fellows to obtain an accurate diagnosis in 95% of cases [22]. Additionally, these models do not apply to patients with altered GI anatomy.

Diverticulitis

Background

Acute colonic diverticulitis is a common presenting symptom in emergency rooms and outpatient clinics. The diagnosis of diverticulitis is primarily clinical; however, radiographic confirmation is often pursued to guide clinical decision-making. While cross-sectional imaging has been the primary modality in recent years, GI PoCUS has potential to be a paradigm shifting modality in the detection of diverticulitis.

Probes

The choice of transducer depends on the patient's body habitus. A lower frequency curvilinear transducer (3 MHz) is preferred for overweight patients and a 5- or 7-MHz probe for average or lean patients. Probes with frequency higher than 7-MHz probe are used for leaner patients, those with superficial abnormalities, and to obtain a more detailed evaluation of focal abnormalities [31].

Scanning technique

The abdomen is scanned using the graded compression technique and the examination can be started at the point of maximum tenderness. The sigmoid colon can typically be identified in the left paracolic gutter (using the left iliac artery as a reference) and then track distally and proximally, as most cases of diverticulitis in the US are left-sided [32]. For distal sigmoid evaluation, the urinary bladder can be used as an acoustic window [31,33].

Diagnosis

Abnormal ultrasound findings of the inflamed bowel include: 1) short segment wall thickening to more than 5 mm, 2) non-compressibility, and 3) presence of inflamed diverticuli characterized by hypoechoic features with hyperechoic fatty tissue surrounding the area [31-35].

Most of the evidence related to the use of ultrasound for the diagnosis and treatment of acute diverticulitis comes from surgical and radiological literature. However, it is important for a gastroenterologist to be able to use ultrasound for the management of diverticulitis in the outpatient setting, as outpatient management of uncomplicated diverticulitis is associated with lower rates of readmission and lower complication rates leading to healthcare cost savings [36]. Several studies have reported a comparable diagnostic accuracy for ultrasound and CT in diagnosing acute colonic diverticulitis. A systematic review conducted by Lameris et al. [37] in 2008, comparing ultrasound to CT, found that the sensitivity (US 92% and CT 94%) and specificity (US 90% and CT 99%) of ultrasound and CT scans did not statistically significantly differ for diagnosing acute colonic diverticulitis. Another review, by Andeweg et al., reported that ultrasound had comparable sensitivity, but that CT had higher specificity [38]. Use of ultrasound, as a first-line imaging modality, was supported by a large prospective study of 802 patients who presented with acute abdominal pain [39] and both ultrasound and CT were found to have high sensitivity (91% and 95%, respectively) and specificity (100% and 99%, respectively) in diagnosing colonic diverticulitis [39]. However, CT was superior in identifying both complications and alternate causes of abdominal pain [39]. Furthermore, the EFSUMB has recently issued several statements regarding the use of ultrasound for acute diverticulitis. These statements indicate that intestinal ultrasound can accurately identify acute diverticulitis and should be the first-line diagnostic tool, with CT performed in patients with inconclusive US findings or where complicated diverticulitis is suspected (i.e., a step-up approach) [32,35,38].

Advantages of PoCUS

GI PoCUS may help reduce the number of CT scans performed, leading to cost-savings and preventing exposure to contrast medium and ionizing radiation. Additionally, PoCUS is a useful tool in confirming clinical suspicion in the outpatient management of low-risk acute diverticulitis.

Limitations

The study by Toorenvliet et al. was performed with the assistance of a radiologist, and it remains unclear how much training would be needed for non-radiologists before being able to perform the ultrasound reliably to detect acute diverticulitis. Since most ultrasound studies derive from Europe, there is need for a cultural shift and more training in the United States [37]. Additionally, the diagnostic accuracy of ultrasound is limited in obese patients and for lesions deeply seated in the pelvis.

Small Bowl Obstruction

Background

SBO is an important consideration in patients with abdominal pain. Currently, abdominal X-rays are often used to diagnose SBO, but evidence suggests that GI PoCUS is superior to abdominal X-ray in diagnosing SBO [40,41]. GI PoCUS can help in the rapid diagnosis of SBO and frequent re-examination while decreasing the cost and radiation exposure to the patient [42].

Probes

The curvilinear probe (3.5–7 MHz) is the best for assessing SBO, but a phased-array probe (1.5–4.5 MHz) can be used. In lean patients, the linear probe (7.5 MHz) can also be utilized.

Scanning Technique

The "lawn mowing" technique has been suggested to assess SBO. The practitioner starts by placing the probe in the transverse plane in the right lower quadrant moving to the right upper quadrant (while applying sequential, graded compression), with the probe moving caudad and cephalad, sequentially, over the abdominal wall until the entire abdomen has been scanned and the probe is in the left lower quadrant (LLQ).

Diagnosis

Diagnosis involves observation of 1) a dilated small bowel > 2.5 cm (multiple bowel loops are more suggestive), 2) to and fro peristalsis, and 3) fluid between bowel loops [41,43].

Of the different ultrasound findings, dilated bowel loops has the highest sensitivity (90.9%) and specificity (83.7%) for SBO, whereas decreased peristalsis on an abdominal ultrasound had poor sensitivity (27.3%), but good specificity (97.7%) [41]. Additionally, the presence of large amounts of fluid between dilated small bowel loops imply worsening obstruction, which may need immediate surgery [43]. In a meta-analysis of 11 studies, Gottlieb et al. [44] found that ultrasound had sensitivity and specificity (92.4% and 96.6%, respectively) comparable to that of CT (87-96% and 81-100%, respectively) in the diagnosis of SBO. In 2019, Shokoohi et al. [45] suggested adding several clinical features (such as age and physician pretest probability of SBO) to ultrasound findings in a nomogram to enhance diagnostic accuracy. Several studies [41,46] have shown that proficiency in GI PoCUS for SBO may require little training (see Table 2).

Advantages of PoCUS

PoCUS is an excellent modality for both diagnosis and serial assessment of SBO, and it can potentially decrease the number of X-rays ordered for SBO monitoring. Currently, CT remains the preferred imaging modality for all SBO, particularly prior to making surgical decisions, and GI PoCUS is unlikely to replace the clinical utility of cross-sectional imaging as the gold standard imaging test. PoCUS can also hasten the diagnosis of SBO, as Boniface et al. found that the average timeof the PoCUS exam was 11 minutes versus the average elapsed time from placing the CT order to the radiology read of 3 hours and 42 minutes [42].

Limitations

Using the lawnmower approach, most of the abdomen can be scanned thoroughly, yet it is still possible to miss dilated loops. Additionally, it can be challenging to determine an etiology of the obstruction by means of GI PoCUS.

Discussion

Point of Care Ultrasound examinations are used routinely in many fields of medicine by physicians to help diagnose and guide treatment in real-time [1]. GI PoCUS can be useful for gastroenterologists to enhance their physical examinations and clinical decision-making, all while improving patient safety, streamlining diagnosis, and reducing the cost of care. However, gastroenterology focused PoCUS examinations have not been universally incorporated into the clinical practice of gastroenterology, despite a mounting body of literature showing its efficacy [1]. Gastroenterologists are typically well trained with respect to skills requiring a three-dimensional understanding of the anatomic relations of GI structures; thus, they may be more adept in mastering GI PoCUS skills quickly [2,3,47].

The studies included in the review did have limitations. Most studies were single-center studies with relatively small sample sizes, and many of the providers performing the exam were experienced ultrasonographers (Table 2). Further research is needed to establish minimum training requirements prior to performing unsupervised GI PoCUS examinations, particularly in the United States. The EFSUMB recommends that gastroenterologists execute five to ten GI PoCUS examinations per week, with a minimum of 300 examinations prior to performing unsupervised GI PoCUS examinations [1,3]. Some medical schools have augmented gastrointestinal physical examination training of medical students with ultrasound, suggesting future clinicians will be capable of integrating GI PoCUS into training programs and subsequent clinical practice [48].

This review does thoroughly delineates the clinical benefit of incorporating GI PoCUS into daily Gastroenterology practice as it

Table 2: Summary of studies included in the review

Author (year)	Country	Study type (No. of participants)	Pathology/Organ	Transducer (Frequency)	Sensitivity	Specificity	PPV	NPV	Conclusions	Training
Novak (2016) [4]	Canada	Prospective (58)	Bowel inflammation in setting of abd pain and diarrhea	Convex (4-9 MHz), Linear (12-15 MHz)	80%	97.8%	88.9%	95.7%	POCUS can accurately detect inflammation in patients presenting with abdominal pain and diarrhea.	Gastroenterologist with formal training and three years of experience with US of the GI tract performed the exams.
Parente (2003) [5]	Italy	Prospective (487)	IBD	Convex (3.5 MHz), Linear (7.5 MHz)	85%	95%	98%	75%	In patients with clinical suspicion of IBD, intestinal US can be highly predictive of inflammation in the ileum or colon.	Two sonographers with experience of more than 5000 abdominal ultrasound examinations and more than 3000 examinations of the bowel performed the examinations.
Sathananthan (2019) [11]	Australia	Prospective (74)	IBD	Low-frequency (1-6 MHz), High-frequency (3-11 MHz), Toshiba Aplio 500	87%	81%	85%	83%	POCUS can accurately define disease activity in IBD patients.	An accredited sonographer with two years of experience and more than 600 GI US exams performed the POCUS exams.
Maaser (2019) [13]	Germany	Prospective (253)	Ulcerative colitis	Convex (1-7 MHz), Linear (1-15 MHz)	-	-	-	-	BWT in the sigmoid colon decreased from 89.3% to 38.6% at 2 weeks, to 35.4% at 6 weeks and to 32.0% at 12 weeks. BWT in the descending colon decreased from 83.0% to 42.9% at 2 weeks, to 43.4% at 6 weeks and to 37.6% at 12 weeks. Intestinal US can be used to monitor disease progression in patients with ulcerative colitis.	
Miles (2020) [18]	Canada	Prospective (100)	NAFLD	Phased-array (5-1 MHz), Handheld	91%	88%	NR	NR	POCUS can detect fatty infiltration of liver with high sensitivity and specificity.	General internist certified in POCUS through the Canadian Point of Care Ultrasound Society and with additional 2 hour training performed the ultrasound exams.
Riley (2006) [19]	USA	Prospective (115)	NAFLD	Curved-array (5-2 MHz), Handheld	80%	99%	94%	96%	Bedside US can be used to diagnose NAFLD.	
Sharma (2018) [20]	India	Prospective (100)	Stomach/NPO	Curved array low frequency (2–5 MHz) probe in abdominal scan mode.	-	-	-	-	Fasting for more than 6-10 hours does not guarantee empty stomach especially in patients with diabetes mellitus, obesity and chronic kidney disease.	Sonographers practiced on healthy volunteers with help of a radiologist for fist 20 cases with re-confirmation of subsequent ultrasound images by a radiologist.
Putte (2014) [21]	Canada	Systematic review	Stomach/NPO	-	-	-	-	-	Empty stomach on ultrasound-> low risk for aspiration Solid food on ultrasound- high risk for aspiration Liquids on ultrasound assessment->need to do volume assessment. If < 1.5 ml/kg, lower risk for aspiration, if > 1.5 ml/kg, high risk for aspiration.	
Perlas (2013) [25]	Canada	Prospective (108)	Stomach/NPO	Curvilinear array, low frequency (2 to 5 MHz) transducer	-	-	-	-	Prediction model to assess gastric volume up to 500 ml was proposed which is applicable to non-pregnant adult patients with BMI < 40kg/m^2. 3-point qualitative grading system was proposed for gastric volume assessment.	
Perlas (2018) [22]	Canada	Review article	Stomach/NPO	-	-	-	-	-	Summarized how to modify exams to assess NPO status among pediatric, obese, septic, critically ill patients.	
Ogata (1996) [40]	USA	Prospective (50)	SBO	NR (3.5 MHz), Biosound Esaote AU530	US: 88% PLAIN X-RAY: 96%	US: 96% PLAIN X-RAY: 65%	-	-	US has as good sensitivity and better specificity compared to X-ray in diagnosis of bowel obstruction.	

Grassi (2004) [43]	Italy	Retrospective (742)	SBO	Convex (3.5-7 MHz), Linear (7.5 MHz)	-	-	-	-	Presence of large amount of fluid between dilated small bowel loops suggests worsening small bowel obstruction.	
	USA	Prospective	SBO	Phased-array transducer(1 to 4 or 5 MHz) in abdominal preset. High frequency linear transducer(5 to 10 or 6 to 13 MHz) where body habitus allowed superficial probe.	87.5% for SBO diagnosis	75.3% for SBO diagnosis	-	-	Point of care ultrasound has a reasonably high accuracy in diagnosing SBO compared with CT and may substantially improve time to diagnosis.	
Boniface (2020) [42]	USA	Prospective	SBO	Phased-array transducer(1 to 4 or 5 MHz) in abdominal preset. High frequency linear transducer(5 to 10 or 6 to 13 MHz) where body habitus allowed superficial probe.	87.5% for SBO diagnosis	75.3% for SBO diagnosis	-	-	Point of care ultrasound has a reasonably high accuracy in diagnosing SBO compared with CT and may substantially improve time to diagnosis.	
Jang (2011) [41]	USA	Prospective (76)	SBO	Phased-array, Ultrasonix CEP	US: decreased peristalsis: 27.3%, Dilated loops: 90.9%, Combined: 93.9% X-ray: 46.2%	US: decreased peristalsis: 97.7%, Dilated loops: 83.7%, Combined: 81.4% X-ray: 66.7%	-	-	Dilated bowel loops were sensitive and specific for SBO, while decreased peristalsis was specific but not sensitive. US had better sensitivity and specificity than X-ray for SBO.	The training involved a ten-minute training module and five prior US exams for SBO.
Unluer (2010) [46]	Turkey	Prospective (174)	SBO	ED residents: Convex (3.5 MHz), Sonosite Titan, Radiology residents: Convex (5 MHz), Shimasonic SDU-450	EM: 97.7%, Radiology: 88.4%	EM: 92.7%, Radiology: 100%	EM: 93.3%, Radiology: 100%	EM: 97.4%, Radiology: 89.1%	After 6 hours training, EM residents used US to diagnose SBO with accuracy similar to radiology residents.	The training period was 6 hours (3-hour didactic course and a 3-hour hands-on abdominal sonography).
Gottlieb (2017) [44]	USA	Systematic review (1178)	SBO	-	92.4%	96.6%	-	-	US can be useful tool in diagnosis of SBO with sensitivity and specificity comparable to CT.	
Shokoohi (2019) [45]	USA	Retrospective (125)	SBO	Phased-array, Linear	Prediction model: 59%	Prediction model: 91%	-	-	Developed nomogram combining patient's clinical features with sonographic findings.	ED providers (residents, fellows, attendings) with previous training in emergency ultrasound with a minimum 16 hour course and a 2 week rotation in emergency ultrasonography. They also had focused training in scanning for SBO including a 20-miunte didactic presentation and performed 5 precepted scans with the lead investigators on patients without bowel obstruction.
Van Dijk (2018) [36]	Netherlands	Systematic review (2303)	Diverticulitis	-	-	-	-	-	Outpatient treatment of diverticulitis was associated with low readmission and complication rates, leading to significant savings in healthcare costs.	
Lameris (2008) [37]	Netherlands	Meta-analysis (630 US, 684 CT)	Diverticulitis	-	US: 92%, CT: 94%	US: 90%, CT: 99%	-	-	Found no statistical difference in diagnostic accuracies between CT and US for the diagnosis of acute colonic diverticulitis.	
Toorenvliet (2010) [39]	Netherlands	Prospective (802)	Diverticulitis	-	US: 91%, CT: 95%, US+CT: 100%	US: 100%, CT: 99%, US+CT: 100%	US=100% CT=95% US+CT=100%	US=99% CT=99% US+CT=100%	Clinical evaluation alone had low sensitivity and specificity for the diagnosis of acute colonic diverticulitis. Both CT scan and US had very high sensitivity and specificity for diagnosis of acute colonic diverticulitis.	

Abbreviations: *POCUS: Point-Of-Care Ultrasound; IBD: Inflammatory Bowel Disease; US: Ultrasound; NAFLD: Non-Alcoholic Fatty Liver Disease; GI: gastrointestinal; SBO: Small Bowel Obstruction; CT: Computed Tomography* can reduce time to endoscopy, expedite urgent procedures, limit CT scans and x-rays, decrease financial burden for patients, and most importantly guide real-time treatment decisions [4,8,29]. It also emphasizes the need for allocating more resources to training in the use of GI PoCUS. Some frameworks for learning GI ultrasound have been proposed [2,3], with a standardized curriculum for GI organ systems, the implementation of which could markedly enhance the quality and quantity of GI PoCUS examinations [2,3].

Disclosure Statement

The authors report no conflicts of interest.

Author contributions:

CM provided substantial contributions to the conception and design of the study, acquisition of data/analysis and interpretation of data, drafting of the article, critical revisions of the article, and final approval of article. EL provided interpretation of data, drafting of the article, critical revisions of article, and final approval of article. CC provided acquisition of data/analysis and interpretation of data, drafting of the article, critical revisions of the article, and final approval of article. AK provided interpretation of data, drafting of the article, critical revisions of article, and final approval of article. FN provided conception and design of the study, interpretation of data, drafting of the article, critical revisions of article, and final approval of article. JR provided conception and design of the study, interpretation of data, drafting of the article, critical revisions of the article, and final approval of article.

Financial support and potential competing interests: This review article did not receive funding of any kind. The authors have no conflict of interest to disclose in the writing of this manuscript.

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Received: June 12, 2022; **Accepted:** July 21, 2022; **Published:** July 24, 2022

Citation: Majeed CN, LePage EM, Cheney C, Kovalic AJ, Nau F, et al. Point of care ultrasound of the digestive tract (“Echoenterogram”)—Current evidence and the need for training. Front Gastroenterol Hepatol. 2022; 2: 109.