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Clinical Application of Intestinal Ultrasound in Inflammatory Bowel Disease

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Abstract

Purpose of Review: Intestinal ultrasound (IUS) is a non-invasive, accurate, and well-tolerated tool that provides real-time assessment of inflammatory bowel disease (IBD) activity and is therefore an ideal monitoring tool. This review describes the evolving role of IUS in each phase of clinical management of IBD.

Recent Findings: Accumulating evidence has demonstrated that IUS is an excellent tool for the assessment of suspected IBD, with a very high negative predictive value. It accurately assesses disease activity, disease complications, and in the pre-treatment phase, provides a benchmark for subsequent follow-up. IUS can detect early therapeutic response and correlates well with other established monitoring modalities with arguably superior predictive capabilities and ability to assess a deeper degree of remission, transmural healing (TH).

Summary: IUS has a crucial role in the management of IBD and has ushered in a new era of monitoring with more rapid evaluation and the opportunity for early optimization, deeper therapeutic targets, and improved outcomes.

Keywords

Intestinal ultrasound; Inflammatory bowel disease; Crohn's disease; Ulcerative colitis; disease monitoring; clinical application

INTRODUCTION

The evolution of inflammatory bowel disease (IBD) care has shifted from reactive to proactive management with frequent surveillance for disease relapse in order to

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prevent complications. This transition has been dependent on the development of effective treatments, objective measures of disease control, and demonstrating that disease modification and improvement of long-term outcomes is achievable.

Intestinal ultrasound (IUS) is a non-invasive, accurate, reproducible, well-tolerated, and patient-preferred monitoring tool. [1,2] Its tolerability, affordability, and non-invasive nature allows for repeatability throughout various phases of care. Notably, IUS is highly sensitive to changes that occur in response to therapy, which improves prognostication and outcomes. [3,4] When compared to other cross-sectional imaging, IUS has been shown to be highly comparable to CT and MR in detecting disease activity and disease related complications [5], with the added advantage of real-time results, and the additional advantage of direct visualization of bowel motility. Moreover, IUS is primarily performed by Gastroenterologists and IBD specialists, which reduces the time to medical decision-making, expedites disease remission [6], and enhances patients' knowledge of their disease and their ability to participate in shared decision-making. [2,7] This review describes the clinical application of IUS in all phases of IBD management.

WHAT IS INTESTINAL ULTRASOUND AND HOW IS IT PERFORMED?

IUS is an imaging technique that utilizes emitted sound waves to produce images of small and large bowel based on their different refractive echoes. IUS is able to detect bowel inflammation and disease-related intramural and extramural complications. No bowel preparation is necessary, and the patient can be fasting or in a post-prandial state. However, for increased sensitivity of detection of small bowel lesions, Small Intestine Contrast-Enhanced Ultrasonography by oral Contrast (SICUS) can be performed, which requires consumption of polyethylene glycol (250 to 800 ml) 20 to 40 minutes before the IUS examination. [8–10]

IUS should be performed in a dimmed room with the patient lying flat in a supine position. It is recommended to start the examination using a low frequency curvilinear probe for deep visualization of the bowel and potential penetrating complications, followed by an examination using a linear, high frequency probe for a detailed assessment of the bowel wall. Color Doppler examination of each bowel segment for assessment of hyperemia. The examination begins by visualizing three landmarks in the right or left lower quadrant of the patient: the iliopsoas muscle laterally, the iliac vessels medially, and the crest of the iliac bone inferolaterally. [11] Once these landmarks are identified, the terminal ileum (if the examination starts on the right lower quadrant) or the sigmoid colon (if the examination is begins on the left lower quadrant) will lie immediately superiorly to the landmarks. (Figure 1) The examination should be systematic in its evaluation of each colonic segment and the terminal ileum, and also include the evaluation of the more proximal ileum and jejunum. The rectum can also be evaluated by this transabdominal approach, however, the sensitivity of detecting inflammation in this location by a transabdominal approach is lower that than when performing transperineal ultrasound (TPUS). [12]

There are several parameters indicative of inflammation that can be assessed by IUS. The bowel wall is comprised of 5 layers, which alternate between hyperechoic and hypoechoic

sonographic appearances. The first layer is the hyperechoic mucosal-lumen interphase, which is not a true bowel layer. This is followed by a hypoechoic mucosal layer (muscularis mucosa), followed by a hyperechoic submucosal layer, a hypoechoic muscularis propria layer, and lastly, a fifth hyperechoic serosal layer. The bowel wall thickness (BWT) is measured from the mucosa-lumen interface to the muscularis propria-serosa interface. (Figure 1) The most important parameter for the assessment of bowel inflammation is BWT. [13] The BWT should be assessed in each bowel segment in both longitudinal and cross-sectional planes with at least two measurements each. [14] A normal adult bowel wall (both small bowel and colon) measures 3 mm or less. BWT >3 mm is suggestive of inflammation with a sensitivity of 89% and specificity of 96% [15], while in the rectum, 4 mm or greater is suggestive of inflammation. [16] The second parameter assessed by IUS is hyperemia, as assessed by Color doppler, which is a measure of increased vascularization of the bowel wall. The inflamed bowel may have hyperemia ranging from spot-like focal signals of hyperemia to coalescing stretches and confluence of Doppler signal; in the most severe cases of inflammation Doppler signals will extend beyond the bowel wall and into the mesentery. [17,18] It is commonly graded as per the modified Limberg score. [17] (Figure 1) Additional parameters associated with bowel inflammation include loss of the bowel wall stratification, increase in mesenteric inflammatory fat surrounding the bowel (hyperechoic areas surrounding the bowel), as well as lymphadenopathy [19] Other transmural and intramural complications can be visualized by IUS, including strictures, fistulas, and abscesses. [20–23] Unique to IUS, peristaltic activity and luminal diameter can be visualized and this is particularly important in the assessment of strictures [24], for which elastography can also be performed as part of the IUS examination to aid in the evaluation of the fibrotic burden of a stenotic lesions. [20–23,25,26]

THE ROLE OF INTESTINAL ULTRASOUND IN IBD DIAGNOSIS AND PRE-TREATMENT ASSESSMENT

IUS at the Time of Diagnosis

The diagnosis of IBD requires endoscopic and histologic confirmation. IUS has a high negative predictive value NPV) and a sensitivity and specificity for diagnosis of CD of 79.7% and 96.7%, respectively. [27] For patients with established CD who undergo initial assessment, the sensitivity and specificity of IUS is 89% and 94.3%, respectively. [28] The most recent ECCO-ESGAR guidelines recommend MR enterography (MRE) and IUS as first-line modalities for assessment of small bowel disease in newly diagnosed CD, due to their comparable accuracy, lack of ionizing radiation, and the ability to assess the entire bowel. [29] In colonic inflammation, IUS has a significantly greater sensitivity for detecting the presence of disease compared to MRE in newly diagnosed patients (67% vs 47%), and is even more beneficial in patients with an established diagnosis who experience disease relapse. IUS has an overall superior ability in assessing disease extension in the colon and ileum (with exception of the rectum), and MRI is superior to IUS for localization of disease in the jejunum and proximal ileum (89% vs 73%). [30]

IUS for Pre-Treatment Assessment

In the pre-treatment phase of disease activity, assessment of baseline IUS parameters to document disease activity and disease extent are of great value for subsequent assessment of therapeutic response. [31] The pooled sensitivity and specificity of IUS in detecting disease activity in CD is 85% (95% CI 79–89%) and 91% (95% CI 87–95%), respectively. The magnitude of IUS changes in response to therapy have been shown to have a high correlation with endoscopic and histologic disease activity. [20] Identifying disease extent is vital for assessment of therapeutic response. Using endoscopy as a reference standard, IUS has a sensitivity of 86% (95% CI 83–88%) and specificity of 94% (95% CI 93–95%) in detecting disease extent in both small and large bowel CD [20], although accuracy is lower in the jejunum and rectum. [32] IUS can also assist in clarifying disease phenotypes in CD, which would often guide therapeutic decisions. The pooled sensitivity of fistula detection is 74% (95% CI 67–79%) and specificity of 95% (95% CI 91–97%) [20], and for abscess detection the pooled sensitivity and specificity is 84% (95% CI 79–88%) and 93% (95% CI 89–95%), respectively. These results are highly comparable to both CT and MR performance. [22,33,34] Notably, areas that are difficult to assess by IUS were not included in these studies, which include the stomach, duodenum, the distal sigmoid, rectum and ileal loops in the deep pelvis. Using a reference standard of surgery, IUS has high diagnostic accuracy for detection small bowel stenosis with a sensitivity of 80% and specificity >90%, which is highly comparable to CT and MR. [20]

IUS for Prognostication

A number of studies have demonstrated the ability of IUS to predict outcomes. Increased BWT ≥ 7 mm, hyperemia, stenosis, and loss of bowel wall stratification are independent predictors of a complex disease course as characterized by need for steroids, treatment escalation, hospitalization, and/or surgery. [35,36] Identification of fibrosis by elastography [37] and lack of improvement in BWT has also been shown to predict need for surgery. [33,38] A recent publication from Milan demonstrated higher accuracy of predicting colectomy in patient with UC when evaluating transmural inflammation severity using the Milan Ultrasound Criteria (MUC) as compared to the Mayo endoscopic score (MES) with the area under the curve (AUC) for the MUC and MES being 0.83 vs 0.71, respectively, with an MUC cut-off score of 7.7 predicting colectomy. [39]

THE ROLE OF INTESTINAL ULTRASOUND IN MONITORING THERAPEUTIC RESPONSE

Given the discrepancy between clinical symptoms and disease activity in IBD, it is now standard of care to combine patient reported outcomes with objective measures for the assessment of response to therapy. [40] A treat-to-target approach that incorporates this strategy has been proposed, but is limited by the tolerability, accuracy, and repeatability of traditional monitoring modalities. In the Selecting Therapeutic Targets in Inflammatory Bowel Disease (STRIDE-II) consensus statement, IUS is recognized for revolutionizing disease monitoring, due to its the ability to assess for disease activity throughout the entire bowel, its repeatability, as well as its ability to assess for transmural healing (TH). [41]

The response rate by IUS has been shown to be comparable to rates of response assessed by endoscopy and MRE. [31] Sonographic response in both CD and UC is defined as either: 1) A reduction of BWT by more than 25%, 2) a reduction in BWT of >2 mm, or 3) a reduction of BWT of 1 mm or more and one point of color Doppler signal reduction. [31] Sole reduction of one color Doppler signal (CDS) point in the absence of reduction in BWT does not correlate with improved outcomes and is insufficient to consider as therapeutic response. [31,42] It is recommended that sonographic response be assessed in all bowel segments and that disease complications (such as abscesses, and strictures) be identified and documented accurately prior to treatment initiation. In a recent systematic review and expert consensus, sonographic response is recommended to be assessed in both UC and CD within 14 +/− 2 weeks of treatment initiation, and again between weeks 26–52. [31]

Although response rates to therapy in IBD are dependent on a number of factors including the therapeutic mechanism of action (MOA), IUS can detect therapeutic response within days to weeks of treatment initiation, and in UC possibly earlier than in CD. The TRUST&UC Study, an observational study of 42 German IBD centers of 242 patients with UC, demonstrated sonographic normalization of BWT in nearly half of patients within two weeks of treatment initiation. [3] In a sub-analysis of the TRUST&UC study of patients receiving anti-TNF therapy, reduction in BWT was demonstrated at week 6 from treatment initiation [43]. In another study of patients with UC receiving vedolizumab, BWT reduction was noted at week 14. Synthetic small molecules and corticosteroids have been noted to elicit sonographic responses at even earlier time points. In a study by de Voogd et al of patients with UC receiving tofacitinib, reduction in BWT was noted at week 8, and was found to be the most important sonographic parameter to evaluate for treatment response when compared to endoscopy. [44] BWT correlated with MES ($\rho = 0.68$, $P < .0001$), and the UC endoscopic index severity ($\rho = 0.73$, $P < .0001$). They further identified BWT of 2.8 mm to be the most accurate in detecting endoscopic remission (AUC 0.87) and decrease by 32% of (AUC 0.87) predicted therapeutic response. A prospective study of patients with acute severe UC, admitted for treatment with IV corticosteroids, demonstrated IUS response as early as 24–72 hours from treatment initiation. This study demonstrated that reduction in BWT by >20% by 72 hours from IV corticosteroid initiation was associated with an odds ratio of 22.6 (95% CI, 4.2–201.2) of therapeutic response by one week. [4]

In luminal CD, several studies have demonstrated sonographic response by 3 months with continued improvement by 52 weeks, and that response at week 12 predicted response at 52 weeks with sensitivity and specificity of 76% and 82%, respectively. [38,45] In an additional study of CD patient treated with anti-TNF, sonographic response was noted as early as week 4–8, and reduction by 18% predicted endoscopic response at week 12–34. [38] In a sub-study of STARDUST, an international, multicenter, phase 3b, randomized controlled trial in ustekinumab-treated CD patients, IUS response rate was noted as early as week 4, with week 16 sonographic response rates for the colon and terminal ileum reported as 40%, and 30%, respectively. [46] Studies in patients with CD-related fistulae or stenoses treated with anti-TNF had variable response rates. [38,47,48] In the TRUST-CD trial, strictures assessed by IUS were present in 25% of patients, and this decreased to 12%, 10% and 9% at 3, 6, and 12 months, respectively. 5% of patients had abscesses at baseline, followed by 2%, 1.5% and 0.7%, respectively.

Given evidence presented here, we propose assessment of therapeutic response in UC and CD to be between 1–3 months from therapy initiation, depending on the MOA and the patient's clinical response. [Figure 2]

INTESTINAL ULTRASOUND FOR THE ASSESSMENT OF REMISSION

There has been a significant evolution in treatment targets in IBD over the last several decades. With discrepancy between symptoms and disease activity, and evidence of disease progression and relapse in the presence of disease activity, therapeutic targets have moved away from symptomatic remission alone, to clinical remission associated with mucosal healing. With CD characterized by transmural inflammation and increasing evidence of transmural healing (TH) being associated with superior outcomes to mucosal healing, TH has been suggested as an adjunctive therapeutic target in CD.41 Specifically, sonographic transmural healing has been associated with lower rates of need for steroids, treatment escalation, hospitalizations and surgery. [49–51]

In a recent expert consensus, sonographic transmural remission (TR) was defined as BWT ≤ 3 mm AND the absence CDS in both CD and UC. In this publication they note that the sigmoid colon may have enlarged muscularis propria allowing for bowel wall thickness up to 4 mm is there is no resemblance of active inflammation. They recommend TR to be assessed between 26–52 weeks from treatment initiation, while recognizing that TR can occur by week 12 and with increased likelihood up to 1 year of therapy. [31] A systematic review and metanalysis in both CD and UC, concluded that colorectal segments with BWT <3 mm can predict endoscopic remission with high likelihood and a negative predictive value of 92.7% for endoscopically active disease[12]. Other studies show a strong association with endoscopic remission (SES-CD <2), $\kappa = 0.63$, $p = 0.01$, and nearly perfect correlation with TR assessed by MRE, $\kappa = 0.9$, $p \leq 0.01$. [48] Anti-TNF therapy has been associated with sonographic TR in 26% of patients, but with thiopurines in only 5% of patients. In a multicenter study from 16 Italian centers, which included 180 patients with CD, sonographic transmural healing rates at 12 months for adalimumab was 26.8%, 37% for infliximab, 27.2% for vedolizumab and 20% for ustekinumab. The authors also showed that colonic lesions were more likely to achieve TH at 3 months, and that greater BWT at baseline was associated with lower rates of TH. Although a number of publications have now called for reevaluation of UC as a transmural disease [52–55], no studies have been done to assess for improved outcome in UC with achievement of TH.

INTESTINAL ULTRASOUND AS A MONITORING TOOL FOR THE PATIENT IN REMISSION

Guideline and expert recommendations endorse IUS for disease assessment [1–3] but its use for routine monitoring in the asymptomatic phase is yet to be recommended. The ECCO-ESGAR consensus suggests surveillance every 3 to 6 months depending on upon the duration of remission and current therapy. They also describe the ideal monitoring test to be non-invasive, simple to conduct, easily interpreted and able to detect an imminent disease flare, and while these criteria are met by IUS, the validity of IUS for monitoring asymptomatic patients remain unknown. [2] With growing evidence on TH as a predictor

of long-term remission and improved outcomes [4,5,6], it can be extrapolated that in the asymptomatic patient with ongoing sonographic disease activity, follow-up IUS is warranted. Although FCP has been shown to predict disease relapse three months prior to clinical symptoms [56], this not yet been clearly studied in IUS.

The optimal frequency of IUS evaluations during remission should be customized to each patient. Targeted monitoring is advisable for patients with 1) discrepancies between symptoms and inflammation, 2) ongoing sonographic activity in the absence of symptoms, and 3) patient at high risk of disease relapse. There is weak symptom-inflammation correlations in IBD, especially in CD [8], underscoring the benefit of incorporating IUS into follow-up evaluations alongside biochemical markers like FCP and CRP. Moreover, ongoing sonographic parameters of inflammation can forecast the need for therapeutic adjustments, including corticosteroid treatment, and predict hospitalization and surgical requirements at 12 months. [9] Frequent IUS assessments are also prudent for patients with aggressive disease severity and extramural complications, due to their increased risk of requiring surgical interventions. For colonic and rectal inflammation, monitoring symptoms and fecal FCP levels may be sufficient, reserving IUS for assessment of symptomatic or biochemical signs of active inflammation, however further evaluation of this strategy is ongoing.

SPECIAL CONSIDERATIONS: INTESTINAL ULTRASOUND IN THE PEDIATRIC PATIENT

The use of IUS is even more consequential in the pediatric population, in which IBD is diagnosed early in life and, if suboptimally treated, can significantly and irreversibly impair growth and development. Close monitoring with IUS can facilitate not only early recognition of inflammation but can alter disease course and prevent irrevocable complications and, in some cases, the need for surgery. There are unique considerations when performing IUS in children. Firstly, prioritizing patient comfort by performing IUS in a quiet, dimly lit room is recommended and involving the child and caregivers in the examination not only facilitates cooperation, but also fosters autonomy and shared decision-making in real-time. In a recent study by Hudson *et al.*, pediatric patients with IBD and their caregivers preferred IUS over other modalities and felt it improved understanding of their disease. [2]

The same standard examination technique is recommended for pediatric and adult patients, however; as children have significantly smaller abdominal habitus, high frequency transducers (7–17MHz) often provide superior visualization and more accurate measurement. [57] Although rarer, children with very early onset (VEO-IBD) with particularly small abdominal habitus may have small bowel loops present in the left lower quadrant, which is not typical of older patients and can impair visualization. Different techniques can be utilized to circumvent this unique challenge, such as maneuvering the transducer horizontally and laterally while applying graded compression to mobilize the bowel. [58] Another distinctive consideration in children, is IUS parameter norms. BWT <3mm is considered normal in adults and this is traditionally extrapolated to pediatric patients, however; there is emerging data that BWT < 1.1 mm is normal with the upper limit

normal of 1.9 mm and studies are ongoing in an effort to assess if BWT ≤2.5 mm may be a more accurate normalized value for BWT in children. [59] Furthermore, mesenteric lymphadenopathy can be an indication of inflammation in adult IBD patients, however; it is common for children to have benign mesenteric lymphadenopathy at baseline and thus, correlation with other IUS parameters is recommended. [57]

In addition to variances in IUS parameters, there are specific IUS scoring systems for children with IBD. Interestingly, recent data suggest that IUS scores may be more accurate in children, correlating better with endoscopy [60], but additional studies are needed. Similar to adult algorithms, when monitoring response to therapy in children, IUS is recommended at baseline, and then repeated following induction or 4–12 weeks after change in therapy to assess for response. Follow-up IUS is recommended every 3–6 months thereafter depending on clinical status. [57] Routine monitoring with IUS provides a unique opportunity to improve engagement in pediatric patients and their caregivers and has the potential to transform clinical care in our most vulnerable patient populations.

INTEGRATION OF INTESTINAL ULTRASOUND INTO CLINICAL PRACTICE

Education and credentialing

Over the last decade there has been an increasing number of Gastroenterologist trained in IUS, however, with the arrival of IUS education to the United States [Review Arrive of IUS to the United States by NKC] a major barrier to integration of this modality into practice has been lifted. Albeit the availability of IUS training and credentialing in the U.S. through the International Bowel Ultrasound Group (IBUS-group.org) in collaboration with the Intestinal Ultrasound Group of the United States and Canada (iUSCAN) [61], this still requires significant dedicated time for both training, and importantly, to achieving competency, which has yet to have been clearly defined. It is important to acknowledge that the unique role of advanced practice providers in the U.S., such as advanced nurse practitioners, and physician assistants, are additional IBD team members who would be of great interest to train and integrate IUS into their clinical practice. The current IBUS curriculum includes three parts, the first is a hands-on-course, followed by 2-to-4-week, one-on-one training at an expert center, and the third component is a didactic course followed by a written examination. With the increasing demand, limited scalability to this approach, and need for competency measures, an electronic educational platform and adaptation of this curriculum is underway to meet the growing demand of IUS in the IBD community.

Equipment

The second requirement to integration of IUS into practice is having the appropriate equipment. Given the need for visualization for the layers of the bowel wall, to the level of 0.1 mm, a modern ultrasound machine with color Doppler capabilities is required. A minimum of two probes are needed for the assessment of the bowel, the first is a lower frequency convex array probe of 1–5 mHz which is utilized for visualization of the deeper structures at lower resolution, and is typically used to assess the bowel anatomy, transmural and intramural complications and for the transabdominal evaluation of the rectum. The second transducer is a medium to high frequency linear array of 5–15 mHz (adults will

require the use of the lower end of this frequency while the pediatric patients whose bowel is more superficial may require the higher end of the range). [62] The higher frequency probe providers a higher resolution assessment of the bowel, allowing for the assessment of the bowel wall layers, and their measurement.

Remuneration

The billing for point of care ultrasound (POCUS) by a trained physician has been an endorsed by the American Medical Association and subsequently accepted by the Centers for Medicare & Medicaid services.63,64 In order to bill for an IUS examination, a dedicated IUS procedure note should be populated as well as documented imaging in the electronic medical record of the patient. Currently an IUS examination is billed in the U.S. using borrowed Current Procedural Terminology (CPT) codes for a limited abdominal ultrasound (76705) and color Doppler examination (93975), along with recommended associated ICD-10 codes for CD (K 50.90) or UC (K 51.90), and in those who are not yet diagnosed, using an ICD-10 code R10.9 for abdominal pain has been recommended. [65] At the time of this review, and depending on the clinical setting and technical, professional, and facility fees, reimbursement to hospital-based clinical centers have been reported to be approximately $800 (USD) per IUS examination [65] (independent of a clinical visit charge for customary IBD care).

Clinical Models for IUS Incorporation into IBD Care

Ideally, IUS should be performed as a POCUS examination by the IBD clinician during the patient visit, as part of the abdominal examination. Alternatively, an IUS experienced colleague can perform the IUS examination for their non-sonographer colleague before, after, or during a visit which still allows for real-time results and clinical decision making. Alternatively, an independent IUS clinic can be established for referral by other colleagues (similar to other imaging modalities), however, this approach should also include clear lines of communications between the sonographer and the primary IBD clinician for timely management decisions to occur.

CONCLUSION

In the pursuit of heightened precision and tighter disease control in the management of IBD, real-time monitoring by IUS not only fulfills a gap in current monitoring capabilities, but also accelerates and refines disease management. This technological evolution allows for comprehensive and dynamic assessment of the disease with inherent advantages of IUS including: real-time imaging and results, performance by expert IBD clinicians, and acceleration of care and therapeutic decision-making. The technical features and performance of IUS contribute to its vital role in every stage of IBD management from pre-treatment assessment, and proactive monitoring in remitted disease to evaluation of meaningful deeper levels of transmural healing. The integration of IUS into IBD care heralds a new era of diagnostic precision, therapeutic optimization, and improved outcomes for our patients.

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JS-P and AK report no relevant disclosures. NKC serves as a consultant to Takeda and for NeuroLogica, a subsidiary of Samsung Electronics, and as a speaker for Bristol-Myers Squibb. DTR has received grant support from Takeda; and has served as a consultant for Abbvie, Alimentiv Inc., Altrubio, Amgen, Avalo Therapeutics, Bristol-Myers Squibb, Buhlmann Diagnostics Corp, ClostraBio, Connect BioPharma, Datos Health Ltd, EcoR1, Evinature Ltd, Ferring Pharma, Image Analysis Group (IAG), Iterative Health, Janssen Pharmaceuticals, Lilly Eli & Co, Menten AI, Odyssey Thera, Pfizer, Prometheus Biosciences, Reistone Biopharma, Samsung Neurologica, Sangamo Therapeutics, Shanghai Pharma Biotherapeutics USA, Takeda, Target RWE, Tissium S.A., and Trellus Health.

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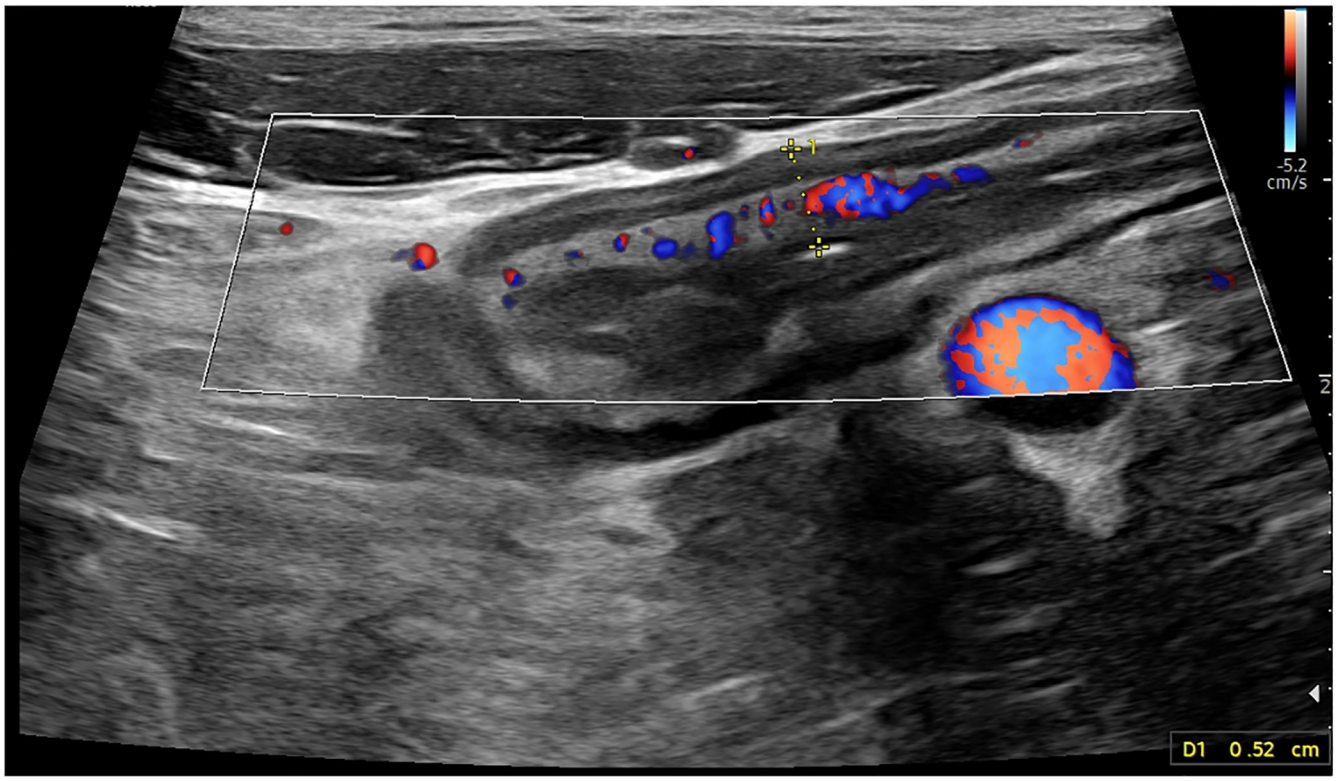

Figure 1:
Intestinal ultrasound image showing a longitudinal view of a sigmoid colon laying superior to the ileac artery. The image depicts a thickened bowel wall (yellow caliper), with loss of haustration, mesenteric inflammatory fat proliferation (hyperechoic surrounding seen to the left of the bowel), and hyperemia under color Doppler view.

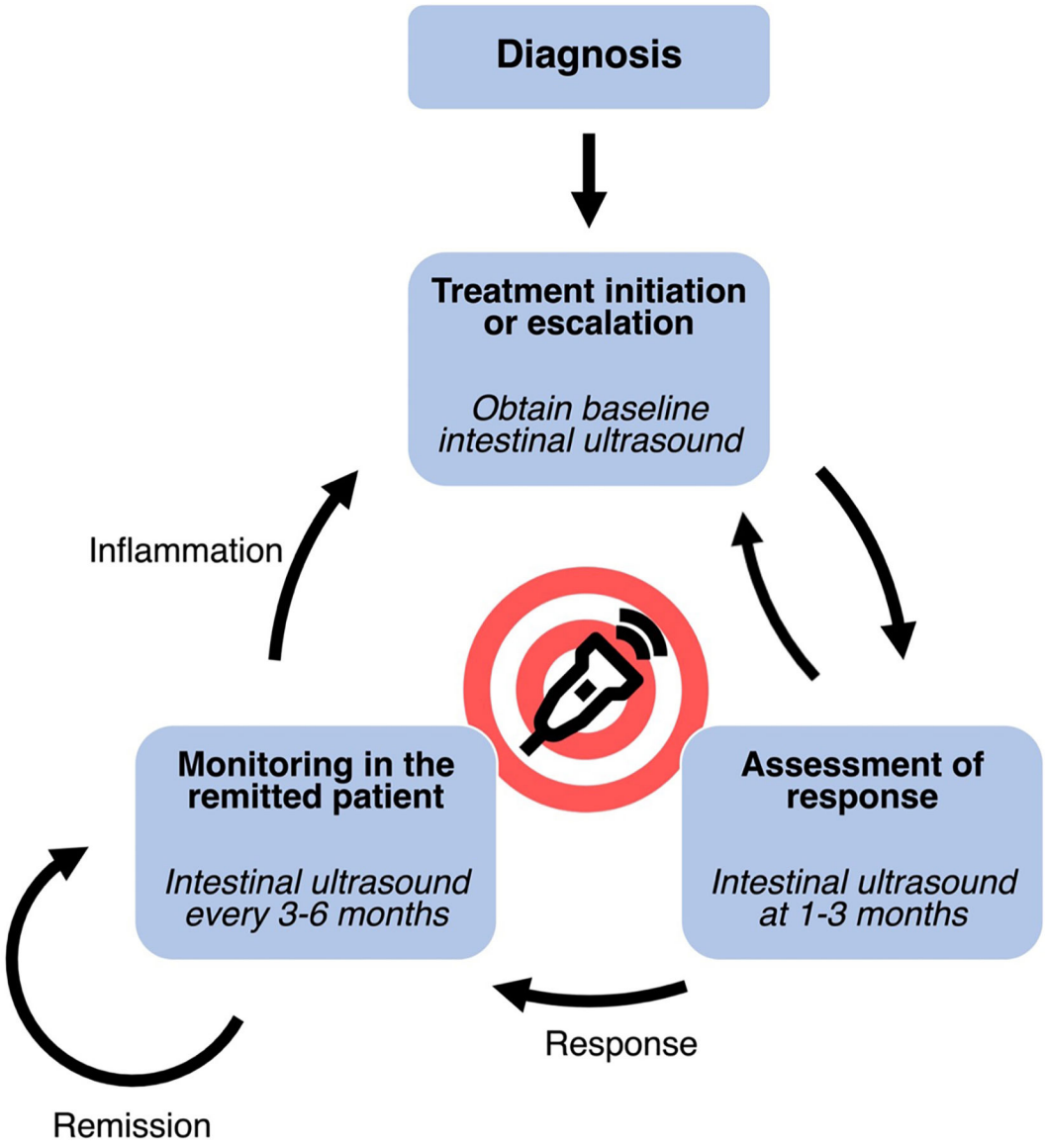

Figure 2:

Proposed Approach to Intestinal Ultrasound for Disease Monitoring in IBD

This flowchart illustrates a step-by-step clinical approach starting with diagnosis, followed by the initiation or escalation of therapy. The assessment of response through intestinal ultrasound can be done between 1 to 3 months after medication change. If response is not achieved, then therapy change or dose escalation can be done, with subsequent assessment of response. If response is confirmed, patient can then enter the monitoring of remission. For this phase, we recommend using IUS every 3–6 months, depending on risk factors, to ensure continued remission or early detection of disease progression.