



AI-powered intestinal ultrasound in inflammatory bowel disease: Advancing toward automated disease assessment

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The management of inflammatory bowel disease (IBD) relies on accurate disease assessment and close monitoring to guide therapy and evaluate treatment response. While endoscopy remains the gold standard for detecting mucosal inflammation, its invasiveness and inability to fully assess transmural disease or extraintestinal complications limit its use as a stand-alone tool. Cross-sectional imaging modalities, such as CT and MRI, provide accurate evaluations but are hindered by high cost, limited accessibility, and patient burden. Therefore, intestinal ultrasound (IUS) has emerged as a safe, non-invasive, and reproducible modality to evaluate transmural inflammation and complications in real time, making it increasingly relevant for both Crohn's disease and ulcerative colitis. However, challenges such as operator dependence, variability in image acquisition, and lack of standardize protocols have limited its widespread adoption. Artificial intelligence (AI) offers transformative potential to overcome these barriers by automating image analysis, standardising interpretation, and reducing interobserver variability. Early applications have shown promise in bowel wall segmentation and thickness assessment, with future opportunities to further integrate imaging features with biomarkers, clinical data, and multi-omics for precision medicine. This review aims to explore the current and future roles of IUS, summarizing the potential of AI in IUS to improve diagnostic accuracy, enhance disease monitoring, and enable personalized patient management. We will discuss the strengths and limitations of existing approaches, highlight barriers to clinical implementation, and outline perspectives on how AI-enhanced IUS may transform both research and routine care in IBD.

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Introduction

Effective management of Inflammatory Bowel Disease (IBD) relies on accurate disease assessment and tight monitoring to guide treatment decisions and evaluate response to therapy [1].

Endoscopy is still the gold standard for detecting mucosal inflammation and dysplastic lesions [2], supported by advanced endoscopic techniques that allow the identification of subtle inflammation and guide targeted biopsy sampling [3]. However, it is invasive, costly, and often uncomfortable, and it does not fully capture transmural activity or extraintestinal complications.

Cross-sectional imaging modalities, such as computed tomography (CT) and magnetic resonance imaging (MRI), provide valuable complementary information, but their routine use is constrained by high cost, limited accessibility, and the time-consuming (MRI).

In this context, intestinal ultrasound (IUS) has emerged as a safe, noninvasive, cost-effective, point-of-care tool for assessing IBD in clinical settings. Its adoption is expanding rapidly worldwide, supported by its feasibility, patient acceptability, and diagnostic accuracy. IUS enables real-time, radiation-free imaging and can be repeated frequently, making it suitable for both

diagnosis and treatment monitoring [4]. Despite its widespread clinical uptake, variability in IUS interpretation can pose challenges for standardized measurement and incorporation as an endpoint in clinical trials. Consensus guidelines emphasize the need for standardized reporting and use of validated scoring systems in IUS. Yet, high interobserver variability persists in quantifying disease severity [2,5,6].

Artificial intelligence (AI) and machine learning (ML) offer powerful opportunities to overcome these limitations by automating image analysis, identifying pathological features, quantifying disease activity, and reducing interobserver variability. Their integration into IUS could enhance objectivity and standardise interpretation, supporting real-time decision-making toward precision medicine [7]. However, AI in IUS is still in its infancy compared with other imaging modalities.

This review explores the current and future roles of AI and ML in IUS, underscoring their transformative potential in optimising disease monitoring and advancing personalised IBD care.

IUS in IBD – strengths and limitations

IUS is increasingly recognized as a key tool for IBD diagnosis and monitoring [6]. It is particularly valuable in CD, enabling real-time evaluation of transmural inflammation [8], therapeutic response, post-operative recurrence [9], and complications like strictures, fistulas, and abscesses [10]. Its use is also expanding in UC, particularly for assessing disease activity and extension when endoscopy is not feasible, assessing early therapeutic response [8], and detecting complications [6] (Figure 1).

It is safe, non-invasive and reproducible [11] making it well-accepted by patients and suitable for point-of-care (POCUS) use during routine clinic bedside examination.

Demonstrating diagnostic performance similar to endoscopy and MRI, it requires minimal equipment and can be performed by a single operator [12]. POCUS has been shown to improve and expedite clinical management [4], and when combined with advanced imaging tools it allows a comprehensive evaluation of disease features, thereby enhancing both disease assessment and optimising patient management. As main anatomical challenge, transabdominal IUS faces significant limitations in assessing the rectum, particularly in visualizing rectal wall layers and perirectal tissues, which reduces its reliability for evaluating disease extension. Therefore, transperineal ultrasound has been proposed as an effective alternative when accurate rectal

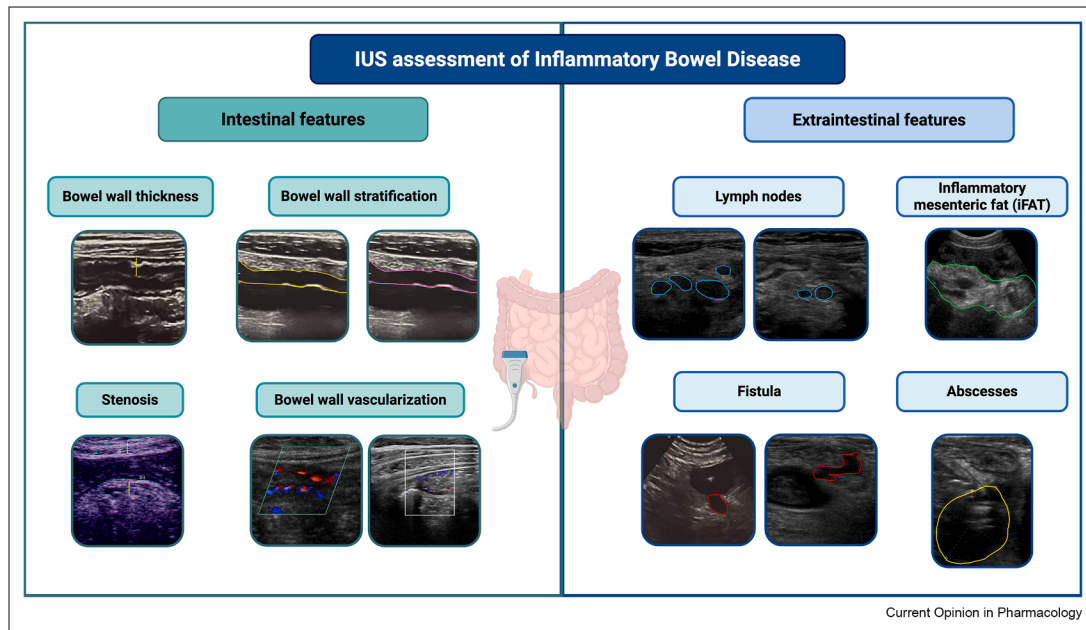
assessment is essential, although less comfortable for patients [13].

Overall, the standard B-mode modality assesses bowel wall thickness (BWT) and stratification (BWS), while Color Doppler signal (CDS) evaluates bowel vascularity [14]. Advanced techniques further expand disease assessment. Small intestine contrast ultrasonography, by contrast ingestion, improves the detection of strictures with near-perfect agreement with endoscopy [15] and over 95% sensitivity and specificity for intestinal lesions [16]. At the same time, CEUS complements CDS by using intravenous contrast agents to enhance the visualisation of tissue perfusion and the intestinal wall's microvasculature [17]. It correlates with clinical activity and endoscopic disease scoring [18], showing potential in characterizing intestinal stenosis and differentiating inflammatory mass from abscesses [19–21]. However, by requiring the injection of a contrast agent and a more extensive set-up, it doesn't share POCUS advantages in terms of rapid access and ease of use. Finally, elastography may offer insights into tissue stiffness, potentially distinguishing fibrotic from inflammatory strictures [22]. However, current evidence is still limited and it is not always possible to achieve a clear differentiation in daily practice [23].

While these methods allow for a nuanced evaluation, variability in parameter definition and lack of standardisation remain challenges for research and incorporation into clinical trials, though clinical adoption is steadily expanding globally. Many of these limitations associated with IUS are shared with other imaging modalities, including endoscopy, CT enterography, and MRI. Efforts toward harmonisation and centralized image review are key strategies to reduce interobserver variability and improve consistency across modalities [23].

To further standardize the assessment of IBD activity, several scoring systems have been developed [24–28], combining several weighted features to gain a total score. Existing scores share core parameters, including bowel wall thickness and CDS, both of which demonstrate good-to-excellent interobserver variability between experts (ICC = 0.96 for BWT, K = 0.63 for CDS) [29]. Nevertheless, variability in features assessed across scoring systems (e.g. BWT, BWS, CDS, inflammatory mesenteric fat), as well as heterogeneity in parameter definitions and reproducibility may contribute to inconsistent interobserver performance and limit broader adoption, particularly in research settings [30]. In addition, performing IUS is often more challenging than interpreting it. A recent prospective study demonstrated a significant performance gap

Figure 1



Overview of the main intestinal and extraintestinal features evaluated through intestinal ultrasound in inflammatory bowel disease.

between trainees with prior ultrasound experience and novices, underscoring the importance of technical skill in image acquisition and probe handling [31].

Indeed, despite the widespread use of IUS as a clinical standard of care, operator variability and differences in equipment remain challenging [8], creating a critical need for AI and ML to enhance accuracy, standardisation and reliability [32].

The rise of AI-enhanced ultrasound in IBD

Artificial intelligence is rapidly transforming medical imaging, offering powerful tools for automating and enhancing image analysis.

In radiology, convolutional neural networks (CNNs) and support vector machines (SVMs) have already demonstrated high accuracy in detecting and classifying patterns of inflammation in CT and MRI scans of IBD patients. These models showed excellent performance in feature extraction and image classification [33–35]. Their success in cross-sectional imaging provides a strong rationale for applying similar approaches to IUS. AI-enhanced ultrasound may offer promising solutions by supporting a more objective and reproducible evaluation of key parameters [36].

Current AI models of IUS in IBD are still in their early stages (Table 1). One promising area is the automation

of image interpretation, particularly in bowel wall identification and measurement of BWT, both of which are critical for assessing disease extension activity.

CNN-based segmentation algorithms are being developed to delineate the intestinal wall layers and quantify bowel wall stratification with high precision, aiming to reduce inter-operator variability and standardize assessments [37].

While the current body of literature on AI-assisted IUS remains limited, early studies underscore its potential for automating measurements and enhancing consistency across operators. Carter *et al.* developed a CNN on 1008 prospectively collected images from 308 patients to distinguish normal from abnormal bowel images according to BWT below or above 3 mm. The model showed an overall accuracy, sensitivity and specificity of 90.1%, 86.4% and 94% in classifying bowel wall thickening. However, this approach was limited by manual region-of-interest (ROI) cropping, suboptimal network configuration, and lack of interpretability [38].

Beyond BWT, AI-driven tools have also been applied to automate bowel segment identification starting from 4565 frames (1478 abnormal and 3087 standard). AI-driven segmentation performed well in identifying specific wall layers [39], and showed 90.29% and 93.7% sensitivity and specificity in classifying BWT >2 mm.

Table 1

Overview on current studies on AI in IUS for IBD.

Author, year	Study design	Sample Size	Model	Training/testing	Outcome	Results
Carter et al., 2023 [38]	Single-center	308 patients 1008 images (50 % normal and 50 % abnormal)	CNN	80 % training	Detection of bowel wall thickening (BWT >3 mm)	Sensitivity 86.4 %, specificity 94 %, AUC 0.98
	Prospective	Classification		20 % testing		
Gu et al., 2024 [40]	Single-center Retrospective	61 patients 125 images (33 % abnormal, 67 % normal)	Radiomics + CNN	80 % training 20 % testing	Differentiation of normal vs abnormal IUS (BWT >3 mm or bowel hyperemia)	Sensitivity 93.8 % Specificity 93.8 % Accuracy 94 % AUC 0.98
Kumaralingam et al., 2025 [37,39]	Single-center Prospective	260 patients 4565 frames (1478 abnormal, 3087 normal)	CNN	80 % training 20 % test (50 % normal/abnormal for each group)	Bowel segment identification and BWT classification (>2 mm)	Sensitivity 90.29 %, specificity 93.7 %; ICC 0.94

However, automated BWT measurements remain limited exclusively to longitudinal views (e.g., ascending, descending, and sigmoid colon), excluding transverse images, which restricts generalizability.

Despite these encouraging results, CNN models face challenges with interpretability. Their “black box” nature means that the rationale behind predictions often remains opaque, raising concerns and undermining trust and clinical adoption.

The role of radiomics offers a potential solution by extracting the quantitative spatial distribution of signal intensities and pixel interrelationships, making it more interpretable than CNN.

In a feasibility single-centre study, Gu et al. evaluated the performance of a radiomics-based CNN classification model in differentiating between normal and abnormal IUS images (BWT >3 mm or bowel hyperemia with modified Limberg score ≥ 1). The model achieved an average test AUC of 0.98, compared to 0.75 for the CNN [38]. Although promising, this work was limited to longitudinal images from the colon, underscoring the need for broader validation.

Furthermore, AI tools should be trained to detect complications such as strictures, fistulas, and abscesses by identifying complex sonographic patterns, which traditionally require expert interpretation.

Beyond image analysis, ML models have the potential to integrate IUS-assessed features with other clinical data, such as electronic health records, biomarker profiles, endoscopic findings, and disease activity scores, to create a more holistic picture of patient disease activity.

This multimodal integration has the potential to facilitate a more accurate disease stratification, prediction of therapeutic response, and real-time monitoring of disease progression, aligning AI-enhanced IUS with principles of precision medicine.

Although in their early stages, these AI-driven advancements in IUS imaging hold significant promise in transforming IBD management, making it more efficient, reproducible, and accessible across varying levels of clinical expertise and scalable across clinical settings. AI-aided IUS could provide substantial value in operator training. Specifically, automated feedback and real-time feature recognition may help to flatten the learning curve, facilitating skill acquisition and improving reproducibility among less experienced users.

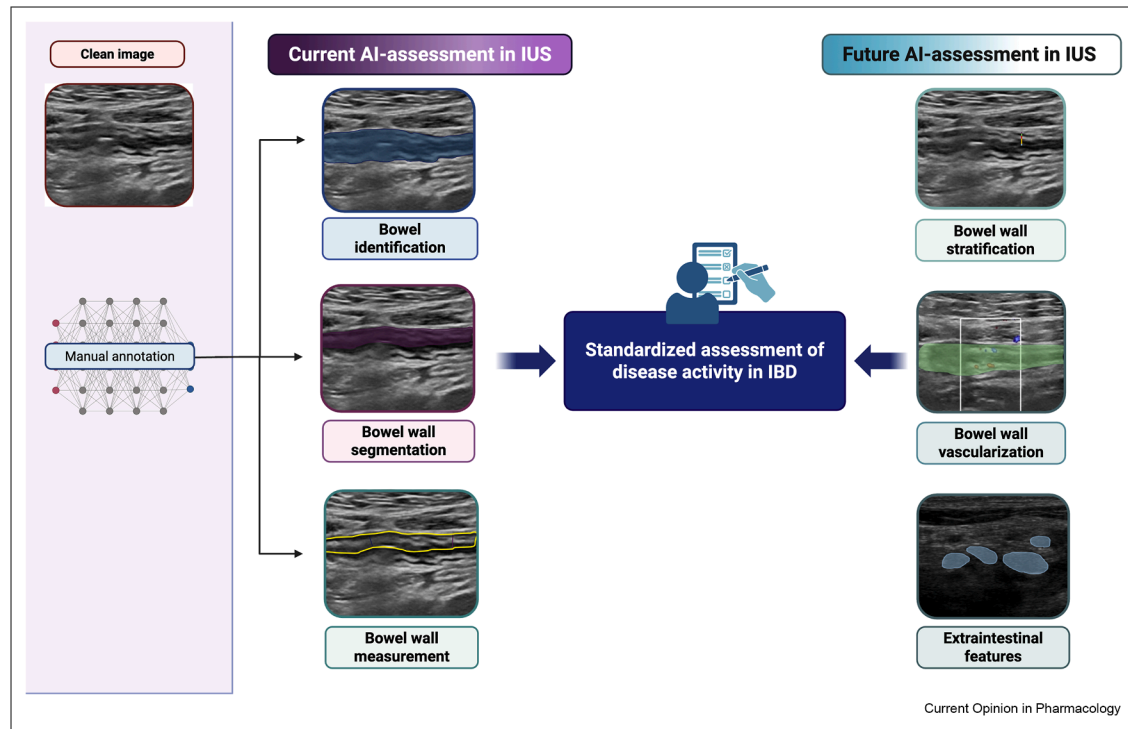
Figure 2 shows current and potential future AI-assessed features in IUS.

Breaking barriers: challenges to AI adoption in IUS

There is an increasing interest in integrating IUS into clinical trials and practice. Despite the significant progress made in the development of AI in IUS, several key challenges remain for its adoption (Table 2).

One major issue is the limited size and diversity of current datasets used to train, test and validate the models [41]. Studies are often single-center, lack variation in demographics, disease phenotypes, disease activity and equipment types. Variability in imaging protocols, machine settings, transducer types, and operator techniques further complicates model training and reproducibility [38–40].

Figure 2



Pipeline of current and future AI-powered assessment of intestinal ultrasound in Inflammatory bowel disease.

Table 2

Advantages and challenges of AI in IUS for IBD.

Advantages	Challenges
Automation of bowel wall thickness measurement Reduced interobserver variability and improved reproducibility Automated assessment of disease activity according to validated scoring systems More interpretable, quantitative analysis through radiomics Standardized endpoints, reduced variability, cost savings from central readout in clinical trials Real-time decision support at point-of-care Enables multimodal integration (EHR, biomarkers, endoscopy, imaging) towards precision medicine	Limited dataset size and diversity Variability in imaging quality, acquisition protocol, annotation Absence of large multicenter validation studies Interpretability issues with CNN (black box models) Ethical, regulatory, and data-sharing challenges (bias, anonymization, accountability) Clinician trust, workflow integration, and training required

Standardization in image acquisition, annotation, and quality represent another challenge. Inconsistent annotations protocols limit model training, validation, and reproducibility. Large multicenter repositories with standardized imaging protocols, consistent annotation standards, and diverse patient representation are needed to overcome these limitations, reducing bias, improving reliability and model performance [42,43].

Moreover, strong model validation is another issue, as few large-scale, multicenter studies currently exist.

Without cross-institutional testing, the generalizability of AI tools remains uncertain. AI systems should be tested across multiple settings and configurations to confirm reproducible performance [43].

Ethical and regulatory considerations are also critical. Secure data sharing, anonymization, prevention of algorithmic bias, and clear definitions of clinician versus AI responsibilities are essential for building trust [44]. Standardized protocols and international training initiatives, such as those promoted by the International

Bowel Ultrasound Group (IBUS) [45], will be essential in developing unified frameworks for AI validation and implementation.

From a regulatory point of view, clear approval pathways and evidence standards must be established to facilitate inclusion of AI-powered tools in clinical guidelines. Policies should emphasize transparency, auditability, and accountability of AI systems [46].

Finally, clinician trust and workflow integration are essential for clinical adoption. AI tools must be user-friendly, interpretable, and provide outputs that align with established clinical frameworks. Education and training will be critical to ensure clinicians understand and effectively incorporate AI-supported insights into their decision-making. Therefore, AI outputs should be transparent and interpretable to be integrated into clinical workflows [46].

By proactively addressing these challenges, the field can move closer to realizing the full potential of AI-enhanced IUS in routine IBD care.

Transformative potential and future perspectives of AI in IUS

The integration of AI and ML into IUS could potentially transform IBD management in both research and clinical practice.

Transmural healing is an emerging aspirational treatment target in CD, with evidence indicating that it is associated with a higher rate of steroid-free clinical remission, reduced hospitalization, lower need for surgery and longer relapse-free intervals compared to mucosal healing alone [47]. Therefore, its accurate assessment is increasingly considered as an endpoint to evaluate treatment response [1,48].

In clinical trials, AI technologies could automate and standardise IUS assessment, reducing inter-centre variability, and improving the reliability and comparability of IUS-based outcomes across studies. While current assessment of bowel wall parameters already relies on objective and often quantitative measures, their automated analysis through AI would further enhance ease of use, speed and consistency. This will lead to more efficient trial design, reduce costs related to central readout and provide objective, quantitative endpoints for evaluating therapeutic efficacy [49].

In the future, AI-enhanced IUS could serve as real-time decision support tool in everyday clinical setting, delivering automated assessment of sonographic findings during point-of-care IUS. This could enable accurate assessments of disease activity to guide treatment adjustment and optimize monitoring intervals. AI could

also bridge expertise gaps, promoting wider adoption of IUS in routine care, while ensuring high-quality IUS interpretation [50].

Looking forward, AI models could evolve from single-task systems (e.g. bowel wall identification; BWT) to comprehensive disease assessment tools capable of evaluating multiple IUS features simultaneously, such as bowel wall stratification and vascularisation, inflammatory mesenteric fat, presence of lymph nodes and disease-related complications. This could result in the ability to predict disease activity according to validated scores, further improving the assessment in both clinical trial and practice.

Finally, the greatest transformative potential lies in the multimodal integration. By combining IUS-derived imaging features, inflammatory biomarkers, endoscopic findings, and emerging multi-omics data (e.g., genomics, proteomics, microbiome profiles), ML models could generate predictive algorithms tailored to individual trajectories. This would enable forecasting of flares, predicting response to specific therapies, and informing long-term management strategies, ultimately bringing precision medicine closer to routine IBD care.

Conclusion

The integration of AI and ML into IUS represents a pivotal step toward advancing the assessment and management of IBD. IUS already offers a safe, non-invasive, and cost-effective tool for real-time disease monitoring, and its adoption in routine clinical care is expanding globally. While operator dependence and variability do not limit its broader clinical use, they can pose challenges for standardisation and incorporation as formal endpoints in clinical trials. AI-driven models offer a promising approach to addressing these challenges by enhancing objectivity, improving reproducibility, and enabling automated assessment of key sonographic features. Overcoming issues related to dataset diversity, model interpretability, and regulatory frameworks will be critical to translating these innovations into clinical practice and validated tools for trials. Looking forward, AI-enhanced IUS could enable multimodal integration with clinical, endoscopic, and biomarker data, driving more precise evaluation of disease activity and therapeutic response in research contexts. While the immediate impact of AI is likely to be concentrated in research settings rather than direct bedside clinical decision-making, these advancements may help refine treatment strategies and accelerate the evolution of precision medicine clinical approaches in IBD.

Author contributions

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Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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- * of special interest
- ** of outstanding interest

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