Automated Endoscopic Diagnosis in IBD

The Emerging Role of Artificial Intelligence

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KEYWORDS

• Convolution neural network • Deep learning • Clinical relapse • Mucosal healing • Crohn's disease • Ulcerative colitis

KEY POINTS

- Artificial intelligence (AI)-assisted endoscopy has been validated for inflammatory bowel disease (IBD) diagnosis, assessment of disease, and dysplasia surveillance in patients with IBD.
- Although the research field has become one of the topics, few systems are yet available for clinical use with regulatory approval.
- AI-assisted endoscopy can substantially contribute to the precision medicine era in the field of IBD.

INTRODUCTION

Artificial intelligence (AI) in endoscopy represents a dynamic and evolving area of medical research and clinical practice, characterized by important milestones and technological advancements. This area reflects widespread trends in AI, from early rule-based systems to the latest machine learning and deep learning technologies. A key transformation in the application of AI to endoscopy began with the rise of deep learning, particularly involving convolutional neural networks (CNNs), in the 2010s. CNNs represented a substantial departure from previous approaches because they could automatically learn complex features from raw images, thereby, greatly improving the accuracy and reliability of diagnostic predictions. Recently, AI has become commercially available in various endoscopy systems tailored for identifying and characterizing colorectal and upper gastrointestinal (GI) lesions.[1,2] The global

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landscape of AI in endoscopy systems is collectively transitioning from the developmental phase toward the practical implementation stage. Unfortunately, the commercial availability of AI for endoscopy applications involving patients with inflammatory bowel disease (IBD) has been limited.[3]

IBD management has evolved extensively in recent decades. The introduction of biologic and molecular therapies has substantially improved patient quality of life.[4] Treatment objectives have shifted from clinical remission to mucosal healing, histologic remission, combined histo-endoscopic remission, and complete disease clearance.[5–8] In this context, endoscopy has solidified its position as the benchmark for diagnostic and monitoring purposes.

In this narrative article, the authors assess the current status of using integrated AI systems to assess patients with IBD during endoscopy (including colonoscopy, capsule endoscopy [CE], and device-assisted enteroscopy [DAE]), primarily by referring to physician-initiated studies in this field.

THE ROLE OF ENDOSCOPY IN PATIENTS WITH INFLAMMATORY BOWEL DISEASE

Endoscopy is crucial for managing patients with IBD, which encompasses conditions such as Crohn's disease (CD) and ulcerative colitis (UC). It is also relevant for diagnosis, disease monitoring, treatment guidance, surveillance, and therapeutic interventions (eg, endoscopic resection of neoplasia and balloon dilation of stricture).[4]

In recent years, CE and DAE have been utilized for managing IBD, along with colonoscopy and flexible sigmoidoscopy. Furthermore, advanced endoscopic techniques have been introduced and clinically utilized, including magnification, image-enhanced endoscopy, and microscopic endoscopy.[9–13]

THE USE OF ARTIFICIAL INTELLIGENCE IN ENDOSCOPY FOR THE DIAGNOSIS OF INFLAMMATORY BOWEL DISEASE

At the initial presentation, endoscopy with histology aids in differentiating IBD from other causes of GI symptoms, such as infections or irritable bowel syndrome, by identifying characteristic inflammatory changes and ulcerations. Furthermore, it is essential to distinguish between CD and UC. Guimarães and colleagues developed a CNN algorithm based on ileo-colonoscopy image analysis for the differential diagnosis of colitis; the algorithm could distinguish IBD, ischemic colitis, and infectious colitis.[14] CNN algorithms based on ileo-colonoscopy images are also helpful in differentiating between CD, Behçet's disease, and GI tuberculosis (TB).[15,16] Additionally, the capacity to distinguish UC from CD have been documented.[17] Recently, Brodersen and colleagues conducted a prospective multicenter study to determine whether pan-enteric CE analysis could identify patients with CD and IBD in a cohort with suspected CD. They used the AXARO platform [Augmented Endoscopy, Paris, France], which was trained on annotated small bowel CE still frames from a multicenter database, computer-assisted diagnosis for capsule endoscopy (CAD-CAP).[18,19] The results showed that observers achieved 92% to96% sensitivity and 90% to 93% specificity for CD detection; they achieved 97% sensitivity and 90% to 91% specificity for IBD detection.[20]

Finally, recent systematic review showed that accuracy of AI to differentiate IBD from non-IBD is 72.1%, UC versus non-UC-98.3% to 99.5%, UC versus CD greater than 90%,CD versus TB (4 studies) and 1 Systematic review and meta-analysis-75.6% to 88.6%.[21,22]Overall, AI in endoscopy may contribute to an accurate diagnosis of IBD. However, most published studies have been retrospective pilot investigations, and further practical feasibility assessments are needed (**Fig. 1**).

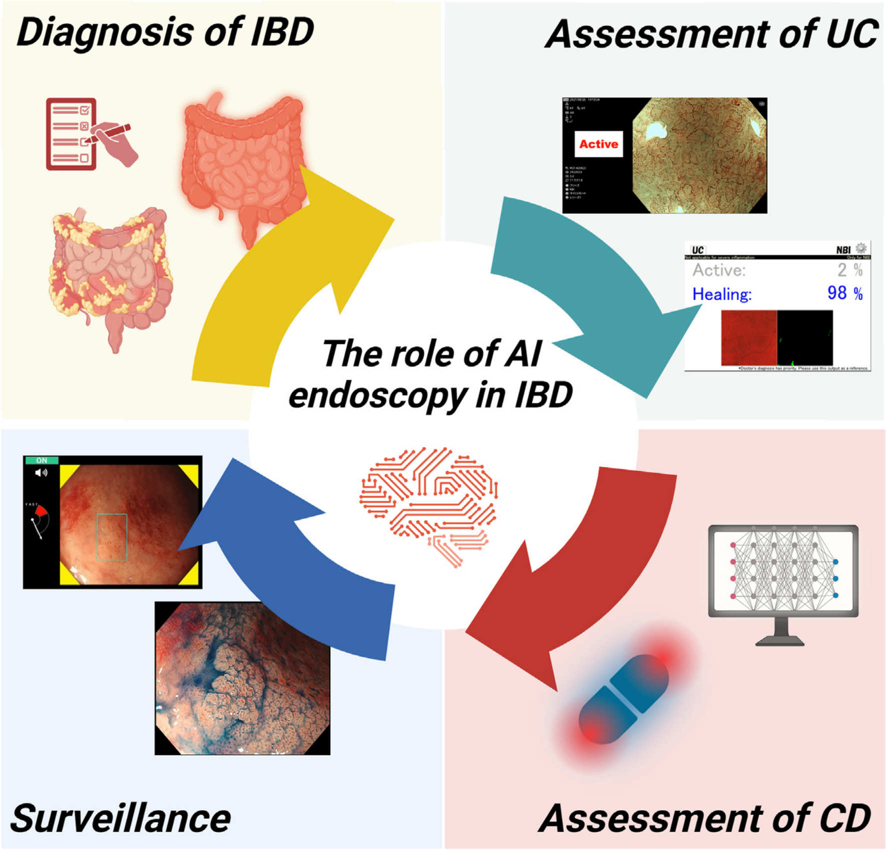

Fig. 1. The role of artificial intelligence in endoscopy of inflammatory bowel disease. (Created with Biorender.com.)

CURRENT ROLE OF ENDOSCOPY MONITORING IN INFLAMMATORY BOWEL DISEASE

IBD management strategies have recently embraced the "treat to target" paradigm, highlighting the importance of establishing therapeutic objectives and considering treatment intensification if these objectives are not achieved.[23] There is widespread agreement that endoscopic remission constitutes the primary long-term therapeutic goal.[23] Nonetheless, there is considerable variation in treatment goals among endoscopists,[24,25] resulting in unintended differences in treatment objectives among physicians and medical institutions. These differences hinder the achievement of a cohesive treatment strategy. Although clinical trials are labour-intensive and expensive, the emergence of biomarkers (eg, fecal calprotectin and leucine-rich alpha-2 glycoprotein) has enabled less-invasive monitoring. However, endoscopic mucosal evaluation remains the preferred approach. To maintain its essential role in monitoring, endoscopy must evolve to provide added value. This evolution may involve fusing AI with innovative endoscopic techniques to yield a product that could enhance endoscopy with superior efficiency and insight.

USE OF ARTIFICIAL INTELLIGENCE IN ENDOSCOPY ASSESSING ULCERATIVE COLITIS

Existing endoscopic scoring systems, including the Mayo Endoscopic Score (MES) and the Ulcerative Colitis Endoscopic Index of Severity (UCEIS), exhibit wide variability among endoscopists. This variability leads to substantial image interpretation costs in clinical trials and hinders the establishment of common treatment objectives among independent physicians and hospitals.

Several studies have demonstrated that endoscopy-specific use of AI could enhance the reproducibility of image interpretation during colonoscopy.[24,26–28] This technology could simplify the labor-intensive and expensive process of central image interpretation in clinical trials, reduce interobserver variability between examiners, and facilitate more consistent evaluations.[29] One challenge in applying AI to endoscopy involves processing low-quality images (eg, images with halation, reflex, poor preparation, insufficient air volume, and proximity to the mucosa)[30,31] at the stage of applying AI from still images to video evaluation.

As a notable example, Takenaka and colleagues developed a deep neural network algorithm for evaluating ulcerative colitis (DNUC).[28] This algorithm was designed to analyze features from conventional white-light still images and forecast endoscopic remission (characterized by a UCEIS score of 0) with 90% accuracy. Subsequently, they optimized the DNUC system by using video-based analysis. A multicenter cross-sectional study showed that the DNUC could accurately assess histologic inflammation status in 81% of cases. Furthermore, a strong correlation was observed between DNUC outcomes and the UCEIS scores assigned by central readers, as evidenced by an intraclass correlation coefficient of 0.93. The system also exhibited high accuracy in identifying endoscopic remission, defined as a UCEIS score of 0 or 1, with 82% sensitivity and 95% specificity. A notable discovery from this study was that discrepancies of greater than or equal to 2 points between DNUC assessments and central evaluations were primarily related to inadequate bowel preparation or the presence of inflammatory polyps.[32] Incorporating an algorithm to automatically exclude such images presumably could further enhance the system's accuracy.

AI is expected to resolve challenges associated with the need for human central readers to score endoscopic disease activity, substantially increasing the cost and duration of clinical trials. Gottlieb and colleagues used the phase II Mirikizumab clinical trial dataset to train and validate a computer-aided detection (CAD) system. This CAD system autonomously generated a final score indicating the endoscopic severity (with an MES of 0–3 and a UCEIS of 0–8) for each full-length video. In a retrospective evaluation, the CAD system demonstrated robust precision, achieving 96% accuracy for endoscopic remission when defined as an MES of 0% and 97% accuracy as a UCEIS of 0.[33]

Current endoscopic scoring systems for UC subjectively classify disease severity based on the presence or absence of specific endoscopic findings, solely focusing on the most severely affected segment. Conversely, IBD endoscopy specialists assess the severity and distribution of inflammation to determine a patient-specific severity level. Current research efforts are centered on developing a more sophisticated endoscopic scale to evaluate inflammatory activity while utilizing CNNs for enhanced expert perception.

Takabayashi and colleagues introduced the innovative Ulcerative Colitis Endoscopic Gradation, which uses a ranking-based CNN[34] to quantify the endoscopic severity of UC on a continuum from 0 to 10; thus, it can serve as a surrogate for IBD endoscopy specialists by providing a comprehensive and reliable assessment of UC inflammation.

Furthermore, innovative user interfaces enhance the understanding of the scale and intensity of inflammation throughout the entire colon. Fan and colleagues developed a novel AI-powered scoring methodology that considers the distribution of inflammation according to video-based AI analysis. This approach segments the colon into predetermined sections, enabling the scoring system to autonomously evaluate inflammatory conditions across 85 specific sites in each video. Thus, the methodology visually represents inflammation throughout the intestinal tract.[35] Stidham and coworkers recently introduced an automated Cumulative Disease Score (CDS) system.[36] This system calculates the aggregate of squared MES values across 50 uniformly distributed segments within the left colon, including the rectum. As part of the clinical trial (UNIFI study), within a cohort of 748 individuals undergoing induction therapy and 348 individuals undergoing maintenance therapy , the CDS showed significant correlations with the MES and all clinical aspects of the partial Mayo score. Compared with the MES, the CDS revealed more pronounced endoscopic differences between ustekinumab and placebo, demonstrating greater sensitivity to changes and requiring 50% fewer patients to detect endoscopic differences between ustekinumab treatment and placebo.

Recently systematic review showed that grading endoscopic activity accuracy in UC: 85.4% to 94.5% Accuracy (2 studies) −95.8% to 98.7%[21]

AI-based assessments of inflammation distribution may provide more exhaustive insights into UC activity and facilitate nuanced assessments of therapeutic efficacy. This innovative approach can enhance, augment, and refine the overall understanding of the disease.

ARTIFICIAL INTELLIGENCE IN PREDICTING HISTOLOGIC ACTIVITY AND INFLAMMATORY BOWEL DISEASE OUTCOMES

Advanced endoscopic techniques can accurately predict histologic disease activity and healing, reducing the need for biopsies. Numerous investigations have shown that these techniques can overcome the limitations of biopsy procedures, producing results comparable to histopathological findings.[37–41] Nonetheless, achieving such results largely depends on specialists' technique-specific expertize rather than contributions from general endoscopists.

Bossuyt and colleagues utilized a red density algorithm Pentax Medical (HOYA Corporation, Tokyo, Japan) developed to predict histologic activity. With a red density score cutoff of less than or equal to 60, this method demonstrated 96% sensitivity and 80% specificity in predicting histologic remission, defined as a Robarts Histopathology Index (RHI) of less than or equal to 6.[42]

In related research, Bossuyt and colleagues conducted a pilot study involving a CAD system that uses illumination from a single short-wavelength monochromatic light-emmiting diode light (produced by Fujifilm, Tokyo, Japan).[43] This innovative system facilitates real-time examination of mucosal architecture, including crypts, peri-cryptal capillaries, and instances of bleeding. This technology allowed accurate identification of histologic remission, defined as a Geboes score of less than 2B.1, with 79% sensitivity and 90% specificity.

Furthemore, Iacucci and colleagues devised an AI tool to generate the Paddington International Virtual Chromoendoscopy Score using short-length videos from iSCAN (Pentax). Their evaluations were based on histologic remission benchmarks, specifically RHI less than or equal to 3, Nancy histologic index less than or equal to 1, and PICaSSO Histologic Remission Index equal to 0, with reported accuracies of 83%, 81%, and 83%, respectively. In a follow-up study of 232 patients the hazard ratios associated with AI-assisted algorithms for adverse clinical outcomes—including UC-related hospitalization, colectomy, and modification of UC treatment because of relapse—were 2.9 for the high-definition white-light endoscopy model and 4.0 for the iSCAN model. This analysis highlights the predictive power of AI algorithms in assessing the risk of significant clinical outcomes among patients with UC.[44]

A distinct CAD system was designed to predict histologic healing, using images from a 520-fold ultra-magnifying contact microscope (Endocyto: CF-H290EC; Olympus Corporation, Tokyo, Japan), which permits real-time inspection of microvessels, crypts, and goblet cells via narrow-band imaging.[4,38,41,45–47] When histologic remission was defined as a Geboes score of less than 3.1, the CAD system's diagnostic performance values were 74% sensitivity, 97% specificity, and 91% accuracy.[48] Consequently, the team utilized real-time AI during colonoscopies in patients with UC who displayed clinical remission. They prospectively follow-up these patients (n = 134) for 12 months after colonoscopy. The AI analysis divided the patients into 2 groups: AI-identified active disease and AI-identified healing. Clinical relapse, defined as a partial Mayo score of greater than or equal to 3, was observed in 28.4% (21/74) of individuals in the AI-identified active disease group, compared with 4.9% (3/61) of individuals in the AI-identified healing group.[49]

An updated version of this CAD system, named EndoBRAIN-UC (Cybernet Systems Corp., Tokyo, Japan), received regulatory approval in Japan and has been commercially available since February 2021. Recently, Omori and colleagues validated the commercially available version of EndoBRAIN-UC in a real-world clinical setting, demonstrating 74.2% sensitivity and 93.8% specificity in the diagnosis of Geboes histologic score less than 3.1[3]; these external validation results were consistent with preliminary findings.[48] However, usage of EndoBRAIN-UC remains limited because of the specialized knowledge required to operate the ultra-high magnification colonoscope. To overcome this barrier, Kuroki and colleagues introduced an alternative system compatible with a broader spectrum of endoscopes, which can provide an objective binary diagnosis of either "AI-based vascular healing" or "AI-based vascular activity." Their results revealed that the incidence of clinical relapse within 12 months after colonoscopy was significantly greater in the group with AI-based vascular activity (23.9% [16/67]) than in the group with AI-based vascular healing (3.0% [1/33]) (P = .01).[50]

Finally, Akiyama and colleagues presented a novel hypoxia imaging algorithm (Fujifilm), which assesses colonic tissue oxygen saturation and indicates its relationships with clinical, endoscopic, and histologic activities.[51] Importantly, they revealed a correlation between rectal oxygen saturation levels and bowel urgency, suggesting a new avenue for objective endoscopic evaluation of functional disorders in patients with UC.

AI-announced advanced imaging allows prediction of histologic disease activity, future outcome and potentially assessment of functional impairment.

USE OF ARTIFICIAL INTELLIGENCE IN ENDOSCOPY ASSESSING CROHN'S DISEASE

Currently, standard measures of endoscopic disease activity include the CD Endoscopic Index of Severity (CDEIS) and the Simple Endoscopic Score for CD (SES-CD); the SES-CD offers a practical and simple alternative to the CDEIS.[52,53] The values of the 2 measurements are closely correlated; the inter- and intraobserver variabilities were lower for SES-CD scores than for CDEIS in a study involving expert central readers. When using the SES-CD, endoscopic healing is defined as SES-CD less than 3 points or the absence of ulcerations (eg, SES-CD ulceration subscore = 0). However, the low reproducibility of testing reduces discrepancies between examiners while imposing significant costs and time on central reading of image interpretation for clinical trials. Small bowel lesion monitoring is essential in CD because the lesions extend throughout the GI tract. In the past 20 years, CE and DAE have been established for endoscopic monitoring of small bowel lesions in CD and for establishing therapeutic efficacy.

Contrast-enhanced (CE), a non-invasive imaging modality, has emerged as a valuable tool for visualizing the small intestine.[54] In patients with IBD, CE provides helpful information concerning disease severity, mucosal inflammation, and complications (eg, strictures and fistulas). However, CE interpretation is time-consuming, and diagnostic accuracy depends on the physician's expertize. Recently, considerable progress has been made in incorporating AI into CE. AI algorithms can now evaluate CE images to pinpoint mucosal abnormalities indicative of IBD, including ulcerations, erosions, and strictures. Klang and colleagues revealed that an AI algorithm could accurately identify ulcers with an area under the curve (AUC) of 0.94 and strictures with an AUC of 0.99.[55] Another study presented an algorithm that could detect ulcers with 83% sensitivity and 98% specificity, whereas erosions were identified with 91% sensitivity and 93% specificity.[56]

Moreover, Majtner and colleagues showed that AI could classify lesions into 4 distinct categories (normal mucosa, aphthous ulcerations, ulcers, and fissures/large ulcers) with substantial agreement ($\kappa = 0.72$).[57] These AI-based innovations in lesion detection facilitate early diagnosis and aid the monitoring of disease progression. AI also enhances CE by omitting low-quality images, thus minimizing diagnostic ambiguity and reducing the physician's workload. For example, Oh and colleagues demonstrated that their algorithm reduced image interpretation time by 36% (from 121 min to 78 min/examination).[58] Kellerman and colleagues reported that their algorithm achieved 81% accuracy, with an AUC of 0.86, in terms of predicting the need for biologic therapy within 6 months among patients with newly diagnosed CD, surpassing the predictive accuracies of human assessments and fecal calprotectin measurements.[59] AI in CE in brief highlighting advantages of reduced reading time and high accuracy (90.5%–99.9%).[21]

DAE—encompassing single- and double-balloon enteroscopy and motorized spiral enteroscopy—has enabled gastroenterologists to obtain tissue samples and perform balloon dilatation of small bowel stenosis in patients with IBD.[60–62] Martins and colleagues developed a multi-brand CNN-based algorithm, practical in real-world clinical settings, for automatically detecting ulcers and erosions in DAE; it could identify ulcers and erosions with 88.5% sensitivity and 99.7% specificity.[63] Unfortunately, most published studies have relied on retrospective analysis of pre-recorded videos and still images. Thus, the results require validation in multicenter prospective studies to confirm their reliability.

In conclusion, the integration of AI with CE and DAE represents a paradigm shift in IBD management, particularly concerning observations of the small intestine, which offers greater diagnostic accuracy, shorter review time, and better patient outcomes.

USE OF ARTIFICIAL INTELLIGENCE IN ENDOSCOPY SURVEILLANCE OF COLITIS-RELATED DYSPLASIA

Patients with IBD should undergo regular surveillance colonoscopies because of their increased risk of colorectal cancer. Endoscopic procedures are used to detect dysplasia early, a precursor to cancer and enable early intervention. Although this surveillance is expected to contribute to lesion detection, characterization, and endoscopic resection, there remains potential for improvement.[9,64] Dye-assisted endoscopy with targeted biopsies has been identified as a potential alternative to conventional random biopsy protocols. However, early-stage IBD-related dysplasia detection remains challenging; it is expected to improve with electronic chromoendoscopy and AI. Several AI CAD systems have been clinically implemented to detect colorectal lesions in non-IBD patients.[65,66] However, there is no commercially available

CAD system for dysplasia surveillance in patients with IBD. Some researchers have modified CAD systems, initially designed for non-IBD patients, and used them to assess patients with IBD. Fukunaga and colleagues[67] successfully established an AI-based computer-aided characterization system (EndoBRAIN; Cybernet Systems)[68,69] that outputs 2-class prediction (neoplasia or non-neoplasia) based on features extracted from images obtained by endocytoscopy (CF-H290ECI; Olympus), enabling suspicious lesions to be identified as neoplasias. Maeda and colleagues[70] reported that another AI-based CAD system (EndoBRAIN-EYE; Cybernet Systems),[71] which accurately identified colorectal lesions in non-UC patients, could detect flat elevated dysplasia. These findings highlight the potential for AI to assist non-expert endoscopists in detecting dysplasia in patients with UC.

Additionally, several IBD patient-specific CAD systems have been reported. Yamamoto and colleagues developed the CADx, which outputs 2 classifications: “adenocarcinoma or high-grade dysplasia” and “low-grade dysplasia or sporadic adenoma/normal mucosa.” The CADx had 72.5% sensitivity, 82.9% specificity, and 79.0% accuracy.[72] Similarly, Vinsard and colleagues established the IBD-CADe model using 1266 high-definition white-light endoscopy (HDWLE) still images and 426 dye-based chromoendoscopy still images of histologically proven IBD-associated colorectal lesions. Although the HDWLE model achieved 95.1% sensitivity, 98.8% specificity, and 96.8% accuracy, the chromoendoscopy model exhibited 67.4% sensitivity, 88.0% specificity, and 77.8% accuracy.[73] Dye chromoendoscopy is currently recommended for surveillance. However, according to this study, the accuracy of the chromoendoscopy model was inferior to that of the HDWLE model This result may be related to the smaller number of learning images, but further validation is required. Finally, Abdelrahim and colleagues reported the early development of an AI deep learning system for detection and characterization of neoplasias in IBD; it exhibited 93.5% sensitivity and 80.6% specificity for detection, and 87.5% sensitivity and 80.6% specificity for characterization.[74] Their system demonstrates the clinical feasibility of CAD in this area, although accuracy improvements are needed.

AI-assisted systems for surveillance are still a challenge, but they are getting there.

In future, if AI can play a role in linking electronic medical record data to colonoscopy videos, it may play a major role in enabling appropriate surveillance methods.

CURRENT LIMITATIONS AND FUTURE PERSPECTIVES

Integrating AI into endoscopic procedures represents a rapidly progressing domain within medical research and clinical practice. Its progress is particularly relevant in managing IBD, where accurate assessments of mucosal inflammation and healing are essential for guiding precise treatment strategies. Although AI has considerable potential for enhanced diagnostic accuracy and monitoring efficiency, its use within the IBD context has several limitations; its future will likely involve challenges and opportunities.

First, the commercial availability of IBD-specific AI applications remains limited, restricting the broader application in a field that could strongly impact patient management and outcome prediction. Integrating AI into clinical practice involves navigating regulatory approvals and addressing ethical considerations, including patient privacy and data security. Ethical use of AI in healthcare requires transparent algorithms, patient consent processes, and stringent data protection measures.

Second, the success of AI algorithms, especially deep learning-based models, heavily relies on the quality of input images. Challenges such as image halation, reflection, poor bowel preparation, and proximity to the mucosal surface can severely diminish the performances of these algorithms. This problem highlights the need for

Table 1
Summary of automated endoscopic diagnosis in inflammatory bowel disease

Author	Study Design	Modality	No. of Training Samples	No. of Test Samples	Outcome Measures	Results
AI in endoscopy for the IBD diagnosis						
Guimarães et al,[14] 2023	Retrospective Single-center	White-light endoscopy	1635 images from 444 pts	161 images from 50 pts	Identification of IBD from infectious and ischemic colitis.	A global accuracy of .709 and areas under the ROC and PR curves of .727 and .585
Kim et al,[21] 2021	Retrospective Single-center	White-light endoscopy	6617 images from 727 patients	683 images	Differentiation between CD, intestinal Behçet's disease, and intestinal tuberculosis	AUC from 0.78 to 0.86
Wang et al,[17] 2022	Retrospective Multi-center	White-light endoscopy	57,597 image from 217 CD pts, 279 UC pts and 100 healthy controls	1458 image	Differentiating CD and UC	CNN showed 92% of accuracy.
Brodersen et al,[20] 2023	Prospective Multi -centre	Capusule endosocpy	N/A	131 suspected CD pts	The identification abilities of CD and IBD	92%–96% sensitivity and 90%–83% specificity for CD and 97% sensitivity and 90%–91% specificity for IBD
AI in endoscopy assessing UC						
Ozawa et al,[26] 2019	Retrospective Single-centre	White-light endoscopy	26,304 images from 841 pts	3981 images from 114 pts	ER (MES = 0 or 1)	AUC = 0.98
Stidham et al,[27] 2019	Retrospective Single-centre	White-light endoscopy	14,862 images from 2778 pts	1652 images from 304 pts 11432 frames from 30 videos	ER (MES = 0 or 1)	AUC = 0.97 (still images) AUC = 0.97 (videos)

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Table 1
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Author	Study Design	Modality	No. of Training Samples	No. of Test Samples	Outcome Measures	Results
Yao et al,[30] 2021	Prospective Multi-centre	White-light endoscopy	N/A	51 videos (internal data) 264 videos (external data)	ER (MES = 0 or 1)	Accuracies of 78% (internal data) and 57% (external data) in predicting MES
Stidham et al,[36] 2024	Prospective Multi-centre	White-light endoscopy	N/A	748 pts	Cumulative disease score performance	Cumulative disease score had better for detecting endoscopic improvement rather than MES.
Takenaka et al,[28] 2020	Prospective Single-centre	White-light endoscopy	40,758 images	4187 images from 875 pts	ER (UCEIS = 0) HR (Geboes < 3.1)	90% accuracy for EH and 93% accuracy for HR
Takenaka et al,[32] 2021	Prospective Single-centre	White-light endoscopy	40,758 images	875 pts	Future hospitalization, colectomy, steroid use, and relapse	Hazard ratios were 48.4, 46.4, 10.2, and 8.8 for hospitalization, colectomy, steroid use, and relapse.
Takenaka et al,[36] 2022	Prospective Multi-centre	White-light endoscopy	N/A	900 segments from 180 pts	HR (Geboes < 3.1)	98% sensitivity and 95% specificity
Byrne et al,[31] 2023	Prospective Single-centre	White-light endoscopy	1,550,030 frames (134 UC videos)	100 videos	Grading of MES and UCEIS	The quadratic-weighted kappa between experts' labels and the model's predictions were 0.90, 0.78 at video-level, for MES and UCEIS, respectively.

Gottlieb et al,[33] 2021	Prospective Multi-centre	White-light endoscopy	N/A	249 videos	Grading of MES and UCIES	A quadratic weighted kappa of 0.84 for MES and 0.86 for UCEIS
Fan et al,[35] 2022	Retrospective Single-centre	White-light endoscopy	5875 images from 332 pts	20 full-length videos from 18 pts	Grading of MES and single UCEIS items in WLE	86.5% accuracy in the MES, UCEIS items with accuracies of 90.7%, 84.6%, and 77.7% for vascular pattern, erosions and ulcers, and bleeding.
Lo et al,[24] 2022	Retrospective Single-centre	White-light endoscopy	1484 images from 467 pts	5-fold cross validation	Grading of MES categories (0 vs 1–3 and 0–1 vs 2–3)	94% and 93% in distinguishing MES 0 vs 1–3 and 0–1 vs 2–3.
Takabayashi et al,[34] 2023	Retrospective Multi-centre	White-light endoscopy	14,208 images	1479 images	The correlation coefficients between IBD expert endoscopists and the AI	Spearman's correlation coefficients were all higher than 0.95 (*P*<.01).
Bossuyt et al,[42] 2020	Prospective Multi-centre	RED density	N/A	29 UC patients and 6 healthy controls	Correlation of RED density score with RHI, MES, and UCEIS	Red density score correlated with RHI (r = 0.74), MES(r = 0.76) and UCEIS (r = 0.74).
Bossuyt et al,[43] 2023	Prospective Single-centre	Single short-wavelength monochromatic LED light illumination	N/A	113 segments from 58 pts	HR (Geboes < 2B.1)	79% sensitivity and 90% specificity.

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Table 1
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Author	Study Design	Modality	No. of Training Samples	No. of Test Samples	Outcome Measures	Results
Iacucci et al,[44] 2023	Prospective Multi-centre	iSCAN	67,280 frames (283 pts)	242 videos	ER (UCEIS ≤1, and PICaSSO ≤ 3) HR (RHI ≤ 3, NHI ≤ 1, and PHRI ≤ 1)	ER of UCEIS ≤1 with a sensitivity of 72%, specificity of 87% and PICaSSO ≤ 3 with a sensitivity of 79%, specificity of 95%. Accuracies ranging of HR from 80% to 85%.
Maeda et al,[48] 2019	Retrospective Single-centre	Endocytoscope-narrow-band imaging	12,900 images from 87 pts	525 segments from 100 pts	HR (Geboes < 3.1)	74% of sensitivity and 97% of specificity.
Maeda et al,[49] 2022	Prospective Single-centre	Endocytoscope-narrow-band imaging	44,097 images	135 pts	Clinical relapse during 12 m after colonoscopy	The relapse rate was significantly higher in the AI-active group (28%) than in the AI-healing group (5%; *P*<.001).
Kuroki et al,[50] 2024	Prospective Single-centre	Narrow-band imaging	8853 images from 167 pts	104 pts	Clinical relapse during 12 m after colonoscopy	The relapse rate was significantly higher in the vascular-active group (24%) than in the vascular-healing group (3%; *P*<.001).

Akiyama et al,[51] 2024	Retrospective Single-centre	Hypoxia imaging	N/A	490 images from 100 pts	Correlation of colonic oxygen saturation, and MES and Geboes score.	At a colonic oxygen saturation cutoff of 45.5%, AUCs for endoscopically and histologically active diseases were 0.79 and 0.72.
Omori et al,[3] 2024	Retrospective Single-center	Endocytoscope-narrow-band imaging	N/A	191 segments from 52 pts	HR (Geboes < 3.1)	74.2% sensitivity and 93.8% specificity.
AI in endoscopy assessing						
Klang et al,[55] 2020	Retrospective Single-centre	Capsule endoscopy	17,640 images from 49 CD patients	Cross validation	The detection abilities of small-bowel ulcers	Accuracies ranging from 95.4% to 96.7%
Klang et al,[56] 2021	Retrospective Single-centre	Capsule endoscopy	27892 images; 1942 strictures images, 14266 normal mucosa images, and 11684 ulcer images	Cross validation	The classifying strictures vs non-strictures	93.5% of accuracy
Majtner et al,[57] 2021	Retrospective Single-centre	Capsule endoscopy	70% images of 7744 images from 38 patients	20% images of 7744 images from 38 patients	The identification of ulcerations	95.7% sensitivity, 99.8% specificity, and 98.4% accuracy
Oh DJ et al,[58] 2024	Retrospective Single-centre	Capsule endoscopy	N/A	90 pts	The comparison of reading time between with and without use of AI.	Compared with the AI non-user group (120.9 min), the reading time was reduced by 35.6% in the AI user group (77.9 min).

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Table 1
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Author	Study Design	Modality	No. of Training Samples	No. of Test Samples	Outcome Measures	Results
Kellerman et al,[59] 2023	Retrospective Multi-centre	Capsule endoscopy	N/A	131 suspected CD pts	The identification abilities of CD and IBD	92%–96% sensitivity and 90%–83% specificity for CD and 97% sensitivity and 90%–91% specificity for IBD
Martins et al,[63] 2023	Retrospective Single-centre	Device-assisted enteroscopy	5546 images from CD pts	1431 images from CD pts	The identification of ulceration	A sensitivity, specificity, and diagnostic accuracy of 95.7%, 99.8%, and 98.4%, respectively.
AI in endoscopy surveillance of colitis-related dysplasia						
Yamamoto et al,[62] 2022	Retrospective Single-centre	White-light endoscopy	862 images from 99 pts	186 images	Identification of adenocarcinoma/ high-grade dysplasia" from "low-grade dysplasia/sporadic adenoma/normal mucosa	72.5% sensitivity, 82.9% specificity, and 79.0% accuracy

Guerrero et al,[73] 2023	Retrospective Single-centre	White-light endoscopy chromoendoscopy	1266 white-light images and 426 chromoendoscopy images	212 white-light images and 184 chromoendoscopy images	The performance metrics for detecting lesions	95.1% and 67.4% sensitivity, and 98.8% and 88.0% specificity on white-light endoscopy and chromoendoscopy images
Abdelrahim et al,[74] 2024	Prospective Single-centre	white-light endoscopy	12 054 images of non-IBD pts and 4146 images of IBD pts	30 pts	The performance metrics for detecting and charaterzation of lesions	The lesion detection rate of 90.4%. The characterization of 87.5 sensitivity 80.6% specificity.

stringent quality control concerning image acquisition during endoscopic procedures. Extensive external validation in real-world clinical settings is required. Furthermore, there is an urgent need for educational initiatives and user-friendly interfaces that can help bridge the gap in expertize, enabling general endoscopists to utilize AI technologies effectively. Efforts to simplify the operation of AI-assisted endoscopic systems and provide comprehensive training could facilitate broader adoption.

Third, there needs to be more evidence concerning the additional value of AI in endoscopy. Existing AI models have great potential in experimental contexts. However, no randomized controlled trials have tested whether AI improves diagnostic accuracy. Some studies using AI-based CAD to identify colorectal neoplasia have revealed negative results concerning the additional diagnostic accuracy of AI[75,76]; objective evaluations of effectiveness in IBD are needed (**Table 1**).

Future studies should explore AI applications beyond diagnostic assistance, such as predictive analytics regarding disease progression, treatment response, and risk stratification. Predicting clinical outcomes and tailoring treatment regimens could revolutionize IBD management.

In conclusion, although the use of AI in the endoscopic assessment of IBD currently has some limitations, this technology holds considerable potential for transforming patient care. Overcoming the aforementioned challenges will require a multidisciplinary approach involving clinicians, researchers, engineers, and regulatory bodies. Through continuous innovation, collaboration, and optimization, AI-assisted endoscopy can substantially contribute to the precision medicine era in the field of IBD, thereby enhancing diagnostic accuracy, and monitoring and surveillance efficiency, leading to better patient outcomes.

CLINICS CARE POINTS

- When utilizing AI, recognize that AI is not perfect.
- It is important to recognize situations in which AI is effective and situations in which it is not.
- AI is an assistive tool. The final decision should be made by the human doctor.
- AI in endoscopy has the potential to improve diagnosis, assessment, and surveillance of IBD.

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DISCLOSURE

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