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REVIEW ARTICLE

Artificial Intelligence in Gastroenterology: A Comprehensive Review

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Abstract
Artificial Intelligence (AI) is revolutionizing gastroenterology by enhancing diagnostic accuracy and streamlining endoscopic procedures in response to the growing prevalence of gastrointestinal diseases. This comprehensive review explores AI's transformative applications, particularly in gastrointestinal endoscopy, where it addresses critical challenges such as diagnostic 'miss rates' and the overwhelming volume of medical images. Through advanced technologies like Computer-Aided detection (CADe) and Computer-Aided diagnosis (CADx) using deep learning models, AI significantly improves polyp detection rates and reduces miss rates, with reported performances of 95% detection and 50% miss rate reduction. In capsule endoscopy, AI can significantly reduce reading time with improved algorithms to increase sensitivity and specificity in identifying gastrointestinal abnormalities. Additionally, AI plays a vital role in early oesophagal cancer detection by analyzing endoscopic images and distinguishing between dysplastic and non-dysplastic tissues. This review highlights AI's multifaceted benefits to Gastroenterology while noting limitations and future perspectives. As AI continues to evolve and integrate into clinical practice, it can enhance patient outcomes and significantly revolutionize diagnostic approaches in Gastroenterology.

Keywords: Artificial Intelligence, Gastroenterology, Endoscopy, Colorectal Cancer, Diagnostic Imaging

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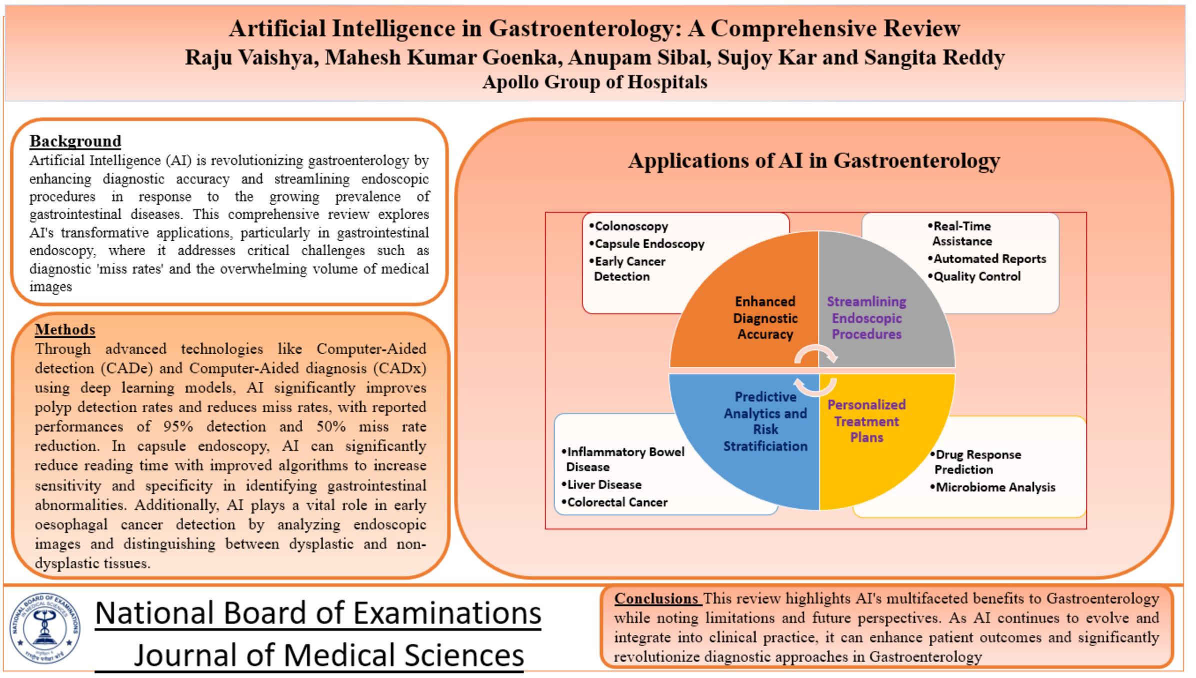
Graphical Abstract



Key Highlights

- AI technologies can enhance diagnostic accuracy and reduce miss rates
- AI automates the review of capsule endoscopy images effectively
- AI plays a pivotal role in the early detection of various cancers and premalignant conditions
- AI-based algorithms can change the approach to a clinical dilemma

Introduction

Gastroenterology has seen significant advancements over the years. With an increasing prevalence of gastrointestinal (GI) diseases, encompassing conditions like inflammatory bowel disease (IBD), colorectal cancer (CRC), and various functional GI disorders, there is a pressing need for practical diagnostic tools and personalized treatment strategies [1]. The barriers to efficient care include complex diagnostic procedures, variations in clinical practice, and errors stemming from human cognition limitations.

In this context, Artificial Intelligence (AI), particularly its branches, machine learning (ML) and deep learning (DL), have surfaced as a transformative tool aimed at addressing these challenges. AI technologies are reshaping how healthcare providers approach diagnostics, treatment planning, and patient management in gastroenterology. By automating routine tasks, providing advanced data analytics, and enhancing diagnostic accuracy, AI is paving the way for its integration into everyday practice [2].

AI is rapidly transforming GI endoscopy, offering significant advancements in detecting, diagnosing, and managing various conditions. As extensively reviewed by Kröner et al. [3] and El Hajjar and Rey [4], current applications leverage AI's capabilities to enhance image analysis. Specifically, AI-powered systems can aid in automating the detection of abnormalities such as bleeding, ulcers, and tumours, as highlighted by Pannala et al. [5]. While offering immense promise, the widespread integration of AI in colonoscopy still faces challenges and limitations, which have been thoroughly discussed by Hann et al. [6]. Despite these hurdles, a recent consensus by the ASGE AI Task Force, led by Parasa, Berzin et al. (2025), outlines the evolving landscape of AI applications in endoscopy, addresses existing roadblocks, and sets a clear path for further advancing AI's role in gastroenterology, ultimately aiming to improve diagnostic accuracy and patient outcomes [7].

This review provides an update on the role of AI in gastroenterology, highlighting its clinical utility, advantages, and limitations. It concludes with insights into future research opportunities and clinical applications of AI in the field.

Methodology

This review article evaluated the applications of AI within gastroenterology on 20th March 2025; a comprehensive literature search was conducted across multiple databases, including PubMed, Scopus, and Web of Science. Keywords related to “AI,” “gastroenterology,” "endoscopy," and "diagnostic imaging" were utilized to identify relevant research articles, clinical trials, and systematic reviews. The selected studies were assessed for their methodologies, findings, and implications regarding AI's role in diagnostic accuracy and efficiency in gastroenterological practices. Key themes were extracted, including advancements in Computer-Aided Detection (CADe), deep learning applications in capsule endoscopy, and early cancer detection methods. This synthesis of existing literature provides a nuanced understanding of the current landscape of AI in gastroenterology, highlighting its benefits and limitations.

Results and Discussion

Applications of AI in Gastroenterology (Figure 1)

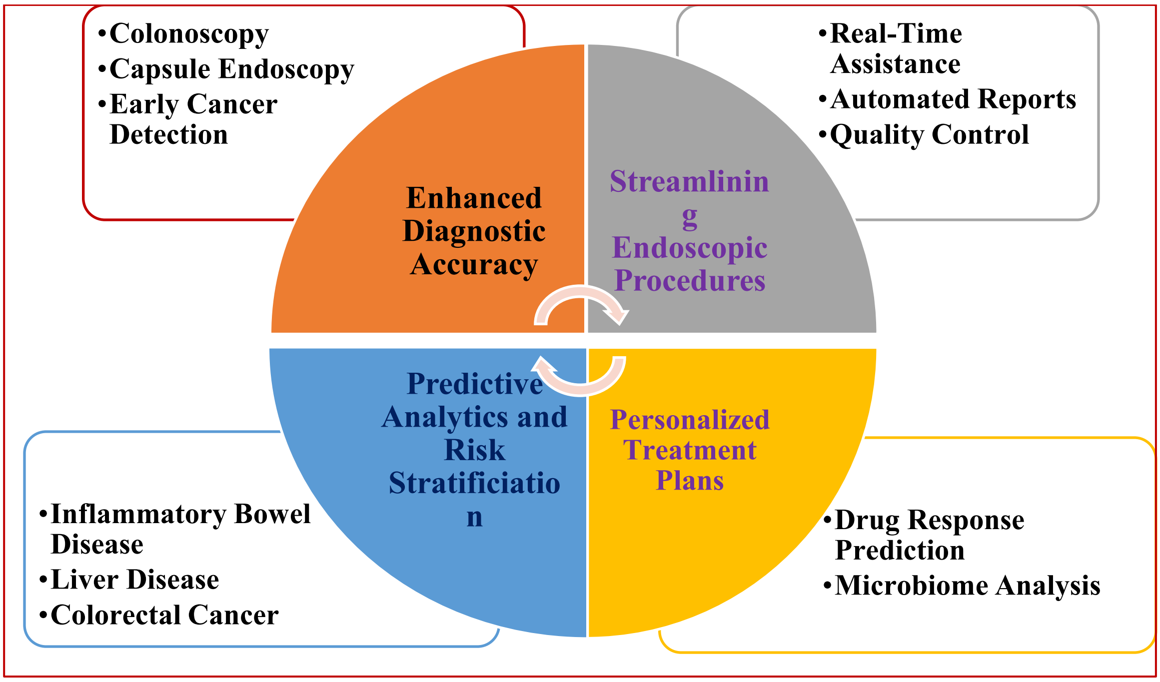


Figure 1. Main applications of Artificial Intelligence in Gastroenterology

Enhanced Diagnostic Accuracy

AI has significantly enhanced gastroenterology diagnostic accuracy, particularly in colon and capsule endoscopy procedures. In the critical area of CRC screening, where timely detection of precancerous lesions is paramount, AI addresses the well-documented issue of endoscopic 'miss rates' (20-30% of significant lesions) through innovative CAD systems. This transformative impact of AI instils optimism about the future of gastroenterology, where diagnostic accuracy is significantly improved [8,9].

AI helps improve adenoma detection rates in a large, asymptomatic screening population across multiple centres [10]. A network meta-analysis of randomized Control Trials (RCTs) compared and found AI to improve adenoma detection compared to other interventions [11]. A recent multicenter (RCT) confirmed the clinical utility of AI for polyp detection during colonoscopy [12]. Furthermore, a multicenter diagnostic study found improved accuracy of AI in upper GI cancer detection, especially for non-expert endoscopists [14].

Colonoscopy

The rapid accumulation of GI endoscopy data, including millions of images and videos annually, presents a unique opportunity for advancing healthcare but poses a significant challenge in managing and utilizing this massive dataset. The sheer volume of data, with 27,000 images from a single 15-minute procedure, highlights the potential for AI and machine learning to extract valuable insights for diagnosis, treatment, and research. The increasing volume of data, while beneficial for AI/ML advancements, poses a challenge to human analytical capabilities, as it is impossible for individuals to process and interpret vast quantities of information effectively. This data deluge creates a bottleneck for researchers and analysts, making extracting meaningful insights and patterns challenging without automated tools. Consequently, gastroenterologists must navigate complex ethical and legal data privacy and ownership issues as AI/ML transforms the field [14].

AI utilizing CADe systems is being investigated to enhance polyp detection during colonoscopy, addressing the issue of missed polyps attributed to human error. Misawa et al. demonstrated CADe's ability to improve polyp detection rates to 95% while reducing miss rates by 50% [15]. These systems shift diagnostics from reliance on human observation alone to a collaborative human-AI approach. Further refining this process, Computer-Aided Diagnosis (CADx) systems classify detected polyps as benign or malignant, with Wang et al. reporting 92% detection accuracy and a 45% reduction in miss rates [16]. Furthermore, DL models, specifically convolutional neural networks (CNNs), have achieved a 94% cross-validation accuracy and an Area Under the Curve (AUC) of 0.991 in real-time polyp detection and localization [17]. The main findings of these studies are summarized in Table 1, highlighting AI's consistent performance in improving endoscopic outcomes.

Table 1. Performance of Artificial Intelligence (AI) Systems in Polyp Detection

Study	Artificial Intelligence System	Polyp Detection Rate	Miss Rate Reduction
Misawa et al. (2021) [15]	Computer-Aided Detection	95%	50%
Wang et al. (2020) [16]	Computer-Aided Diagnosis	92%	45%
Urban et al. (2018) [17]	Deep Learning	94%	48%

Hassan et al., in a systematic review and meta-analysis, reported the good performance of AI in colonoscopy for polyp detection [18]. Byrne et al. also demonstrated the real-time capabilities of deep learning in polyp differentiation during colonoscopy [19].

Capsule Endoscopy

Beyond colonoscopy, AI streamlines *capsule endoscopy,* where the high volume of images traditionally challenges thorough review. Capsule endoscopy presents a unique challenge due to its non-invasive nature and the substantial volume of images it produces, making the review process cumbersome and susceptible to human error. AI technologies can significantly streamline this process, enhancing efficiency and accuracy in detecting GI abnormalities. A significant advancement in the field of AI in capsule endoscopy has been AI's ability to reduce image reading time from 96 minutes to less than 10 minutes [20]. CNNs automate the detection of abnormalities like bleeding, ulcers, and tumours, achieving 96% sensitivity and 94% specificity in identifying GI bleeding (Table 2) [21,22]. This reduces diagnostic delays and alleviates clinician workload, underscoring AI's role in optimizing accuracy and efficiency across gastroenterological diagnostics.

Table 2. Artificial Intelligence (AI) Performance in Capsule Endoscopy

Application	AI Model	Sensitivity	Specificity
Bleeding Detection	CNN	96%	94%
Tumor Identification	ResNet	92%	90%
Ulcer Detection	InceptionV3	89%	91%

CNN-Convolutional Neural Network; ResNet-Residual Network

Early Cancer Detection

AI is also helpful in early cancer detection. Barrett's oesophagus, a precursor to oesophagal adenocarcinoma, necessitates diligent monitoring through endoscopic evaluations. AI systems have been developed to analyze endoscopic images, identifying morphological changes that signify dysplasia or early malignancy [23]. AI algorithms can distinguish between dysplastic and non-dysplastic tissues, guiding clinicians in biopsy procedures and subsequent management [24]. These systems contribute to earlier oesophagal cancer detection, positively impacting treatment outcomes [25]. Cai et al. (2019) developed and validated a deep neural network (DNN) CADe system for early esophageal squamous cell carcinoma (ESCC) screening using white-light endoscopy. The DNN-CAD, trained on over 2,400 images, achieved an AUC above 96% and, in validation, demonstrated high sensitivity (97.8%) and accuracy (91.4%). Notably, when used as an aid, the CAD system outperformed endoscopists, particularly junior ones, and improved diagnostic accuracy across all experience levels. The study concludes that the DNN-CAD system effectively detects early ESCC lesions, potentially reducing missed diagnoses during routine endoscopy [19].

Streamlining Endoscopic Procedures

Real-Time Assistance in Endoscopic Procedures

AI not only aids in diagnostics but also enhances the quality and efficiency of endoscopic procedures. Goenka et al. (2023), in a pilot study, assessed the completeness of esophagogastroduodenoscopy (EGD) using AI analysis of 277 procedures (114 by trainees, 163 by experienced endoscopists). While common areas like the greater curvature of the antrum (97.47%) and the second part of the duodenum (96.75%) were well-visualized, critical areas like the vocal cords (99.28% missed) and epiglottis (93.14% missed) were frequently overlooked. The incisura also showed significant misses (posterior 78.70%, anterior 73.65%, lateral 73.53%). Experienced endoscopists (category B) performed significantly more complete procedures (88.68% vs. 11.32%, $p < 0.00001$). The study concludes that AI effectively evaluates EGD quality and could be valuable in endoscopy training [**26**]. Real-time feedback mechanisms allow the detection of abnormalities instantaneously, improving procedural outcomes. AI systems can guide endoscopic procedures by highlighting areas requiring attention, such as regions with inflammation or bleeding, ensuring that critical findings are not overlooked**.** This emphasis on the role of AI in streamlining procedures reassures the audience about the quality and efficiency of patient care in gastroenterology.

Automated Reporting and Quality Control

Clinicians often face the challenge of time-consuming documentation. AI can mitigate this with automated reporting solutions that synthesize findings from endoscopic evaluations into structured reports, thus reducing administrative workload while enhancing report accuracy [27]. These tools can also facilitate quality control by evaluating colonoscopy metrics, ensuring procedures meet established standards, and reducing the chance of missed lesions [28]. AI can also monitor bowel preparation during colonoscopy, an essential quality parameter for colonoscopic quality that can impact the diagnosis [29].

Predictive Analytics and Risk Stratification

AI excels at analyzing large datasets to predict disease outcomes and stratify patient risk. Below are some key applications:

Inflammatory Bowel Disease

AI is revolutionizing predictive analytics in gastroenterology by analyzing vast datasets to forecast disease progression and optimize patient risk stratification. A key application lies in *IBD*. AI models demonstrate strong potential in predicting disease flares, which is critical for a condition marked by unpredictable exacerbations and remission periods [30]. AI can categorize patients by risk level by integrating clinical data, biomarkers, and genetic information, facilitating personalized treatment plans. Advanced ML algorithms can process medical history, dietary patterns, medication adherence, and lab results to anticipate impending flares. This enables early, proactive interventions that may prevent hospitalizations and reduce the need for aggressive therapies, ultimately improving outcomes while lowering healthcare costs.

There is considerable interobserver variation in scoring the severity of IBD at endoscopy. Abadir et al. (2020) have demonstrated AI's ability to differentiate different severity grades [28]. Furthermore, it is sometimes challenging to differentiate ulcerative colitis from Crohn's disease in the pediatric population. Mossotto et al. (2017) explored the use of ML to improve the diagnosis of pediatric IBD, specifically Crohn's disease, ulcerative colitis, and IBD-unclassified, in 287 children. Unsupervised ML models showed overlapping disease patterns, but hierarchical clustering identified four novel subgroups based on colonic involvement. Using endoscopic, histological, and combined data, supervised ML models achieved classification accuracies of 71.0%, 76.9%, and 82.7%, respectively. The combined model, validated on an independent cohort of 48 patients, correctly classified 83.3% [31].

Liver Disease

AI algorithms help analyze imaging, laboratory results, and patient history to predict the progression of liver fibrosis, cirrhosis, and hepatocellular carcinoma (HCC). This enables early intervention and improves patient outcomes [32]. Thus, as discussed ahead, AI plays a significant role in liver disease diagnosis, prognosis, and treatment.

A) Diagnosis and Imaging: AI can analyze medical images like CT scans and MRIs to detect subtle changes in the liver that the human eye might miss. Furthermore, AI models are being developed to assist in the diagnosis of various liver diseases, including non-alcoholic fatty liver disease (NAFLD), cirrhosis, and HCC. AI can also help classify and segment liver masses, improving diagnostic accuracy [33,34]. Beyond current applications, AI's role in identifying new biomarkers and pathways involved in liver diseases is crucial, leading to the development of new diagnostic tools that can be incorporated into imaging analysis.

B) Prognosis and Prediction: AI models can predict the progression of liver fibrosis and cirrhosis, helping to identify patients at higher risk of developing complications. AI can also be used to predict the response to treatment and the risk of recurrence of HCC. It can also help prioritize patients for liver transplants by predicting one-year mortality and post-transplant survival [35,36]. This predictive power is constantly being refined through AI's ability to identify new biomarkers and pathways relevant to disease progression and patient outcomes, enhancing the accuracy and scope of prognostic models.

C) Treatment and Management: AI can help select the optimal treatment strategy for different liver diseases, considering individual patient characteristics and helping personalize treatment plans and predict treatment outcomes. Furthermore, AI tools can assist in monitoring patients after liver transplantation, helping to identify risk factors for disease recurrence and other complications [37,38]. AI also plays a vital role in accelerating drug discovery and development for liver diseases, leading to new therapeutic options that can then be optimized and managed with AI-driven strategies.

Colorectal Cancer (CRC)

AI also enhances CRC *screening* through sophisticated risk stratification models [39]. AI refines individual risk assessments by analyzing family history, lifestyle factors, and comorbidities, allowing physicians to tailor screening recommendations more precisely. This ensures that high-risk patients receive timely colonoscopies or other interventions, improving early detection rates and survival outcomes. Through these applications, AI is transforming gastroenterology into a more proactive, data-driven field that is shifting from reactive treatment to predictive, precision-based care.

Table 3. Artificial Intelligence Applications in Predictive Analytics

Disease	AI Model	Prediction Task	Accuracy
Inflammatory Bowel Disease	Random Forest	Disease Flare Prediction	88%
Liver Fibrosis	SVM	Fibrosis Progression Prediction	90%
Colorectal Cancer	Neural Network	Risk Stratification	85%

SVM- Support Vector Machines; AI- Artificial Intelligence

Table 3 presents some AI applications in predictive analytics in IBD, Liver Fibrosis, and CRC. AI's prowess extends to predictive analytics, where large datasets are analyzed to effectively forecast disease outcomes and stratify patient risks. This potential of AI in predicting disease outcomes instils hope about the future of patient care in gastroenterology, where proactive interventions can be made to prevent hospitalizations and reduce the need for aggressive therapies.

Personalized Treatment Plans

AI is revolutionizing precision medicine in gastroenterology by facilitating personalized treatment strategies tailored to individual patient profiles.

Drug Response Prediction

AI models can process genetic, clinical, and lifestyle data to forecast patient-specific therapeutic outcomes. For instance, ML algorithms can predict the effectiveness of biological therapies in Crohn's disease patients or estimate the probability of achieving sustained virologic response in hepatitis C treatment regimens [40].

AI-driven microbiome analysis

AI-driven microbiome analysis deciphers complex gut microbiota patterns to guide customized dietary and probiotic interventions for conditions like irritable bowel syndrome (IBS) and IBD. Advanced AI systems can pinpoint specific bacterial signatures linked to disease progression and recommend precision-targeted therapeutic approaches [41]. These innovations demonstrate AI's transformative potential in shifting gastroenterology from generalized protocols to genuinely personalized, data-driven patient care.

Commercially available Computer-Aided Diagnosis systems

Several commercial CAD systems are now available, with key developments in both diagnostic (CADx) and detection (CADe) capabilities for endoscopy (Table 4). The pioneering CADx system, EndoBRAIN, developed by Kudo and Mori et al. with Cybernet Systems Co., uses ultra-high-magnification endoscopy and a machine learning algorithm. Initial studies showed its diagnostic accuracy for differentiating neoplastic from non-neoplastic lesions (89%), comparable to that of a specialist clinician (91%). Following successful multicenter trials, it significantly outperformed non-specialist clinicians (97% sensitivity, 98% accuracy vs. 71% sensitivity, 69% accuracy). An extensive prospective study further confirmed its utility in real-time clinical practice, achieving 92.7% sensitivity and 89.8% specificity for distinguishing neoplastic lesions. In the realm of CADe, the EndoBRAIN-EYE, designed for automatic colorectal lesion detection, demonstrated strong performance with 90.5% sensitivity and 93.7% specificity in a frame-based analysis of over 150,000 images. Extending beyond basic lesion differentiation, the new EndoBRAIN-Plus system, using ultra-high magnification endo-cystoscopy, achieved high diagnostic reliability for invasive cancer (89.4% sensitivity, 98.9% specificity). Furthermore, the EndoBRAIN-UC, designed to assess inflammatory activity in ulcerative colitis, has also been approved, expanding AI's application to inflammatory bowel disorders [42].

Table 4. Commercially available Computer-Aided Diagnosis/Detection Systems

PRODUCT NAME	COMPANY	CAD NAME
EndoBRAIN	Cybernet Systems Co. (Tokyo, Japan)	CADx
EndoBRAIN-EYE	Cybernet Systems Co. (Tokyo, Japan)	CADe
EndoBRAIN-Plus	Cybernet Systems Co. (Tokyo, Japan)	CADx
EndoBRAIN-UC	Cybernet Systems Co. (Tokyo, Japan)	CADx
GI Genius	Medtronics Co. (Dublin, Ireland)	CADe
DISCOVERY	Pentax Medical Co. (Tokyo, Japan)	CADe
ENDO-AID	Olympus Co. (Tokyo, Japan)	CADe
CAD EYE	Fujifilm (Tokyo, Japan)	CADe, CADx
EndoScreener	Shanghani Wision AI Co. (Shanghai, China)	CADe
WISE VISION	NEC Co. (Tokyo, Japan)	CADe

CADx: Computer-Aided Diagnosis; CADe: Computer-Aided Detection.
Adapted from Kamitani and Isomoto, 2022 [42]

Challenges and Limitations of AI in Gastroenterology

Despite AI's significant advantages in gastroenterology, several challenges and limitations must be addressed to ensure its effective and ethical implementation. One primary concern is data quality and availability, as the performance of AI models depends heavily on the volume and consistency of training data [43]. In gastroenterology, imaging technique variations and data collection discrepancies can negatively impact model accuracy. Additionally, ensuring diverse and representative datasets is crucial to minimizing biases and improving the generalizability of AI tools across different populations. Since AI training requires the collection of vast amounts of data, the issue of data privacy remains paramount.

Another challenge is the integration of AI into clinical workflows. Adopting AI solutions may disrupt established practices, and clinicians' reluctance to embrace new technologies can hinder implementation [44]. Financial barriers, particularly in low-resource settings, further complicate developing and deploying AI-driven tools in GE. Hassan et al. (2024), reviewing 50 studies from a pool of 2,514 articles, identified 18 categories of barriers and facilitators, emphasizing that trust is a critical catalyst for AI adoption, necessitating robust governance and regulatory frameworks [45]. This need for trust is echoed by Esteva et al. [46], who highlight that clinician and patient trust is essential for successful AI implementation. Clinician trust requires rigorous validation through real-world trials and interpretable AI algorithms, while patient trust hinges on stringent privacy measures and advanced data handling techniques like federated learning. Both reviews conclude that overcoming these trust-related obstacles is crucial to realizing AI's potential to create a more accessible and equitable healthcare system.

Ethical considerations also play a critical role regarding accountability and transparency in AI-assisted decision-making [47]. Clinicians must be able to interpret AI-generated recommendations confidently to maintain patient trust, which requires clear explanations of how these systems arrive at their conclusions. Regulatory and legal challenges present ongoing hurdles as the AI landscape in healthcare evolves [48]. One important area is how to divide accountability between machines and men while doing root cause analyses in cases of improper diagnosis. Compliance with medical and technological standards demands a thorough understanding of both fields [49-51], and establishing clear guidelines for responsible AI deployment in gastroenterology remains a priority for policymakers and practitioners alike (Figure 2).

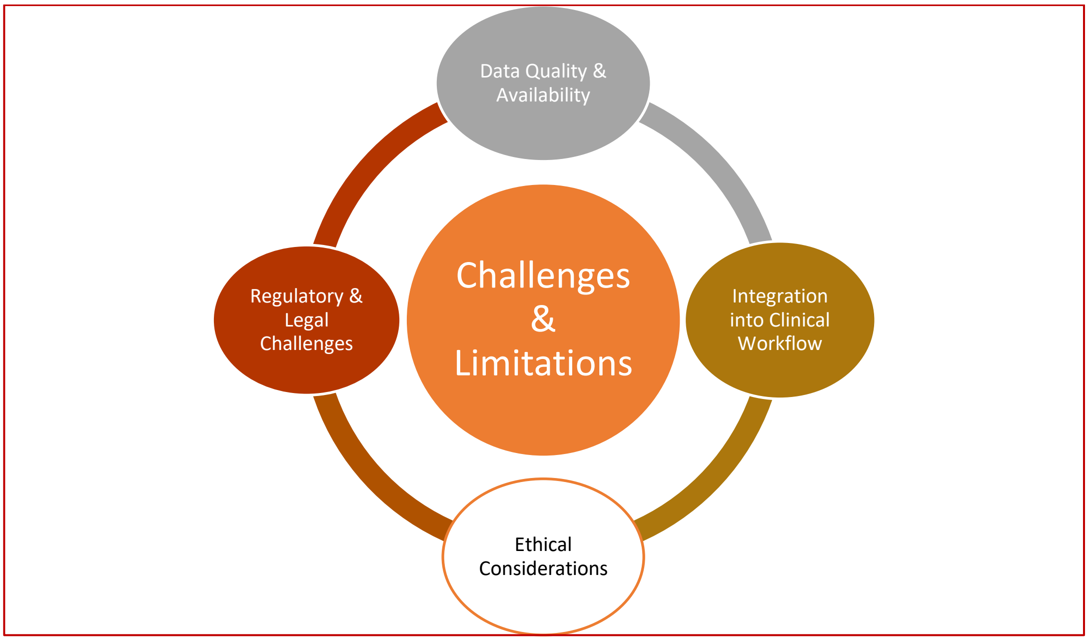


Figure 2. Challenges and Limitations of Artificial Intelligence in Gastroenterology

Future Directions

The future of AI in gastroenterology holds significant promise, with several key areas poised for advancement (Figure 3). Natural Language Processing (NLP) technologies are expected to play a crucial role by automating the analysis of unstructured clinical narratives, streamlining documentation, and synthesizing data from diverse sources to enhance the diagnosis and management of GI disorders. Additionally, utilizing real-world data from electronic health records (EHRs) and patient registries will provide valuable insights into the effectiveness of AI applications across diverse populations, helping refine predictive models and treatment protocols [52]. Collaboration among healthcare professionals, data scientists, and industry stakeholders will be essential to drive innovation and develop clinically relevant AI tools that prioritize safety and efficacy [53]. To ensure successful integration, healthcare providers will need targeted education and training to build competency in AI technologies to augment diagnostic and clinical decision-making [54].

Figure 3. Future of Artificial Intelligence in Gastroenterology

Further advancements include the development of multimodal AI, which integrates imaging, genomic, and clinical data for a more comprehensive disease assessment [52]. AI-driven robotic endoscopy systems may also enhance precision in complex endoscopic procedures [55,56]. Additionally, patient-centric AI applications, such as wearable devices and mobile apps, could enable continuous GI health monitoring, empowering patients to take a proactive role in their care [57,58].

Conclusion

The review highlights the transformative impact of Artificial Intelligence (AI) on gastroenterology, particularly in enhancing diagnostic accuracy and optimizing endoscopic procedures. AI technologies, including Computer-Aided Detection (CADe), significantly improve polyp detection rates and reduce miss rates during colonoscopy. In capsule endoscopy, AI efficiently analyzes large volumes of images, facilitating the timely identification of gastrointestinal abnormalities with high sensitivity and specificity. Additionally, AI contributes to the early detection of oesophagal adenocarcinoma by effectively distinguishing between dysplastic and non-dysplastic tissues through advanced image analysis and overall, integrating AI in gastroenterology promises to improve patient outcomes by addressing existing diagnostic challenges and streamlining clinical workflows.

Statements and Disclosures

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but have checked the final manuscript and take the full responsibilities of its contents.

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Conflict of Interest

The authors declare that they do not have conflict of interest.

Ethical approval

Not required for a narrative review

Authors' Contributions (CRediT statement)

RV: Conceptualization, Methodology, Literature Search, Manuscript writing, editing and final approval; MKG, AS, SK and SR: Conceptualization, Literature Search, Manuscript writing, editing and final approval

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