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MINIREVIEWS

Gastroenterology in the age of artificial intelligence: Bridging technology and clinical practice

Yagna Mehta, Saumya Mehta, Vishwa Bhayani, Sankalp Parikh, Rajiv Mehta

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Abstract

The integration of artificial intelligence (AI), deep learning (DL), and radiomics is rapidly reshaping gastroenterology and hepatology. Advanced computational models including convolutional neural networks, recurrent neural networks, transformers, artificial neural networks, and support vector machines are revolutionizing both clinical practice and biomedical research. This review explores the broad applications of AI in managing patient data, developing disease-specific algorithms, and performing literature mining. In drug discovery, AI-driven computational chemistry is significantly speeding up drug discovery and development by accelerating hit identification, lead optimization, and formulation development. Machine learning models enable the precise prediction of molecular interactions and drug-target binding, thereby improving screening efficiency and reducing reliance on conventional experimental methods. AI also plays a central role in structure-based drug design, molecular docking, and absorption, distribution, metabolism, excretion, and toxicity simulations, while facilitating excipient selection and optimizing formulation stability and bioavailability. In clinical endoscopy, DL-enhanced computer vision is advancing ambient intelligence by enabling real-time image interpretation and procedural guidance. AI-based predictive analytics further support personalized medicine by forecasting treatment response in inflammatory bowel disease. Remote monitoring systems powered by AI are proving vital in managing high-risk populations, including patients with acute-on-chronic liver failure, liver transplant recipients, and individuals with cirrhosis requiring individualized diuretic titration. Despite its promise, AI potential in gastroenterology faces challenges stemming from data inconsistencies, ethical concerns, algorithmic biases, and data privacy issues including health insurance portability and accountability act and general data protection regulation compliance. Establishing standardized protocols for data collection, labeling, and sharing, alongside robust multicenter databases and regulatory oversight, are essential for ensuring safe, ethical, and effective AI integration into clinical workflows.

Key Words: Artificial intelligence; Gastroenterology; Predictive analytics; Endoscopy; Drug discovery; Personalized medicine; Remote monitoring

Core Tip: Artificial intelligence (AI) is transforming gastroenterology and hepatology by enhancing diagnostic accuracy, enabling personalized therapy, and accelerating drug discovery. This review highlights key AI applications such as real-time polyp detection, predictive modeling in inflammatory bowel disease, and early risk stratification in acute pancreatitis. AI also supports drug repurposing, *de novo* molecule design, and formulation optimization through absorption, distribution, metabolism, excretion, and toxicity profiling. In hepatology, AI facilitates remote monitoring and guides complex cancer care *via* tumor boards. Educational tools like GastroAGI (AI-powered learning in gastroenterology) further extend its impact. Addressing data quality, interpretability, and ethical challenges is essential for integrating AI into clinical practice.

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INTRODUCTION

Artificial intelligence (AI) has emerged as a transformative force in gastroenterology and hepatology by enhancing diagnostic accuracy and offering new therapeutic strategies[1-4]. Leveraging machine learning (ML), deep learning (DL), convolutional neural networks (CNNs) and recurrent neural networks, natural language processing (NLP), and large language models, AI can interpret complex datasets including electronic health records (EHRs), endoscopic images, capsule endoscopy videos, and genomic or proteomic data[1,3,4]. These tools enhance lesion detection, automate report generation, and improve disease classification. AI also supports predictive modeling to forecast disease progression and therapeutic response, enabling personalized treatment strategies in conditions like inflammatory bowel disease (IBD) and chronic liver disease[5]. AI significantly accelerates drug discovery by identifying novel therapeutic targets, facilitating drug repurposing, and improving clinical outcomes by modeling molecular interactions and analyzing large datasets. Remote monitoring technologies integrated with AI, such as AI-powered wearable biosensors, provide real-time tracking of patient parameters, enabling optimized management of cirrhosis, acute-on-chronic liver failure (ACLF), and liver transplantation recipients. Furthermore, AI enables the continuous assessment of treatment efficacy, guiding timely dose adjustments and improving safety profiles. By streamlining workflows, enhancing diagnostic accuracy, and supporting therapeutic innovation, AI is poised to transform the future of gastrointestinal and hepatic care[2].

BIG DATA IN GASTROENTEROLOGY

The advent of big data has transformed gastroenterology by enabling the integration and analysis of large-scale, heterogeneous datasets including electronic medical records, endoscopic imaging, laboratory tests, and multi-omics data[6,7]. Powered by AI/ML, big data facilitates real-time lesion detection, automated disease classification, and predictive modeling for outcomes such as cancer risk and treatment response[7]. Integrating genomic, proteomic, and metabolomic data supports precision medicine, while clinical decision support systems (DSS) enhance diagnostic accuracy and reduce human error[8,9]. In drug discovery, big data accelerates biomarker identification, phenomapping, and post-marketing safety surveillance. Despite its promise, challenges remain including data quality variability, privacy concerns, and the need for sophisticated analytic tools and interdisciplinary collaboration. As these hurdles are addressed, big data will continue to advance personalized care, real-time monitoring, and population-level health strategies in gastroenterology [7].

PREDICTIVE ANALYTICS FOR PATIENT OUTCOMES

Predictive analytics in gastroenterology harnesses AI to forecast disease progression, therapeutic responses, and clinical outcomes by analyzing large-scale, high-dimensional data[3,10]. In hepatology, ML models have demonstrated accuracy in predicting cirrhosis-related complications, liver transplant outcomes, and mortality in patients with ACLF[11]. Similarly, in IBD, AI algorithms can analyze clinical, laboratory, imaging, and genomic data to predict treatment responses to steroidsandbiologic therapies, as well as anticipate disease flares[12]. These tools aid clinicians in tailoring therapy, avoiding ineffective treatments and improving long-term patient outcomes. Predictive models have also shown utility in assessing the severity of acute pancreatitis during early hospitalization, allowing timely escalation of care[13]. As these technologies evolve, their integration into clinical workflows may support proactive and personalized management strategies in gastroenterology.

AI-based predictive analytics tools are gaining traction in risk stratification, outcome forecasting, and personalized treatment planning. These models utilize large datasets comprising clinical, imaging, genomic, and lifestyle parameters to forecast complications such as gastrointestinal bleeding, post-procedural infections, or relapse in IBD. In acute pancreatitis, ML algorithms have outperformed conventional scoring systems such as bedside index for severity in acute pancreatitis or acute physiology and chronic health evaluation-II in predicting severity, intensive care unit requirement, and mortality. Similarly, AI models can predict treatment response in viral hepatitis, the likelihood of hepatocellular carcinoma recurrence, and hospital readmission risk. Predictive analytics not only support clinical decision-making but also guide resource allocation, discharge planning, and early warning systems. To maximize clinical impact these models must be externally validated and seamlessly embedded into EHR systems.

REAL-TIME DSS

AI has become integral to real-time DSS in gastroenterology and hepatology, enhancing diagnostic precision, optimizing therapeutic strategies, and streamlining clinical workflows[14]. Leveraging various technologies, AI enables the dynamic interpretation of complex clinical, imaging, and procedural data, leading to more accurate diagnoses, personalized treatments, and improved patient outcomes. In endoscopy, AI significantly enhances lesion detection and improves procedural quality by facilitating real-time polyp detection, dysplasia localization in Barrett's esophagus (BE), and automated analysis of capsule endoscopy[15,16]. In hepatology, AI is being leveraged to enhance ultrasound elastography, improving the real-time assessment of liver fibrosis and predicting the progression of ACLF at the time of hospital admission. Integrating AI into EHRs allows for the anticipation of complications like bleeding or decompensation, enabling proactive management by healthcare providers[11]. Additionally, NLP systems automate structured reporting, and radiomics and radiogenomics inform tumor behavior and therapy response in hepatocellular carcinoma[17]. Collectively, AI-driven DSS are revolutionizing healthcare by empowering clinicians with actionable insights at the point of care, reducing variability, improving outcomes, and enhancing operational efficiency.

ML MODELS FOR DISEASE DIAGNOSIS

ML has significantly advanced diagnostic capabilities in gastroenterology by analyzing structured and unstructured datasets to identify patterns and anomalies, stratify risk, and support clinical decisions[5]. For example, in pancreatic disorders, ML models such as gradient boosting machines and support vector machines effectively distinguish between benign and malignant cystic lesions, aiding in surgical decision-making and reducing overtreatment[18,19]. In the management of IBD, ML algorithms incorporate endoscopic, imaging, and serological data to predict disease severity and flare risk, facilitating personalized care[12]. Ensemble models, especially those using algorithms like extreme gradient boosting, are increasingly used in real time during colonoscopy to detect diminutive polyps, significantly enhancing adenoma detection rates and procedural quality[20,21]. These models, based on DL, have demonstrated high accuracy, sometimes reaching 96% in identifying polyps, potentially improving screening outcomes. Additionally, explainable AI frameworks enhance transparency and foster trust in diagnostic processes, aiding in informed decision-making[22,23]. These technologies collectively improve diagnostic accuracy, reduce interobserver variability, standardize diagnostic criteria, and streamline complex data analysis, laying the foundation for precision medicine in gastroenterology. For example, in pancreatic disorders, ML models such as gradient boosting machines (commonly referred to as gradient boosting machines) and support vector machines (commonly referred to as support vector machines) distinguish benign from malignant cystic lesions effectively, aiding in surgical decision-making. DL models have also been trained to predict early pancreatic cancer from imaging biomarkers and EHR data. In chronic pancreatitis, AI tools are being explored for their potential in pain phenotype clustering and prediction of exocrine insufficiency progression; although, the clinical implementation of each remains limited due to the small dataset sizes and lack of external validation.

AI FOR PERSONALIZED MEDICINE

AI is rapidly transforming personalized care by enhancing therapeutic precision, treatment responsiveness, and long-term disease management in gastroenterology. In IBD, AI algorithms are increasingly used to predict patient responses to medications, including both biologics and small molecule drugs, using clinical records, genetic information, and data from medical imaging, reducing empirical treatment selection and minimizing adverse effects[24,25]. Advances in the ability of AI to analyze microbiome data are transforming targeted interventions, such as fecal microbiota transplantation and probiotic therapy for IBD and irritable bowel syndrome. By identifying dysbiosis patterns, AI predicts which therapeutic outcomes are most likely to be successful, leading to more personalized and effective treatments[26,27]. Real-time integration of data from wearable devices and EHRs allows for dynamic treatment adjustments based on patient-reported outcomes and biometric trends, which are particularly valuable in chronic conditions such as IBD and acute pancreatitis[28]. Furthermore, AI leverages multi-omics datasets including genomics, proteomics, and metabolomics to develop precision therapy frameworks, such as tailoring hepatocellular carcinoma treatment based on radiogenomic signatures[17].

REMOTE MONITORING AND TELEMEDICINE

The integration of AI into telemedicine is set to revolutionize remote monitoring in gastroenterology, particularly for chronic conditions requiring continuous follow-up. AI-powered virtual assistants offer symptom tracking, medication adherence support, and personalized lifestyle recommendations, enhancing disease control in IBD and reducing hospital visits[28]. In hepatology, AI-enhanced devices (wearable biosensors, paired with real-time AI analytics) monitor vital signs and liver-specific biomarkers in patients with ACLF and cirrhosis, enabling timely intervention and avoiding late intensive care unit admissions[29]. Similarly, in cirrhosis and portal hypertension, continuous monitoring of physiological parameters allows for the timely adjustment of diuretics and beta-blockers. AI also enables the remote assessment of nutritional status and sarcopenia, particularly relevant in liver disease management, through analysis of muscle mass and metabolic indicators[30]. Beyond clinical applications, AI-integrated telemedicine improves patient satisfaction, reduces healthcare costs, enhances accessibility to specialized care, and streamlines workflows by automating routine tasks.

AI is revolutionizing telemedicine in gastroenterology, particularly in the management of chronic diseases. Advanced AI models have enabled remote patient monitoring through wearable sensors, home-based diagnostics, and integration with mobile health applications. In IBD, AI algorithms track symptoms and medication adherence and predict flare-ups, prompting timely clinical intervention. Similarly, in patients with cirrhosis and those post-liver transplant, AI-driven platforms monitor weight, blood pressure, creatinine, and international normalized ratio to detect early signs of decompensation or graft dysfunction. These systems, integrated with teleconsultation platforms, support proactive care and reduce hospitalization rates. Moreover, AI-enhanced NLP tools assist in automated documentation during virtual visits, improving workflow efficiency for clinicians. The convergence of AI and telemedicine offers scalable and equitable care, especially in underserved regions.

AI-BASED TUMOR BOARDS: STREAMLINING COMPLEX CANCER CARE

Complex gastrointestinal cancers often require input from multidisciplinary tumor boards comprising surgeons, oncologists, radiologists, pathologists, and gastroenterologists to formulate optimal treatment strategies. While indispensable, these meetings can be time-consuming and resource intensive. AI-powered platforms offer a scalable solution by integrating patient demographics, clinical history, imaging, pathology, and genomic data to generate evidence-based, personalized treatment recommendations[31,32]. These systems align therapeutic decisions with established guidelines and emerging research, thereby expediting clinical workflows and improving access to expert-level care, especially in resource-limited or remote settings. Although not a substitute for human expertise, AI-assisted tumor boards can enhance multidisciplinary discussions, ensure consistency in treatment decisions, and continuously adapt to new evidence. This approach represents a paradigm shift in gastrointestinal oncology, enhancing precision, efficiency, and equity in cancer care[33,34]. In hepatobiliary cancers, AI-driven radiomics and radiogenomics approaches have shown promise in predicting tumor grade, recurrence risk, and treatment response in hepatocellular carcinoma. However, their incorporation into clinical decision-making awaits prospective validation.

AI IN GASTROENTEROLOGY EDUCATION AND RESEARCH

GastroAGI: AI-powered learning in gastroenterology

GastroAGI, developed by YRaM Biosolutions, an AI startup located in Gujarat, India, is a valuable tool designed to aid students and researchers in gastroenterology. This AI-powered platform offers in-depth educational resources, interactive learning modules, and real-time access to updated medical literature. By leveraging ML algorithms, GastroAGI customizes learning pathways based on user engagement, providing tailored recommendations on research articles, case studies, and clinical guidelines. It enables postgraduate students and trainees to streamline their academic pursuits, making it an essential resource for evidence-based learning in gastroenterology.

AI integration in drug discovery

AI is revolutionizing drug discovery in gastroenterology by accelerating the identification of novel chemical entities and enabling the repurposing of existing drugs for complex diseases such as idiopathic pancreatitis and IBD. In *de novo* drug design, DL tools such as AlphaFold2 enable the accurate prediction of protein structures, supporting the development of targeted therapies for gastrointestinal malignancies[35]. Generative models are also utilized to assess efficacy and toxicity profiles in early-stage compounds, significantly reducing late-stage attrition in clinical trials[36,37]. Furthermore, AI enhances safety by predicting drug-drug interactions in polypharmacy scenarios, which are particularly relevant for the management of cirrhosis and portal hypertension. Beyond discovery, AI contributes substantially to formulation science by identifying optimal excipients through computational chemistry. ML algorithms evaluate the compatibility and molecular interactions between active pharmaceutical ingredients and excipients, optimizing solubility, stability, and bioavailability especially critical for poorly soluble drugs. In parallel, AI is increasingly applied to predict absorption, distribution, metabolism, excretion, and toxicity properties with high precision[37,38]. By integrating physicochemical, structural, and biological datasets, these models provide early pharmacokinetic and safety profiles, enabling more informed candidate selection. Collectively, these AI-driven innovations are streamlining drug development and formulation, paving the way for personalized and precision-based therapeutics in gastroenterology[39].

ROLE OF AI IN ENDOSCOPY

Diagnostic endoscopy

Recent breakthroughs in computer vision, powered by DL, are driving the evolution of ambient intelligence in healthcare environments. In gastrointestinal endoscopy, these advances enable the more sophisticated and accurate interpretation of endoscopic images[40,41]. AI-powered systems, especially computer-aided detection (CADe) and computer-aided diagnosis (known as CADx), utilize CNNs to identify lesions such as colorectal polyps, early gastric cancer, and BE with high sensitivity[15,42,43]. Tools such as EndoAngel (Wuhan Endoangel Medical Technology Co., Ltd., Wuhan, Hubei Province, China) demonstrated diagnostic accuracy exceeding 90% for early gastric cancer and have been shown to significantly reduce missed anatomical sites. In IBD, AI supports automated scoring of mucosal inflammation in ulcerative colitis and enables the accurate interpretation of capsule endoscopy in Crohn’s disease, thus facilitating timely diagnosis and disease monitoring[23,44].

Therapeutic endoscopy

In therapeutic endoscopy, AI aids in real-time procedural decision-making. After endoscopic mucosal resection or endoscopic submucosal dissection, AI can assess residual neoplastic tissue, helping confirm complete removal and reducing the risk of recurrence. In complex procedures such as endoscopic retrograde cholangiopancreatography or endoscopic ultrasound, AI is improving anatomical navigation, particularly in mediastinal regions, improving outcomes in challenging scenarios like biliary strictures or pancreatic lesions. Moreover, AI-based risk stratification tools assist in determining malignancy potential in indeterminate lesions, guiding biopsy decisions and treatment strategies.

The integration of AI tools into clinical gastroenterology requires adherence to stringent regulatory standards. Several AI-based systems have received regulatory approval for use in the real world. For instance, GI Genius (Medtronic plc, Dublin, Ireland) obtained the Conformite Europeenne (CE) Mark in Europe and approval by the Food and Drug Administration (FDA) in the United States for the real-time detection of polyps during colonoscopy. EndoAngel, developed in China, has demonstrated efficacy in improving adenoma detection rates and is undergoing international validation. These approvals reflect growing regulatory confidence, yet challenges remain. Regulatory pathways must evolve to accommodate adaptive algorithms that continually learn and adapt over time. Furthermore, guidance from agencies such as the FDA and European Medicines Agency emphasizes transparency, explainability, and clinical validation as essential criteria for approval. Clear documentation of data sources, model performance, and safety metrics will be essential for future AI deployments.

ADVANCED FEATURES

AI systems enhance procedural standardization and quality control in endoscopy by monitoring key aspects like withdrawal speed, bowel preparation, and completeness of mucosal inspection, providing real-time alerts for blind spots or missed areas, and improving accuracy and thoroughness. In endoscopy training, AI simulators offer interactive guidance, improving skill acquisition for novices. Furthermore, AI offers automation of structured reporting and image documentation, optimizing workflow. As validation continues, AI is poised to become an integral part of endoscopy, combining precision with efficiency in clinical practice.

CHALLENGES OF AI ADOPTION IN HEALTHCARE

While AI holds immense promise for revolutionizing gastroenterology and hepatology, its adoption faces several significant challenges including data heterogeneity, poor interoperability, and lack of high-quality, standardized datasets, which hinder model training and generalizability[45]. Privacy concerns governed by regulations such as health insurance portability and accountability act and general data protection regulation complicate data sharing, while high computational costs and limited infrastructure pose barriers, particularly in resource-constrained settings[46,47]. Bringing AI into clinical practice requires thorough testing through studies and clinical trials to ensure safety and efficacy. There are also ethical concerns, such as algorithmic bias, lack of transparency in how AI makes decisions (often referred to as the “black box” problem), and unequal access to AI technologies (democratizing AI)[48-51]. In addition, maintaining and updating AI systems over time can be challenging, especially in budget-constrained environments. Resistance from clinicians, often due to workflow disruption and skepticism about AI-driven decisions, necessitates a cultural shift and targeted training.

Table 1 Artificial intelligence applications in gastroenterology

Application domain	AI technologies used	Clinical utility	Examples
Diagnostic endoscopy	CNN, CADe, CADx	Real-time polyp detection, dysplasia localization	GI Genius, EndoAngel
Disease prediction	GBM, XGBoost, SVM	Severity scoring, relapse prediction, treatment response	IBD, acute pancreatitis models
Drug discovery	Deep learning, AlphaFold2	Target identification, ADMET profiling, formulation optimization	AI-driven computational chemistry
Tumor boards	Multimodal AI integration	Personalized therapy recommendations in GI cancers	AI-assisted tumor boards
Remote monitoring	RNN, wearable integration	Decompensation alerts in cirrhosis, post-transplant monitoring	Telemonitoring platforms
Education and NLP	Transformers, NLP	Automated reporting, AI tutors for endoscopy training	GastroAGI, report auto-generation
Regulatory-approved tools	CNN-based commercial systems	Clinical deployment for screening and diagnosis	GI Genius (FDA), EndoAngel (CE)

NLP: Natural language processing; CNN: Convolutional neural network; CADx: Computer-aided diagnosis; CADe: Computer-aided detection; GBM: Gradient boosting machine; XGBoost: Extreme gradient boosting; SVM: Support vector machine; RNN: Recurrent neural network; ADMET: Absorption, distribution, metabolism, excretion and toxicity; AI: Artificial intelligence; GI: Gastrointestinal; IBD: Inflammatory bowel disease; GastroAGI: Artificial intelligence-powered learning in gastroenterology; FDA: Food and Drug Administration; CE: Conformite Europeenne.

Additionally, uncertainty around liability and regulatory approval pathways hinders the commercialization of AI solutions. AI can reduce care disparities by extending specialist-level support to underserved regions but that unequal digital access may worsen disparities if not addressed. Overcoming these barriers requires a multifaceted approach to standardize data, invest in secure and scalable infrastructure, streamline validation, and embed ethical, regulatory, and educational frameworks into AI deployment strategies. Furthermore, a significant translational gap persists between experimental AI models and their integration into clinical workflows. Many promising algorithms remain in the research phase due to insufficient real-world validation, limited generalizability, and lack of regulatory approval. Bridging this gap requires robust multicenter studies, regulatory harmonization, and clinician engagement to support safe and effective deployment of AI tools in everyday practice. Addressing these issues is essential to unlock AI’s full potential in delivering equitable, efficient, and evidence-based care in gastroenterology and beyond.

RECENT ADVANCES IN AI-GUIDED ENDOSCOPY

Recent presentations at digestive disease week in San Diego on May 3 to May 6, 2025, highlighted the potential and current limitations of AI in endoscopic practice. CADe systems have shown promise in improving the detection and diagnosis of dysplasia in BE using image and video-based training datasets; however, their real-world accuracy remains uncertain due to variability in endoscopic techniques for mucosal visualization and the subtlety of early lesions. These systems are not yet commercially available; while holding a CE mark in Europe, they do not have United States FDA approval. In colonoscopy, the impact of CADe on improving outcomes in real-world practice may be more modest than initially suggested by controlled trials. However deeper analysis has revealed that the effectiveness of CADe depends heavily on the specific study design and the endoscopist’s commitment to utilizing the technology. Current CADe platforms represent an early phase in AI development. Future advancements are expected to incorporate a more comprehensive suite of tools including CADe, CADx, and computer-aided quality control to provide integrated real-time decision support, improve consistency, and enhance outcomes across various clinical settings.

CONCLUSION

The integration of AI in gastroenterology has marked the beginning of a transformative era in precision medicine, delivering significant advances in diagnostics, therapeutic planning, medical education, and multidisciplinary cancer care. AI-powered tools ranging from predictive models and endoscopic image analysis to computational drug discovery and personalized treatment algorithms including remote monitoring are redefining the clinical approach to complex gastrointestinal and hepatic disorders (Table 1). Real-world applications, such as predicting the severity of acute pancreatitis and forecasting treatment response in IBD, underscore the tangible impact of AI on patient outcomes. However, to fully realize these benefits, several challenges must be addressed including data privacy, ethical considerations, the interpretability of AI models, and the need for robust clinical validation. Ensuring transparency in AI decision-making is essential to build clinician trust, while rigorous trials are needed to verify safety, reliability, and generalizability.

Protecting patient data and ensuring equitable access to AI technologies remain critical priorities. Moving forward, the successful and responsible adoption of AI will require sustained interdisciplinary collaboration among clinicians, data scientists, regulatory authorities, and ethicists. With thoughtful implementation, continuous evaluation, and adherence to ethical standards, AI holds the potential to enhance clinical care, improve patient outcomes, and bring scalable innovation to every level of gastroenterology practice. The future is promising but must be navigated with diligence, equity, and scientific rigor. As such, we see many robust and substantive future directions, including integrating AI into routine clinical workflows, ensuring interpretability and clinician trust, expanding multicenter datasets for better generalization, and building equitable access to AI tools.

FOOTNOTES

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