DOI: 10.5281/zenodo.17643523
UDC: 004.8:616.3-072.1

ARTIFICIAL INTELLIGENCE IN GASTROINTESTINAL ENDOSCOPY: ADVANCES, CHALLENGES, AND CLINICAL APPLICATIONS

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Summary
Objectives. This review evaluates and summarizes current evidence on the use of artificial intelligence (AI) in gastrointestinal (GI) endoscopy and digestive disease management. We highlight recent advances in AI-based image analysis, diagnostic accuracy, and clinical use while identifying challenges such as standardization, education, and ethical issues.
Methods. We conducted a structured literature review of AI in GI endoscopy, focusing on publications from 2023 to 2025. We searched databases like PubMed and EMBASE using the following terms: "artificial intelligence," "machine learning," and "gastrointestinal endoscopy." We included systematic reviews, meta-analyses, clinical trials, consensus statements, and narrative reviews. Studies were selected and reviewed according to PRISMA principles, focusing on their diagnostic outcomes, technology features, and quality assessments.
Results. AI-enhanced endoscopy has significantly improved lesion detection compared to standard endoscopy. For instance, AI-assisted colonoscopy increases the adenoma detection rate by about 20% and lowers miss rates by around 55%. AI models demonstrate high sensitivity and specificity for upper GI neoplasms, such as early esophageal and gastric cancer, and Helicobacter pylori infection. Recent society guidelines recognize AI's role, with the ASGE listing "AI in endoscopy" as a top research topic, and recommend standardized evaluation through QUAIDE consensus. Explainable AI tools are being developed to tackle concerns about the "black box" nature of these systems. Other applications include capsule endoscopy, where AI assesses bowel cleanliness more consistently than human raters, and inflammatory bowel disease (IBD), where AI combines multi-omic data for disease phenotyping. However, challenges persist, including the risk of operator deskilling after extended AI use, data bias, cost-effectiveness, and regulatory barriers. Recent reviews highlight ethical issues related to patient privacy and dataset diversity.
Conclusions. AI is quickly transforming GI endoscopy by improving diagnostic accuracy and efficiency. To promote clinical adoption, we need rigorous validation and standardization, as suggested by QUAIDE, along with strategies for integrating AI into endoscopist training while maintaining human expertise. Future efforts should focus on large multicenter trials, explainable algorithms, and integrating AI into clinical workflows.
Keywords: Artificial Intelligence, Gastrointestinal Endoscopy, Machine Learning, Computer-Aided Detection

Introduction

Gastrointestinal (GI) endoscopy plays a critical role in diagnosing and managing digestive diseases, such as colorectal cancer, gastric cancer, and inflammatory bowel disease. However, traditional endoscopy has limitations, including missed lesions and differences in operator performance. Recently, artificial intelligence (AI), especially deep learning, has emerged as a promising tool for improving image analysis and decision-making in endoscopy. AI algorithms can automatically detect polyps, identify lesions, and analyze histology, which may lead to better early detection of GI tumors. For instance, a review found that AI-assisted endoscopy has demonstrated strong performance in diagnosing early digestive cancers, including esophageal squamous cell carcinoma [1].

Professional societies have acknowledged AI as a key innovation in endoscopy. An ASGE editorial listed "advances in AI in endoscopy" among the top 10 topics for 2024 [2]. Despite this progress, adopting AI requires addressing both technological and clinical challenges. In this review, we systematically examined recent literature on AI in GI endoscopy, summarizing performance outcomes, applications across colonoscopy, upper GI endoscopy, capsule endoscopy, and IBD assessment, and considerations for practice and training.

Materials and Methods

We conducted a structured review of the literature on AI in GI endoscopy of articles published between 2023-2025. PubMed and EMBASE were searched using the following terms: "artificial intelligence," "deep learning," and "machine learning" combined with "gastrointestinal endoscopy," "colonoscopy," "esophagogastroduodenoscopy," "capsule endoscopy," and "inflammatory bowel disease."

Additionally, reference lists of key articles were examined to identify supplementary sources. Eligibility criteria included peer-reviewed studies, systematic reviews, meta-analyses, guidelines, and consensus statements, focused on AI applications in GI endoscopy. There were included only articles published in English. Extracted data included study objectives, AI methods, outcomes (such as accuracy and detection rates), and noted limitations or recommendations. Findings were qualitatively summarized, following PRISMA guidelines for review structure. Notably, key position statements and consensus documents (e.g., QUAIDE) were included to contextualize recommendations [3].

Results

Diagnostic Precision of AI in Endoscopy

AI models have demonstrated substantially improved lesion detection during endoscopy. With colonoscopy, in a recent meta-analysis including randomized controlled trials (RCTs), computer-aided detection (CADe) increased adenoma detection rate (ADR) from about 40% to 48% (RR≈1.20) and reduced the miss rate by approximately 55% [4]. Diminutive adenomas demonstrated the most benefits, advanced adenoma detection was not appreciably changed [4]. AI algorithms in esophageal endoscopy are more sensitive in the detection of superficial squamous cell carcinoma than endoscopists. AI assistance achieved overall sensitivity of 57.4% to 66.5% and accuracy of 68.6% to 75.9% [5], to benefit both experienced and inexperienced readers. In upper GI (gastric) endoscopy, convolutional neural networks (CNNs) were extremely accurate in diagnosing early gastric cancer and depth of invasion prediction [6]. AI models have also been employed for non-neoplastic findings; e.g., one systematic review reported pooled sensitivity of approximately 93% and specificity of approximately 92% for the detection of Helicobacter pylori infection on endoscopic images [7]. One umbrella review reported AI was better than experts in the detection of most gastrointestinal tumours and has "high diagnostic performance in capsule endoscopy and esophageal squamous cell carcinoma" [1].

Explainable AI and Model Development

Existing AI models (usually deep neural networks) are very accurate, but are inherently complex. "Black box" predictions raise trust and explainability issues. Existing reviews mention the incorporation of Explainable AI (XAI) techniques (e.g. saliency maps, attention mechanisms) for determining image features that contribute to decisions [8]. For instance, Mascarenhas et al. (2025) note that explainable methods can increase clinician trust by delineating how models differentiate polyps or ulcers [8]. Parallel to this is the rapid advancement of training methods and datasets. Large collections of endoscopy images (e.g., the GastroNet-5M consortium dataset for heterogenous GI images [9] and data augmentation are dominant trends. Model building pipelines consist of detailed image annotation, use of CNN architectures, and human expert validation. Elamin et al. (2025) highlight that GI endoscopy leads the way in medicine with more than 40 AI-related randomized trials [10]. Colon polyp CADe systems have received FDA approval and utilized routinely [4]. This illustrates the shift from proof-of-concept to preclinical validation.

Clinical Guidelines and Quality Frameworks

Professional organizations have started incorporating AI into clinical guidelines. ESGE and ASGE have published position statements endorsing CADe in colonoscopy using evidence of benefit. The European guideline (ESGE) mentions that CADe should be used to improve ADR for screening [11]. The Japanese Gastroenterological Endoscopy Society also published statements on AI applications (e.g. for the detection of polyps) to guide implementation [12]. In response to variability in AI research design, the QUAIDE consensus group introduced standard quality criteria for AI research in endoscopy [3, 13]. They include standards on dataset diversity, outcome reporting, and external validation to facilitate reproducibility [3, 13]. More generally, ASGE's 2024 top-10 list of endoscopy topics emphasized the revolutionary role of AI [2]. These initiatives collectively emphasize the importance of consistency: adherence to reporting checklists (e.g. CLAIM or TRIPOD-AI) and multi-center validation before clinical application.

Training and Education

AI impacts endoscopist training as well. AI-powered training devices (e.g. simulators with feedback ability) are being developed to aid learning. Budzyń et al. (2025) pointed out that continuous AI support may reduce vigilance – they detected a reduction in ADR by repeatedly using CADe trained endoscopists, suggesting a potential "deskilling" threat [14]. Therefore, training programs are evolving to train with and without the assistance of AI, emphasizing that AI is a supplement and not a replacement for expertise. Rodriguez et al. (2024) discuss incorporating AI literacy into education in such a way that trainees can critically assess AI output [15]. Preliminary surveys indicate general support among endoscopists for AI, but they desire more learning on its limitations [16].

Emerging Applications and Modalities

Aside from colonoscopy, AI is applied in other GI conditions. In capsule endoscopy, frame analysis is automated through CNNs. For instance, one system assessed colon cleanliness in capsule endoscopy videos, reporting Cohen's kappa (0.586) being higher than that of inter-observer agreement (0.546) [17], aiding quality control. In Barrett's esophagus and early gastric cancer, models detect lesions and provide invasion predictions to guide therapy [18]. AI is also being applied in pathology: machine learning can evaluate digital histology slides of IBD and measure inflammation or detect dysplasia, potentially reducing pathologist workload. In addition, AI-facilitated augmented reality and robotics are emerging areas of research (e.g. automated polyp measurement, biopsy targeting).

Challenges and Limitations

Despite promise, challenges exist. Data variability and bias undermine AI performance in the field. Ethical issues are patient confidentiality (data use permission) and potential bias if the training data set is non-diverse [19]. Robustness is another challenge: some AI tools struggle with video data or edge cases. The "black box" nature of of AI provokes regulatory suspicion – metrics of explainability are needed [8]. Cost and cost-effectiveness are still under research. Early studies suggest that AI could be cost-effective by preventing missed lesions, but upfront device and software expenses could be extremely high [20]. Finally, widespread clinical endorsement has to be incorporated into workflow and payment systems.

Discussion

Our review shows that AI in GI endoscopy has quickly moved from being experimental to being evaluated clinically. This matches recent systematic reviews that demonstrate AI-enhanced colonoscopy improves adenoma detection [4] and polyp characterization. AI systems in esophagogastroduodenoscopy also exhibit better sensitivity for early cancers [21]. These results reflect the strong role of gastroenterology in AI research, with over 40 RCTs [10]. Some significant publications, like ASGE's top 10 topics, emphasize that "AI advances" are recognized priorities [2]. However, moving from research to practice is not certain. Our findings support concerns expressed in the literature; without strict standards, many preclinical AI studies have limited applicability [13]. The QUAIDE framework and similar guidelines are crucial for improving study quality [3, 13]. Another issue is the risk of operator overreliance. The observed deskilling effect [14] suggests that endoscopists may stop paying attention to systematic inspection if they overly trust AI. Training programs should address this by highlighting that AI is a support tool. From an ethical viewpoint, responsible use of AI requires a focus on data governance. The World Journal of Gastroenterology's editorial discusses issues related to privacy, bias, and fair AI use [19]. These broader concerns are increasingly seen as essential steps, much like past technology adoptions, such as standardized safety protocols for new endoscopy equipment [22].

Finally, while many studies examine technical performance, few have looked at long-term clinical outcomes or cost-effectiveness. A review of current literature shows that AI-assisted systems significantly boost endoscopic performance in various areas [23]. As recent editorials mention, multi-center trials, like ongoing RCTs, and health-economic analyses are the next steps. In the future, AI may even take over some diagnostic tasks, like virtual histology for small polyps, but this will need high levels of evidence and regulatory approval [24].

Conclusion

AI is transforming gastrointestinal endoscopy by enhancing lesion detection and improving diagnostic consistency. Current evidence indicates that AI-assisted systems substantially enhance endoscopic accuracy and efficiency across multiple applications. To fully harness these benefits, the field should implement standardized evaluation frameworks like QUAIDE and ensure that AI tools operate with transparency, fairness, and minimal bias. Integrating AI training into endoscopic education while preserving core procedural skills is essential to prevent overreliance. Collaboration among clinicians, engineers, and policymakers will support the smooth integration of AI into clinical workflows. Future efforts should emphasize multicenter validation, real-time implementation, and assessment of clinical outcomes to advance AI from experimental use to standard practice in gastrointestinal care.

Acknowledgments

The authors thank their colleagues and mentors for insightful discussions on AI in gastrointestinal endoscopy. The authors are grateful to Dr. Tudor Braniste from the National Center for Materials Study and Testing, Technical University of Moldova, for fruitful discussion and guidance during the preparation of this paper. The authors express graditude to "Nicolae Testemițanu" State University of Medicine and Pharmacy, for institutional support and access to research databases.

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Received – 02.11.2025, accepted for publication – 12.11.2025
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Conflict of interest Statement: The authors report no conflicts of interest in this work.
Funding Statement: The authors report no financial support.
Citation: Negarî N, Minchevici D, Bour A, Pitel E, Sardari V. Artificial intelligence in gastrointestinal endoscopy: advances, challenges, and clinical applications. Arta Medica. 2025;97(4):63-66.