

# Artificial Intelligence in *Gastrointestinal Endoscopy*

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# Artificial Intelligence in Gastrointestinal Endoscopy

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*Artificial Intelligence in Gastrointestinal Endoscopy*

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The primary aim of *Artificial Intelligence in Gastrointestinal Endoscopy* (AIGE, *Artif Intell Gastrointest Endosc*) is to provide scholars and readers from various fields of artificial intelligence in gastrointestinal endoscopy with a platform to publish high-quality basic and clinical research articles and communicate their research findings online.

AIGE mainly publishes articles reporting research results obtained in the field of artificial intelligence in gastrointestinal endoscopy and covering a wide range of topics, including artificial intelligence in capsule endoscopy, colonoscopy, double-balloon enteroscopy, duodenoscopy, endoscopic retrograde cholangio-pancreatography, endosonography, esophagoscopy, gastrointestinal endoscopy, gastroscopy, laparoscopy, natural orifice endoscopic surgery, proctoscopy, and sigmoidoscopy.

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## Utility of artificial intelligence in colonoscopy

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### Abstract

Colorectal cancer is one of the major causes of death worldwide. Colonoscopy is the most important tool that can identify neoplastic lesion in early stages and resect it in a timely manner which helps in reducing mortality related to colorectal cancer. However, the quality of colonoscopy findings depends on the expertise of the endoscopist and thus the rate of missed adenoma or polyp cannot be controlled. It is desirable to standardize the quality of colonoscopy by reducing the number of missed adenoma/polyps. Introduction of artificial intelligence (AI) in the field of medicine has become popular among physicians nowadays. The application of AI in colonoscopy can help in reducing miss rate and increasing colorectal cancer detection rate as per recent studies. Moreover, AI assistance during colonoscopy has also been utilized in patients with inflammatory bowel disease to improve diagnostic accuracy, assessing disease severity and predicting clinical outcomes. We conducted a literature review on the available evidence on use of AI in colonoscopy. In this review article, we discuss about the principles, application, limitations, and future aspects of AI in colonoscopy.

**Key Words:** Artificial intelligence; Colonoscopy; Colorectal cancer; Inflammatory bowel disease; Adenoma detection rate; Adenoma

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**Core Tip:** Artificial intelligence (AI) pertains to performance of intelligent tasks like human beings by computer-controlled machines. Machine learning, one of the most important and fundamental principles of AI, essentially means automatically using the available data to learn and make decisions without human intervention. AI based detection models have been developed for polyp detection and to differentiate

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malignant from nonmalignant lesions. It has been also utilized to analyze endoscopic images for inflammatory bowel disease diagnosis, grading its severity and predicting treatment response.

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## INTRODUCTION

### What is artificial intelligence

The capability of human brain to perceive, analyze and react is defined as intelligence. Gottfredson[1] described it as ability of a human beings to reason, plan, solve problems, think abstractly, comprehend complex ideas, learn quickly and learn from experience. It has been a long desire of human beings to build machines which can think and act autonomously to ease human work. Several complex computer algorithms and models have been developed to provide automation to these machines. The famous Turing test invented by Alan Turing in 1950 demonstrated that it may be difficult for a blinded investigator to distinguish humans from intelligent machines[2]. However, intelligence of these machines is still way below human intelligence which is based on logic, reasoning, and adaptive learning. In 1997 International Business Machines's artificial intelligence (AI) driven chess playing system defeated world chess champion Garry Kasparov. Although this victory of computer programs over human beings in chess was criticized by many, and it was argued that machines can only be as good as the programs developed for them by human beings, nevertheless it remains an important landmark in the history of AI.

There is no one formal definition of AI. It is vaguely defined as ability of computer-controlled machines to perform intelligent tasks like human beings. There are two basic subtypes of AI- weak or soft and strong or hard AI[3]. Weak or soft AI is also called as narrow AI and as the name suggests it specializes in a very specific task like face recognition, voice recognition capabilities. On the other hand, strong or hard AI which is also known as general AI has more broad application due to its capability to understand, think and act like human beings. It is at the core of advanced robotic systems.

Machine learning (ML) is one of the most important and fundamental principles of AI. ML is at the heart of any AI system and essentially means automatically using the available data to learn and make decisions without human intervention. It is an adaptive technology which is continuously learning and hence gets better with each use. ML utilizes three fundamental methods which include supervised learning, unsupervised learning, and reinforcement learning. Artificial neural network (ANN) is a ML algorithm adapted from model of biological neurons in humans. ANN is an information processing technology, also considered as mathematical models utilized to analyze data.

## AI IN THE FIELD OF GASTROENTEROLOGY

In the last two decades, substantial progress has been made in the use of AI driven algorithms in the field of medical science. Use of AI in the field of medical practice can be categorized in two broad categories-virtual and physical[4]. The virtual category of AI pertains to its use in electronic health record. It is based on ML and deep learning *via* mathematical algorithms to identify individuals at risk of some specific disease and help in clinical decision making. The physical category of AI includes use of medical devices and robotics for delivering medical care.

AI operated systems have been utilized to monitor patient's medical conditions remotely. More specifically in gastroenterology, AI based detection models have been developed to differentiate malignant from nonmalignant lesions, detect gastrointestinal bleeding using wireless video capsule endoscopy, detecting pancreatic cancer,

and detecting liver fibrosis. In the subsequent sections, we have detailed progress of AI and its application during colonoscopy.

## AI AND COLON POLYPS

Colorectal cancer (CRC) is the third most common form of the cancer worldwide and is the 2<sup>nd</sup> most common cause of cancer related mortality globally[5]. Colonoscopy is the primary method for detection and removal of polyps and thus for prevention of CRC. It has been shown in the study that with every 1% increase in the adenoma detection rate (ADR), the risk of CRC decreases by 3%[6]. However, colonoscopy is not the perfect tool as polyps can be missed during colonoscopy mainly because of two factors: Blind spot and proceduralist error. The error due to blind spot can be overcome by using wide-angle camera, but the error due to proceduralist cannot be overcome easily. Small polyps (1-5 mm) are prone to be missed regardless of experience of proceduralist. Some studies have shown improvement in the rate of polyp detection with the help of second observer[7,8]. The factors responsible for proceduralist error could be fatigue, distraction, visual perception, impaired level of alertness, recognition error and poor bowel preparation. The application of AI in endoscopic field has shown improvement in ADR in recent studies and it helps in overcoming proceduralist error. Computer-aided detection and characterization of colorectal polyps is now getting popular among endoscopists.

## PRINCIPLES AND APPLICATION OF AI IN COLONOSCOPY FOR POLYP DETECTION

AI has been a part of medical field since early 1950s. The concept and use of basic technology of computer-aided diagnosis (CAD) for colonoscopy has been explored since past one decade[9]. Use of CAD system in detection of colon polyps was first demonstrated by Karkanis *et al*[10]. Although the sensitivity of detecting adenomatous polyps demonstrated by these authors was 90%, this system was not used in clinical practice as it relied on static images rather than live endoscopic videos. In 2011, Bernal *et al*[11] introduced how intelligent systems can help in colonoscopy. Bernal *et al*[12] later introduced window median depth of valley accumulation (WM-DOVA) energy maps as a tool for automatic polyp detection in colonoscopy images. Fernández-Esparrach *et al*[13] for the first-time reported use of CAD system based on WM-DOVA maps and utilized colonoscopy videos in assisting colon polyp detection. With significant advancements in computer power and emergence of deep learning algorithms over past decade, it is being realized that CAD assistance during colonoscopy can be used in real time[14]. The inclusion of CAD for colonoscopy can help by automatic detection of polyps in real time which could be easily overlooked by endoscopists visually, thus resulting in higher ADR. Additionally, it helps in characterization of polyps in real time that in turn would help in reducing unnecessary biopsies of non-neoplastic polyps significantly[15].

There have been multiple studies to prove the advantage of inclusion of AI in the field of colonoscopy (Table 1). Most of these studies are of retrospective design, however few of them done recently were conducted prospectively. Luo *et al*[16] conducted a prospective, randomized cohort study using 150 participants to explore whether a high-performance, real-time automatic polyp detection system could improve the polyp detection rate in the actual clinical environment. The results showed that a real-time automatic polyp detection system can increase the ADR, especially for small polyps which are usually easily missed by conventional colonoscopy technique. Furthermore, Misawa *et al*[17] developed a 3-D convolutional network model for automated polyp detection which worked nearly in real time. They demonstrated sensitivity of 90% and a specificity 63% using 50 polyp videos and 85 non-polyp videos as test sets. Subsequently, Urban *et al*[18] developed a CAD model to improve polyp detection rate and they tested the model for its diagnostic capability on 8641 hand-labeled colonoscopy images collected from more than 2000 patients and on 20 colonoscopy videos. The results showed diagnostic accuracy of 96.4% and an area under the receiver operating characteristic curve of 0.991. However, the false positive rate was 7%. Additionally, Wang *et al*[19] developed the deep-learning algorithm which provided > 90% sensitivity and specificity for video-based analysis after testing their model on many polyp images and colonoscopy video recordings from patients.



**Table 1** List of studies evaluating role of artificial intelligence in the detection of colon polyps during the colonoscopy

Ref.	Country of origin	Study design	Results
Fernandez-Esparrach <i>et al</i> [13], 2016	Spain	Retrospective	Sensitivity 70%, Specificity 72 %
Geetha <i>et al</i> [36], 2016	India	Retrospective	Sensitivity 95%, Specificity 97%
Misawa <i>et al</i> [37], 2017	Japan	Retrospective	Accuracy higher than trainees (87.8 <i>vs</i> 63.4%; $P = 0.01$ ), but similar to experts (87.8 <i>vs</i> 84.2%; $P = 0.76$ )
Zhang <i>et al</i> [38], 2017	China	Retrospective	Accuracy 86%
Yu <i>et al</i> [39], 2017	China	Retrospective	Sensitivity 71%, PPV 88%
Billah <i>et al</i> [40], 2017	Bangladesh	Retrospective	Sensitivity 99%, Specificity 98.5%, Accuracy 99%
Chen <i>et al</i> [23], 2018	Taiwan	Retrospective	Sensitivity 96.3%, Specificity 78.1%
Urban <i>et al</i> [18], 2018	United States	Retrospective	Accuracy 96.4%
Misawa <i>et al</i> [17], 2018	Japan	Retrospective	Sensitivity, Specificity, and Accuracy were 90%, 63%, and 76%, respectively
Wang <i>et al</i> [19], 2018	China	Retrospective	Sensitivity 94.38%, Specificity 95.92%
Su <i>et al</i> [41], 2019	China	Prospective	Polyp detection rate was 38.3% as compared to 25.4% in control group ( $P < 0.001$ )
Wang <i>et al</i> [42], 2019	China	Prospective	Polyp detection rate was 45% as compared to 29% in the control group ( $P < 0.001$ )
Klare <i>et al</i> [43], 2019	Germany	Prospective	Larger polyp detection, Odds ration 2.71, $P = 0.042$
Figueiredo <i>et al</i> [44], 2019	Portugal	Retrospective	Sensitivity 99.7%, Specificity 84.9%, Accuracy 91.1%
Yamada <i>et al</i> [45], 2019	Japan	Retrospective	Sensitivity 97.3%, Specificity: 99%
Lee [46], 2020	South Korea	Retrospective	Accuracy 93.4%, Sensitivity 89.9%, Specificity 93.7%
Luo <i>et al</i> [16], 2020	China	Prospective	Polyp detection rate for diminutive polyps increased (38.7% <i>vs</i> 34%, $P < 0.001$ ). No difference was found for larger polyps
Gong [47], 2020	China	Prospective	Polyp detection rate was 47% as compared to 34% in control group ( $P = 0.0016$ )
Liu <i>et al</i> [48], 2020	China	Prospective	Polyp detection rate was 44% as compared to 28% in control group ( $P < 0.001$ )
Ozawa <i>et al</i> [49], 2020	Japan	Retrospective	Sensitivity 92%, PPV 86%, Accuracy 83%
Wang <i>et al</i> [50], 2020	China	Prospective	Polyp detection rate was 52% as compared to 37% in control group ( $P < 0.0001$ )
Hasssan <i>et al</i> [51], 2020	Italy	Retrospective	Sensitivity 99.7%
Repici <i>et al</i> [52], 2020	Italy	Prospective	Adenoma detection rate was 54.8% as compared to 40.4% in control group ( $P < 0.001$ )

PPV: Positive predictive value.

In a recent meta-analysis[20] from the researchers in Norway, who included five randomized control trials, AI aided colonoscopy had a ADR of 29.6% as compared to 19.3% without AI. In another recent meta-analysis involving 5 randomized control trials including 4354 patients, ADR was 36.6% with AI aided colonoscopy as compared to 25.2% in the standard control group ( $P < 0.01$ )[21].

In addition to improvement in colorectal polyp detection, AI has also been shown accuracy in polyp characterization in several studies. Byrne *et al* [22] developed an AI model for real-time characterization of colorectal polyps. They assessed their model using 125 unaltered endoscopic videos containing diminutive polyps. The AI model did not generate sufficient confidence to predict the histology of 19 out of 125 diminutive polyps which was about 15% of the polyps. For the remaining 106 diminutive polyps, the accuracy of the model was 94%, the sensitivity for identification of adenomas was 98%, specificity was 83%, negative predictive value (NPV) was 97%, and positive predictive value (PPV) was 90%. On the other hand, Chen *et al* [23] assessed their model using 284 diminutive polyps. The model identified neoplastic or hyperplastic polyps with 96.3% sensitivity, 78.1% specificity, NPV of 91.5% and PPV of 89.6%. There have been several other studies from across the world analyzing capacity of AI to characterize colon polyps (Table 2).

**Table 2** List of studies evaluating role of artificial intelligence in characterization of colon polyps during the colonoscopy

Ref.	Country of origin	Study design	Results
Misawa <i>et al</i> [53], 2016	Japan	Retrospective	Sensitivity 84.5%, Specificity 98%
Mori <i>et al</i> [54], 2016	Japan	Retrospective	Accuracy 89%
Kominami <i>et al</i> [55], 2016	Japan	Prospective	Sensitivity 93%, Specificity 93.3%
Komeda <i>et al</i> [56], 2017	Japan	Retrospective	Accuracy 75%
Takeda <i>et al</i> [57], 2017	Japan	Retrospective	Sensitivity 89.4%, Specificity 98.9%, Accuracy 94.1 %
Chen <i>et al</i> [23], 2018	Taiwan	Retrospective	PPV of 89.6%, and a NPV of 91.5%
Renner[58], 2018	Germany	Retrospective	Sensitivity 92.3% and NPV 88.2%
Mori <i>et al</i> [59], 2018	Japan	Prospective	Accuracy 98.1%
Blanes-Vidal <i>et al</i> [60], 2019	Denmark	Retrospective	Accuracy 96.4%
Min <i>et al</i> [61], 2019	China	Prospective	Sensitivity 83.3%, Specificity 70.1%
Byrne [22], 2019	Canada	Retrospective	Accuracy 94%
Sánchez-Monteset al[62], 2019	Spain	Retrospective	Sensitivity 92.3%, Specificity 89.2%
Horiuchi <i>et al</i> [63], 2019	Japan	Prospective	Sensitivity 80%, Specificity 95.3%
Lui <i>et al</i> [64], 2019	China	Retrospective	Sensitivity 88.2%, Specificity 77.9%
Ozawa <i>et al</i> [49], 2020	Japan	Retrospective	Sensitivity 97%, PPV 84%, NPV 88%
Jin <i>et al</i> [65], 2020	South Korea	Prospective	Sensitivity 83.3%, Specificity 91.7%
Rodriguez-Diaz et al[66], 2020	United States	Prospective	Sensitivity 96%, Specificity 84%
Kudo <i>et al</i> [67], 2020	Japan	Retrospective	Sensitivity 96.9%, Specificity 100%

NPV: Negative predictive value; PPV: Positive predictive value.

## AI AND INFLAMMATORY BOWEL DISEASE

Inflammatory bowel disease (IBD) comprises of mainly ulcerative colitis and crohn's disease. It results from complex interplay of environmental, immunological, microbial, and genomic factors[24]. The prevalence of IBD has exceeded 0.3% in the Western countries, and its incidence is rising in newly industrialized countries all over the world[25].

Over the last decade, role of AI has been explored in the field of inflammatory bowel disease (IBD). It has been utilized to analyze endoscopic images for disease diagnosis, grading of severity of disease and predicting treatment response. It has been also utilized to build risk prediction models based on integration of clinical, laboratory as well as gene expression data[26]. There are limited studies exploring the utility of AI aided colonoscopy in the field of IBD. Mosotto *et al* employed machine learning mathematical model of endoscopic and histologic data to distinguish different types of pediatric IBD and found 83.3% accuracy[27]. Similarly, a study from China found AI through machine learning model to be a promising approach specially for unexperienced endoscopists for subtyping of IBD[28].

There are clinical scores available for grading the severity of IBD. AI assisted models have been applied to improve accuracy and precision in assessing the disease severity. In a prospective study from Japan, deep neural network was utilized for evaluating endoscopic images from patients with ulcerative colitis and it showed 90.1% accuracy for endoscopic remission and 92.9% accuracy for histologic remission[29]. In another study from Belgium, computer algorithm for pattern recognition from endoscopic images had significantly better accuracy in determining endoscopic and histologic inflammation in patients with ulcerative colitis[30]. In a retrospective study involving 777 patients with ulcerative colitis, deep learning aided assessment of Mayo endoscopic sub-score for the automated grading of disease yielded 72.4% sensitivity, 85.7% specificity, 77.7% PPV, 87% NPV[31]. Ozawa *et al*[32] constructed a CAD system using convolutional neural network and the results showed better performance for identification of normal mucosa in patients with ulcerative colitis. In a prospective trial, Gottlieb *et al* showed that deep learning algorithm can be used effectively in



predicting ulcerative colitis disease severity[33].

Currently, these AI aided algorithms are mainly used in research setting. Further studies are needed to explore their utility in clinical practice and management of patients with IBD.

## LIMITATIONS

One of the possible limitations for the use of CAD could be significantly large number of false positive results[34]. Sometimes CAD system may flag frames which usually endoscopists may never have considered as suspicious area. Thus, the endoscopists may have to spend some extra time to go through all those flagged frames to differentiate between actual false positives and possible false negatives[35]. Additionally, false positive results may lead to unnecessary biopsy and thus related complications which could have been avoided. Hassen *et al*[34] conducted a post hoc analysis of randomized trial comparing colonoscopy with and without CAD to assess relative distribution of false positives in real life setting. During this analysis, two main reasons were found as causes of false positive results, such as artifacts from either mucosal wall or bowel content. Out of total false positives, 88% were due to artifacts from bowel wall, while 12% were due to artifacts from bowel content. However, most of the false positives were rejected by endoscopists right away and there was only 1% increase in the total withdrawal time due to false positives. Another limiting factor is cost effectiveness of the use of AI in colonoscopy, and it needs to be established. Also, the impact of the use of AI in colonoscopy on long-term clinical outcomes, such as decrease in CRC rate or increase in surveillance interval for colonoscopy is not known [35]. We require long-term prospective cohort studies to address these issues.

## FUTURE DIRECTIONS

Food and Drug Administration has recently approved the first real-time CAD system for colonoscopy in April 2021, known as gastrointestinal (GI) Genius. It can identify the regions of the colon within the endoscope's field of view where a colorectal polyp might be located, allowing for a more extended examination in real time during colonoscopy. After getting the alert from the device, it is up to the clinician to decide whether the identified region contains a suspected lesion, and how the lesion should be managed and processed per standard clinical practice and guidelines. However, GI Genius is not intended to characterize or classify a lesion, nor to replace lab sampling as a means of diagnosis. The device does not provide any diagnostic assessments of colorectal polyp pathology, nor does it suggest to the clinician how to manage suspicious polyps.

Although many studies have shown good results but most of these studies were retrospective studies which could be subject to considerable selection bias. On the other hand, only few prospective studies are available till date which are more statistically significant than retrospective studies. Thus, we need to design more prospective studies and should be directed towards polyp characterization during real-time colonoscopy. Additionally, future studies can explore AI assisted identification of polyps with submucosal invasion. The prospect of a fully automated independent colonoscopy system is still too premature at this stage. Furthermore, trials to build more cost-effective models should be conducted in near future before considering use of CAD assisted colonoscopy widespread in daily practice.

## CONCLUSION

In conclusion, utility of AI methods and algorithms have significantly evolved over the last decade. AI technology provides us a very robust tool to improve the accuracy and precision during the colonoscopy. ML models of AI technology provide us a valuable tool to transform the healthcare. Further larger and prospective studies are needed to see if these positive outcomes can be replicated in a cost-effective manner in clinical practice.

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