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Role of Artificial Intelligence in Detecting Colonic Polyps during Intestinal Endoscopy

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Abstract

With the inter- and multi-disciplinary collaboration of the medical community with technologists in conjunction with a disproportionately alarming doctor-patient ratio, it has now become a matter of concern for researchers to enhance patient care with advanced technology along with the reduction of burden on medical professionals. Artificial Intelligence (AI) has now been accepted willingly in the healthcare sector, which has led to a tremendous increase in computational power and large data handling capabilities and is widely used in gastrointestinal endoscopy. The objective of this review is to explore the state of current literature on different AI-based methods applied in intestinal endoscopy for the detection of colonic polyps. A detailed non-systematic literature review was conducted to identify all relevant studies using PubMed/MEDLINE, Scopus, EMBASE, and Google Scholar databases. The technique of AI systems, model building steps, and diagnostic measuring techniques are also discussed. In the automated diagnosis of polyps, AI-based platforms have achieved clinically acceptable diagnostic efficiency. AI-based methods can be of clinical importance in gastroenterology, and as computing strength and algorithms enhance, the application is likely to grow and expand in the field.

Keywords: Artificial Intelligence; Colonic Polyps; Endoscopy; Gastroenterology; Neural Networks
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1. Introduction

With the increase in collaboration of the medical community with technology and the continuously alarming doctor-patient ratio of 1:1000 in Indian hospitals, it has now become a matter of concern for researchers to uplift patient care with advanced technology along with the reduction of burden on medical professionals.[1] From its early applications in board games, Artificial Intelligence (AI) has now been accepted willingly in the healthcare sector. This has led to a tremendous increase in computational power and large data handling capabilities. When training on enormous quantities of information, traditional monitored-training algorithms suffer. Deep learning, a subset of artificial intelligence, is used to fix this issue. Image recognition using artificial intelligence mimicking human cognitive function incorporated with the machine and deep learning has long been applied for diagnostic usage in various clinical fields such as classification of skin cancers, benign or malignant proliferative breast lesions, radiation oncology, diagnosis of diabetic retinopathy diagnosis fundus photographs, histological classification of stomach biopsy or characterization of colorectal lesions by endocytoscopy.[2-8] Hence, the performance of neural networks has increased rapidly using deep learning algorithms.

A computer is traditionally provided a set of instructions for completing a task. They undergo a task 'Machine Learning' to enable machines to create autonomous choices, *i.e.*, without any programming. Hence, machine learning is a method in which a computer is trained on sampled information with a

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validation dataset and a fundamental algorithm learning structure is selected. Artificial intelligence has shown important promise in clinical assignments. It enables machines to analyze distinct training images and use a backpropagation algorithm to obtain particular clinical characteristics. Machines can prospectively diagnose freshly obtained clinical images based on the accumulated clinical characteristics. It is with the aid of deep learning that it has now become possible to detect colonic polyp using Wireless Capsule Endoscopy (WCE) images.[9,10] With the aid of Convolutional Neural Network (CNN), it has now become feasible to imitate the structure and functioning of neurons on a computer.

2. Artificial intelligence in colonic endoscopy

2.1 Need for incorporating artificial intelligence with endoscopy

Intestinal malignancies originate from precursor lesions known as adenomatous polyps. Although intestinal endoscopy is the standard procedure for investigating these lesions, the false-negative rate for detecting smaller polyps can be high.[11] It becomes more difficult to distinguish early neoplastic lesions from background mucosa that show only subtle morphological changes.[12,13] In most cases, inexperienced endoscopists tend to also overlook cancer due to surrounding atrophic mucosa. Therefore, some polyps can go undetected and evade during an endoscopic examination. Endoscopists must therefore have long-term special training and experience in detecting gastric cancers.

Early-stage endoscopic detection of colon cancer integrated with artificial intelligence can be the single most efficient measure to reduce morbidity and mortality associated with delayed detection of colon cancer. This scheme of adopting adenoma detection could enhance the capacity of endoscopists to find adenomas in the early phase correctly and also help to reduce the length of the endoscopic operation.[14,15] Studies have shown that models of deep learning can almost attain and sometimes even exceed human performance. Hence, as the concept of AI in gastrointestinal endoscopy increases, resulting cost-reduction of the procedure would be accompanied by a quicker examination of the patients even by less experienced staff.[16,17]

2.2 Breakthrough in the detection of colonic polyps

Artificial intelligence in gastrointestinal endoscopy has been widely used in many applications including automatic colonic polyp detection, optical biopsy and Esophagogastroduodenoscopy (EGD), and capsule endoscopy. Automatic colonic polyp detection works by alerting endoscopists via digital graphic manufacturer or sound to the existence of a polyp on the screen. Adenoma miss rates remain comparatively high (around 6-27%) during colonoscopy screening.[18] One of the multiple reasons could be inadequate mucosal inspections, possibly due to difficult locations behind folds of the colonic mucosa, absence of identification of subtle mucosal flat polyps, and variable quality of preparation of bowel.[19,20] There is evidence that the visual field contains some of the missed polyps, however unfortunately it is missed by many endoscopists. Therefore, an ideal automatic polyp instrument needs to have high polyp detection sensitivity, low frequency of false positives, and low latency to track and recognize polyps in near-real-time.

Several techniques of Computer-Aided Detection (CADe) have been suggested to aid endoscopists identify undetected polyps.[21-24] CADe was used and validated in optical colonoscopy using still images acquired from endoscopic videos.[25] Pre-processing image or series of images to discard noise, feature extraction tool to recognize and extract a feature or mix of image characteristics such as texture, shape or color, and machine learning or deep learning classification using these characteristics to discover polyps used in CADe. Edge detection method for abdomen ulcer detection, abnormality identification in the decreased gastrointestinal tract, and a region-widening method for extracting large intestinal lumen contours were some of the early attempts in CADe using pixel-based image segmentation approach for extracting large intestinal lumen contours and detecting lower gastrointestinal tract pathology.[21,26] Some of the pitfalls of human-based diagnosis such as variance and fatigue between and intra-observers are not subject to CADe systems, assisting in detecting lesions in static endoscopic images, combining texture, color, or mixed analytical methods with classifications of smart patterns in the healthcare sector.[27] Predicting neoplastic and pre-neoplastic lesions have become more efficient with microscopic characteristics and macroscopic characteristics of lesions within the colon.[28,29]

Neural network based on gray level texture analysis of endoscopic images includes the use of texture range, co-occurrence matrix, Local Binary Patterns (LBP), and wavelet domain co-occurrence matrix characteristics.[24,30-32] Co-occurrence matrix characteristics of the wavelet domain have also been implemented for tumor identification in colonoscopic video frame sequences.[33] It is incorporated into a versatile and standalone software scheme called Colorectal Lesion Detector (CoLD) to detect colorectal lesions in endoscopic video frames.[33] Color is used as an extra clue to detect lesions in endoscopic images. The combination of texture range and color histogram characteristics are used for colon status analysis.[34] Higher sensitivity relative to gray

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level characteristics or color texture input is accomplished through Colour Wavelet Covariance (CWC) using a color extraction system based on wavelet decomposition. Using a Bayesian fusion system combining color, texture, and light contour data, a smart clinical decision support tool was used to help detect bleeding lesions better.[23] Pattern identification framework accepting conventional low-resolution video input was developed as well.

Moving on from analyzing static endoscopic images and video frames, the focus has been on translating techniques for polyp detection into real-time video analysis. With the use of the hybrid context shape approach, the CADe system was developed that removed the analysis context data with non-polypoid constructions and used shape data by AI to detect polyps.[35] Furthermore, optical colonoscopy concentrated on validating modalities of real-time polyp detection for bigger databases of colonoscopy images. To use energy maps based on location, Window Median Depth of Valleys Energy Map Method (WM-DOVA) has been developed.[36] A polyp warning software created using visual characteristics of the edge cross-section and a classification based on rules to detect edges of polyps was also in place.[25] Recently, the incorporation of deep learning methods into CADe polyp detection systems has shown that deep learning computer vision programs can properly identify colorectal adenomas from colonoscopic images.[37] Following this accomplishment, deep learning polyp detection software based on SegNet architecture and deep learning-based AI system have come into the timeline.[38,39]

Thus, to summarize as in Fig. 1, the method of automatic polyp detection primarily consists of three steps. First, large amounts of image collection are needed and relative experts must label the characteristic lesions. Second, computers use a specific program to extract disease characteristics from the input of labeled images. Finally, a specific image can be distinguished from other types of disease by the statistical characteristics of the target lesions.

2.3 Practical implications

A detailed review of the diagnostic models will help endoscopists to make rapid and accurate decisions to determine the progression of different polyps that have been constructed. It can also provide other models as a platform for improvement. CADe systems are expected to fill the gap between endoscopists with different levels of experience. Existing polyp detection techniques incorporating artificial intelligence-based technologies in polyp detection have been summarized in Table 1. [40-48]

3. Methodology

A detailed scoping review of literature of AI models in gastrointestinal endoscopy was conducted to include the studies that use AI-based platforms to automatically detect polyps during colonoscopy. The search terms include: artificial intelligence, gastrointestinal, CADe, CoLD, neural network, edge detection, deep learning, machine learning, diagnostic endoscopy, image recognition.

Inclusion and exclusion criteria

1) *Exposure of interest:* The scoping review includes studies with polyp detection using on artificial intelligence-based systems, from January, 1990 to December, 2020.
2) *Language:* Only English-language studies have been included.
3) *Reported results:* Only results acquired using objective measures have been included.
4) *Release type:* Original articles and case series/reports are included. Reviews have been excluded.

4. Results and discussion

Automatic testing and diagnosis with AI help for increased polyp detection can help maximize the presence of physicians in the clinic. Artificial intelligence platforms outside the clinic give patients more health possibilities and decrease obstacles in intestinal care where there are no endoscopists. It can help relieve the overloaded and overcharged healthcare system issues. The detection rate of adenoma has been inversely correlated with the hazards of colorectal cancer interval, advanced stage interval cancer, and deadly cancer interval. In a study carried out by Ahn *et al*, it was observed that even in quality-adjusted, back-to-back colonoscopies, a substantial rate of error was present in the identification of colonic adenomas.[18] During colonoscopy insertion, the adenoma miss rate decreased with adequate observation time. Nurse

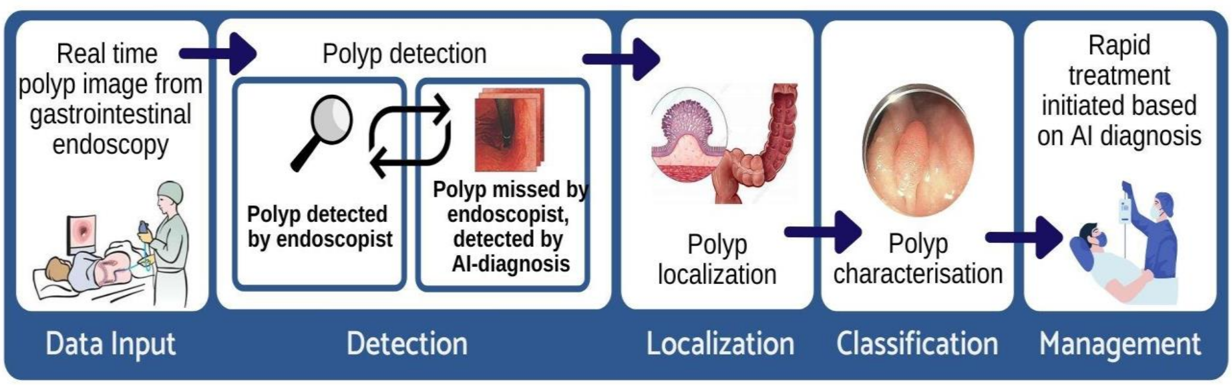

Fig. 1 Process of automatic polyp detection and management.

Table 1. Existing technology incorporating AI in colonic polyp detection.

Technology	Special characteristics
Computer-Aided Detection (CADe)	Pre-processing image or series of images to discard noise, extraction tool to recognize and extract a function, mixing characteristics such as texture, shape, or color within the image.
Edge detection method	Abdomen Ulcer detection and abnormality identification
Region widening method	Segmentation of the pixel-based image — Extracting big lumen contours and detecting gastrointestinal (GI) pathology
Mixed analytical methods with smart pattern classification	Combination of texture and color. Prediction of neoplastic and pre-plastic lesions
Neural Network based on gray level texture analysis of endoscopic images	Texture range, co-occurrence matrix, Local Binary Patterns, Wavelet Domain Co-occurrence—Tumour identification
Colorectal Lesion Detector (CoLD)	Detect colorectal lesions in endoscopic video frames
Texture range along with color histogram	Colon status analysis
Colour Wavelet Covariance (CWC)	Color extraction system based on wavelet decomposition
Bayesian fusion	Combined color, texture, light contour data— detect bleeding lesions
Hybrid Context shape approach	Removed from analysis context data with non-polypoid constructions
Window Median Depth of Valleys Energy Map Method (WM-DOVA)	Use energy maps based on location—detect edges of polyps
Integration of deep learning techniques into CADe polyp detection schemes	Identify colorectal adenomas from colonoscopic images
Deep learning polyp detection software	Based on SegNet architecture and AI system

observation during colonoscopy led to a rise in the number of polyps and adenomas discovered per colonoscopy, along with a trend towards enhanced general adenoma detection rate (ADR) and all-polyp detection as shown in a study by Aslanian *et al.*[19] and Lee *et al.*[20]further showed that experienced engagement in endoscopy nurses improved polyp detection rate (PDR) and ADR during colonoscopy screening. A new boundary extraction algorithm based on the growth of fuzzy rule-base region integration and the detection of blurred rule-base edges was described by Krishnan *et al.*[21] It was successful to identify the closed boundary of an intestinal lumen to enable the diagnosis of colon abnormalities. Later, Krishnan *et al.*[22] showed how curvature shift of the contour of a haustra creases detected an abnormality. Their results indicated that the suggested technique could be used to detect the polyps or tumors present along the colon haustra creases. Iokovidis *et al.*[39] suggested a novel, smart scheme capable of correctly detecting, locating, and marking colonic and gastric adenomas in endoscopic images. The rate of true positive markings counted in this test frames reached 97.8% and the rate of false-positive markings reached 1.7%.

Wang *et al.*[25] discussed the first technology capable of detecting polyps efficiently, alerting endoscopists, and extracting polyp shots in near real-time. Polyp-Alert could provide feedback for a smooth display of feedback up to ten per second. They used edge-cross-section visual features and a rule-based classifier by Polyp-Alert to detect a polyp edge — an edge along a polyp contour. Esgiar *et al.* showed how to texture characteristics obtained from images could lead to an extremely important classification and discrimination of ordinary colonic mucosa and cancer.[28] They researched six characteristics based on texture analysis. These were obtained from the matrix of co-occurrence and were second moment angular, entropy, contrast, the moment of inverse distinction, dissimilarity, and correlation. Optical density was studied as well. By magnifying endoscopy, stereomicroscopy, and histopathology, 2050 colorectal tumor lesions were examined and categorized according to pit pattern by Kudo *et al.*[29] This technique offered a precise instantaneous histological evaluation of colorectal tumor lesions and assisted colonoscopy decision making. Karkanis *et al.*[24] described a new framework for discriminatory use of data from the texture spectrum of distinct texture areas in images. Exploration of efficiency of a straightforward system for discrimination in colonoscopic images of distinct texture areas was done by Karkanis *et al.* This scheme could detect abnormalities with high accuracy in the same image. To detect defects that belonged to distinct kinds of cancer, it could also be effectively applied to distinct images. Magoulas *et al.*[30] introduced a new scheme for neural network-based colonoscopic diagnosis. It utilized an adaptive learning rate online back-propagation approach to seed the original population of the Differential Evolution strategy online. Neural networks trained with the suggested internet evolution strategy showed satisfactory efficiency under altering environmental circumstances as the network was displayed with information from separate frames. Wang *et al.*[46] described a new technique for classifying endoscopic images. This excellent finding indicated their high potential to contribute to a fully smart endoscopy scheme for auto-diagnosis. The summary of research carried out and outcomes related to Artificial Intelligence in colonic polyp detection is presented in Table S1.

A novel Discrete Wavelet Transform (DWT)-based methodology was suggested by Karkanis, Magoulas *et al.* to estimate the characteristics of second-order wavelet image transformation statistics. This methodology for allocation of DWT was the one that obtained the highest outcomes. Tajbakhsh *et al.*[35] successfully achieved automated polyp detection using shape and context information in colonoscopy videos. The study on effectiveness of a computer-visual automatic polyp detection technique, showed that the energy maps used performed well for colonic polyp detection, indicating their potential applicability in clinical practice. Wang, Tavanapong *et al.*[25] worked on a polyp-alert to have near real-time feedback during colonoscopy. Detection and feedback of real-time polyps possibly assisted to decrease the rate of polyp error to enhance the quality of care and paperwork. The suggested algorithm for polyp identification was quick, efficient, and possibly helpful to improve colonoscopy quality. Later, Wang *et al.* found the effect of colonoscopy on colorectal cancer mortality was limited by several factors, including a certain rate of error, resulting in limited ADRs.[38] An automatic polyp detection system used during colonoscopy resulted in a significant increase in the number of detected diminutive adenomas as well as an increase in the rate of hyperplastic polyps in a low prevalent ADR population. Recently, Misawa *et al*.[43] developed an original CADe system supported by artificial intelligence that has the potential to make colorectal polyps automatically detected. CADe systems are expected to fill the gap between endoscopists with different levels of experience.

Research Limitations

The current constraints of precise diagnosis of colonic polyps include,

a) Quality of training sets: If the training set images do not have strong reference standards, the labeled set of images tends to be of low precision.

b) Black box dilemma: The majority of image recognition models use CNN-based systems. Wherever a CNN analyses data, some self-generated rules are followed and decisions made by the algorithms are difficult to interpret.

c) Incorrect diagnosis: CNN systems are highly sensitive to even minor changes in pixel-level images leading to inaccurate diagnosis of normal variants.

5. Conclusion

Artificial intelligence is a thrilling new frontier for clinical gastroenterology. Techniques such as deep learning and machine learning hold the promise to increase precision in diagnosis and rapidly process big quantities of information thereby helping in patient management. In the automated diagnosis of polyps, artificial intelligence-based platforms have achieved clinically acceptable diagnostic efficiency. Using artificial intelligence as an addition to conventional GI methods can enhance the pace and precision of diagnostic testing while aiming to discharge human suppliers from time-consuming duties. To optimize clinical workflow, it will be essential to integrate artificial intelligence systems with current electronic medical records (EMR) and endoscopy platforms. AI systems in endoscopy tend to eliminate diagnostic latency and promote the actual applicability of these technologies in clinical scenario.

6. Future perspectives

Newer applications incorporating artificial intelligence-based diagnostics need to be able to read information from a video input or EMR readily, enabling the systems to use the information for instruction and support for real-time decision-making. Further studies are required to know the ethical and pragmatic factors of the inclusion of artificial intelligence instruments into the practice of gastroenterology. To improve the clinical acceptance of AI systems, it is important to reuse existing and future methodologies. There is a lacuna on how artificial intelligence methods can provide important clinical relevance in gastroenterology, and this needs stringent validation because as computing strength and algorithms advance, the amount of application is likely to continue to grow. Future research is crucial to evaluate the clinical deployment and cost-effectiveness of different AI systems in clinical practices. Research needs to continue in developing techniques to balance elevated sensitivity with low latency and enhanced false-positive rates. A watchful eye is required as the field evolves to guarantee that safety, regulation, and ethical norms are maintained. While challenges lie ahead, automated detection platforms based on artificial intelligence are likely to influence medicine and improve overall healthcare.

Conflict of Interest

The authors declare no conflict of interest.

Supporting information

Applicable.

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