The Efficacy of AI-Assisted CADe Systems in Colorectal Polyps and Adenomas During Colonoscopies: A Systematic Review

Abstract

Colorectal polyps and adenomas are a significant health concern that can lead to colorectal cancer. Detecting polyps and adenomas early is important to remove them in a timely manner, reducing the risk of cancer. Artificial intelligence (AI) could assist in identifying polyps and adenomas more efficiently.This study will investigate the potential benefits of AI technology in detecting colorectal adenomas, using AI-assisted colonoscopy diagnostic systems. The goal is to determine if there are differences in detection rates using AI compared to standard colonoscopy methods.PRISMA Statement 2020 guidelines were adhered to in this systematic review. Three databases were searched including PubMed/MEDLINE, Embase and Web of Science through February 23, 2023. A combination of the following keywords was used: AI, Artificial, Intelligence, Colorectal, Polyp, Adenoma. The adenoma detection rate (ADR) and polyp detection rate (PDR) were additionally meta-analyzed for proportions, and reported as odds ratio (OR), applying 95% confidence intervals (CI). A total of 9 randomized clinical trials were included in this review, pooling in 6981 participants. The findings were presented systematically, based on the design, technology used, effects on ADR and PDR, and key conclusions. The meta-analytical findings were reported as follows. On applying a random-effects model, the odds ratio (OR) for ADR was 1.532 (95% CI=1.125-2.087), with significant detection favoring CADe systems (P=0.0068). Similarly, when assessing the chance of diagnosing colorectal polyps with CADe systems as an add-on compared to standard colonoscopy alone, the odds ratio (OR) was 1.893 (95% CI=1.687-2.125, P<0.0001).This systematic review found that real-time computer-aided detection during colonoscopy improved the detection of adenomas and polyps. The use of the system is feasible and safe, and future studies should focus on improving colonoscopy quality indicators including the most widely used– ADR. Larger randomized controlled studies are needed to evaluate the impact of this system on adenoma and serrated polyp detection and its effect on endoscopists with lower detection rates.

Keywords: *Colorectal Polyps; Colorectal Adenomas, Colonoscopies; Artificial Intelligence; CADe*

Introduction

Colorectal polyps and adenomas represent a significant public health concern, with a global incidence of approximately 15-20% in the adult population[1]. The sequela of polyps and adenoma – colorectal cancer is a widespread and lethal disease, ranking third in prevalence and second in mortality globally[2]. In 2020, it was diagnosed in approximately 1.93 million individuals, resulting in 0.94 million deaths[1]. This trend is predicted to continue, with the global burden of colorectal cancer anticipated to reach 3.2 million cases by the year 2040[1, 2]. Adenomatous polyps, a subtype of colorectal polyps, account for approximately two-thirds of all colorectal polyps and are a well-established risk factor for the development of colorectal cancer[2]. These polyps are characterized by epithelial proliferation, cellular atypia, and architectural dysplasia, and they may be categorized by their size, shape, and histologic features. The precise etiology of colorectal polyps and adenomas remains incompletely understood, but several risk factors have been identified, including age, obesity, smoking, and a family history of colorectal cancer.The early detection of colorectal polyps and adenomas is essential, as this can allow for their prompt removal, reducing the risk of cancer development. Of concern, while high-income countries have seen a rise in the incidence of colorectal cancer, low-income and middle-income countries are also experiencing an uptick in reported cases[2]. China and the United States are projected to have the highest estimated rates of new colorectal cancer cases over the next two decades[2, 3].

As the incidence of colorectal cancer continues to rise, artificial intelligence (AI)-supported screening strategies for colorectal polyps and adenomas may prove beneficial in facilitating timely detection[4]. Adenomas and polyps are benign glandular tumors that form in the colon and rectum, which are known to be precursors to colorectal adenocarcinoma. While colonoscopy is the preferred diagnostic method, optical evaluation of colorectal adenomas that appear as polyps is considered an acceptable alternative as long as endoscopists can achieve a minimum of 90% agreement with histopathology results and negative predictive value for adenomatous histology[4]. However, endoscopists may still have concerns about inappropriate surveillance intervals, potential medico-legal issues, and misdiagnosis[5].

The AI method that will be focused on in this study is Deep Learning (DL), specifically using Convolutional Neural Networks (CNNs). Deep Learning is a subset of machine learning, which in turn is a branch of artificial intelligence. Deep learning algorithms learn from large amounts of data, making them well-suited for tasks that involve image recognition, such as identifying polyps or adenomas from colonoscopy images. Convolutional Neural Networks (CNNs) are a type of deep learning model that are especially effective for image analysis. They can process images directly, without the need for manual feature extraction. CNNs are built with convolutional layers that apply a series of filters to the input data, allowing the network to automatically learn and extract features from the images. In the context of colonoscopy, a CNN can be trained to recognize patterns and features associated with polyps and adenomas, such as their shape, size, and texture. The CNN can then use this information to identify potential areas of concern in new images, providing real-time feedback to the endoscopist during the procedure. As part of the systematic review, we will be reviewing studies that have employed CNNs in AI-assisted colonoscopy diagnostic systems (CADe).

To address the limitations of colonoscopies, this study focuses on the potential benefits of AI technology in clinical practice, particularly through the use of AI-assisted colonoscopy diagnostic systems (CADe) to detect colorectal adenomas[6]. The study aims to investigate if AI can provide real-time support to physicians during colonoscopies by suggesting possible histology and confidence levels[7]. It is hypothesized that integrating AI technology will lead to improved adenoma and polyp detection rates during colonoscopies.The objective of this systematic review is to present quantitative differences in polyp and adenoma detection rates using CADe and quality control systems compared to standard colonoscopy methods in adult patients. The specific aims of this review are as follows:

1. To systematically review and analyze the current literature on the use of AI-assisted colonoscopy diagnostic systems (CADe) for the detection of colorectal polyps and adenomas.
2. To compare the detection rates of colorectal polyps and adenomas using CADe with those achieved through standard colonoscopy methods.
3. To evaluate the potential of CADe systems in providing real-time assistance during colonoscopies by suggesting possible histology and confidence levels, thus improving the accuracy and efficiency of the procedure.
4. To investigate the potential benefits of integrating AI technology into clinical practice, specifically in the diagnosis and management of colorectal polyps and adenomas.
5. To discuss the implications of CADe systems for future research, clinical practice, and policy-making in the field of colorectal cancer prevention and treatment.

Methods

This systematic review was conducted in adherence to PRISMA Statement 2020 guidelines. The PRISMA flowchart is illustrated in **Figure 1**, depicting the full study selection process. Database searches were conducted in 1) PubMed/MEDLINE, 2) Web of Science, and 3) Embase. The search strings were applied using an ‘and/or’ framework by combining the following: AI, Artificial, Intelligence, Colorectal, Polyp, Adenoma. All studies conducted until February 23, 2023 were included in this review with no language restrictions. The bibliographic management tool utilized in this study was EndNote v10.

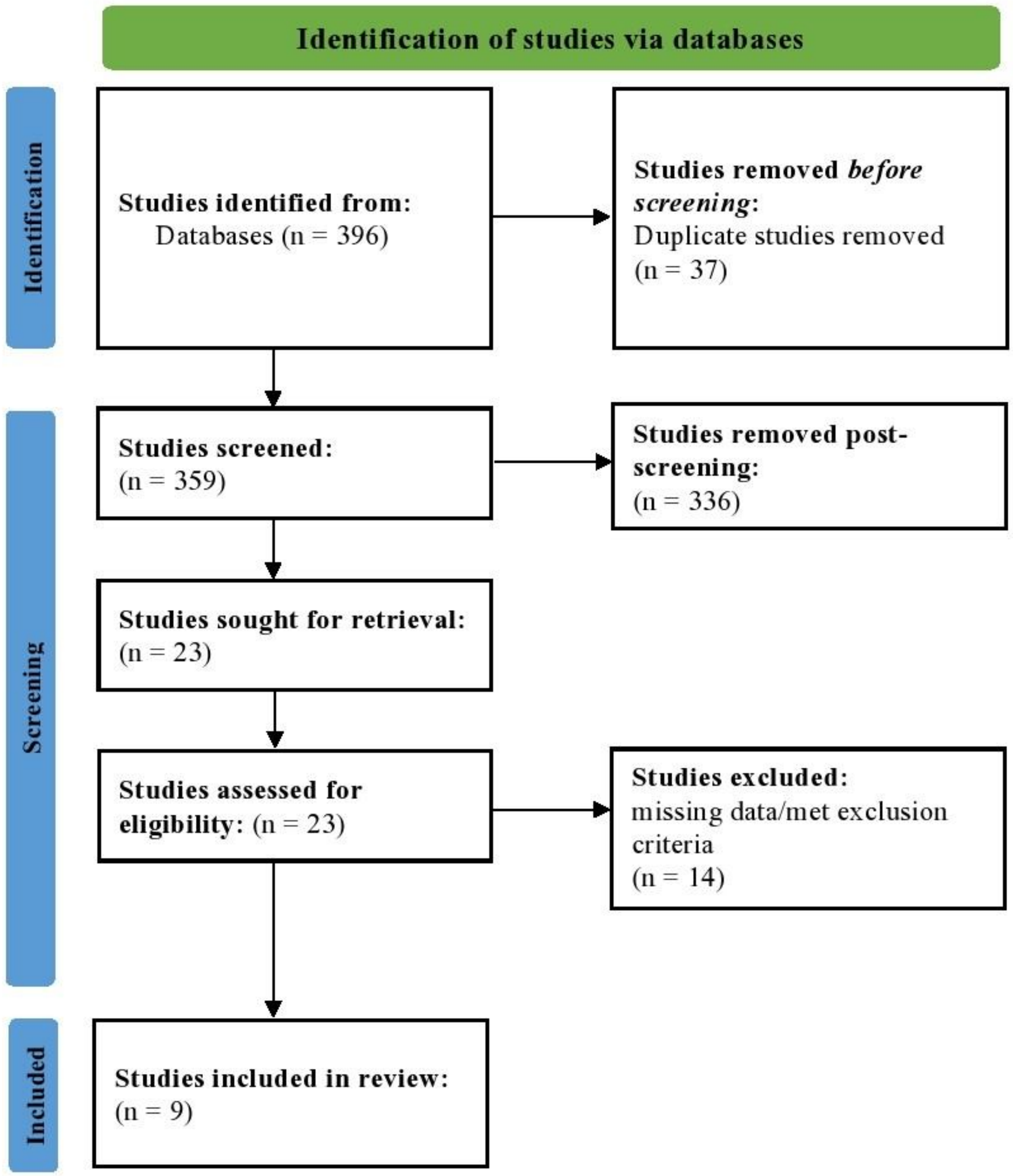

Figure 1. PRISMA flowchart depicting the study selection process.

Only randomized clinical trials were included that had an artificial intelligence-powered system as the interventional group versus a standard group where regular colonoscopy was employed. Non-randomized studies, observational cohorts, case series, case reports, letter to editors, and previously conducted systematic reviews/meta-analyses were omitted. There were two primary outcomes: the adenoma detection rate (ADR) inter-group proportional differences, and the polyp detection rate (PDR) inter-group proportional differences. All authors extracted study data in Microsoft Excel. The data was extracted as follows: Sr. No., Author, Year, Title, Participant Count, Design, Technological Overview, Key Conclusions. The numerical values were extracted and presented separately depicting adenoma and polyp detection in CADe and standard groups respectively.

The findings were computed in a meta-analytical format as well. Wherein, the Mantel-Haenszel method applying a random-effects model was used to compare the proportional outcome of adenoma and polyp detection among the CADe (i.e., experimental) and the standard (i.e., control) group. The findings were presented as odds ratio (OR), by applying 95% confidence intervals (CI). The I^2 index findings were also computed and thereby presented.

Results

In total, 9 randomized clinical trials were included in this systematic review. The total participant count was 6981. The tabulated findings are presented in Table 1.The study-by-study summary is presented in the subsequent text.

Table 1. The tabulated findings are present. The study-by-study summary is presented in the subsequent text.

Sr. No.	Author, Year	Title	Participant Count	Design	Technological Overview	Conclusions
1	Wang, 2019[8]	Real-time automatic detection system increases colonoscopic polyp and adenoma detection rates: a prospective randomized controlled study	1058	Open, non-blinded, prospective randomized trial	Real-time automatic polyp detection system	The use of an automatic polyp detection system can significantly increase the detection rate of diminutive adenomas and hyperplastic polyps in populations with low polyp prevalence
2	Gong, 2020[9]	Detection of colorectal adenomas with a real-time computer-aided system (ENDOANGEL): a randomized controlled study	704	Randomized controlled trial	An ENDOANGEL system using real-time quality improvement system based on deep learning	The ENDOANGEL system was found to be both safe and effective in improving the adenoma detection rate during colonoscopy,

						with no reported adverse events in the RCT
3	Liu, 2020[10]	Study on detection rate of polyps and adenomas in artificial-intelligence-aided colonoscopy	1026	Prospective randomized trial	CADe system	It was found that the CADe, AI-powered system was feasible in detecting both adenomas and polyps during colonoscopy
4	Repici, 2020[11]	Efficacy of real-time computer-aided detection of colorectal neoplasia in a randomized trial	685	Randomized controlled trial	AI-powered medical device	In the multicenter, randomized trial, it was observed that CADe-aided colonoscopy increased the adenoma detection rate and the overall number of adenomas detected per colonoscopy, without affecting the procedural timings
5	Su, 2020[12]	Impact of a real-time automatic quality control system on colorectal polyp and adenoma detection: a prospective randomized controlled study (with videos)	659	Prospective, randomized, controlled trial	Software analyzing prospective images obtained from colonoscopies	The detection of adenomaswas improved with AQCS enhancing colonoscopists' performance
6	Wang, 2020[13]	Effect of a deep learning computer-aided detection system on adenoma detection during colonoscopy (CADe-DB trial):	1046	Double-blind randomized trial	CADe system	High-performance CADe systems can detect polyps during colonoscopies that may be difficult for

		a double-blind randomized study				skilled endoscopists to recognize
7	Wang, 2020[14]	Lower adenoma miss rate of computer-aided detection-assisted colonoscopy versus routine white-light colonoscopy in a prospective tandem study	369	Prospective randomized trial	CADe system	Using CADe systems during colonoscopies reduced the overall miss rate of adenomas, resulting in an ultimate decrease in the incidence of interval colon cancers
8	Kamba, 2021[15]	Reducing adenoma miss rate of colonoscopy assisted by artificial intelligence: a multicenter randomized controlled trial	358	Multicenter randomized controlled trial	CADe system	With the assistance of CADe systems, the miss rate of adenomatous lesions during colonoscopies was reduced
9	Yao, 2022[16]	Effect of an artificial intelligence-based quality improvement system on efficacy of a computer-aided detection system in colonoscopy: a four-group parallel study	1076	Single-center, placebo-controlled, randomized trial	ENDOANGEL polyp detection	The CADe system was significant in improving adenoma detection

In 2019, Wang et al. conducted a study to examine how using deep learning, an automatic polyp detection system could affect ADR and PDR. They carried out an open, non-blinded trial. The primary objective was to determine ADR. The results showed that the AI system significantly increased ADR with a ratio of 29.1 as compared to 20.3 ($P<0.001$). The researchers concluded that using an automatic polyp detection system during colonoscopy in populations with low ADRs could notably increase the detection of diminutive adenomas and hyperplastic polyps.

The efficacy of the ENDOANGEL system, an AI-based system utilizing deep neural networks and algorithms, in enhancing adenoma yield during standard colonoscopies was investigated by Gong and colleagues (2020). ADR was the primary endpoint. 704 patients were included, with the ENDOANGEL group (16%) displaying significantly greater ADR than the control group (8%) (P=0.0010). No unfavorable events were reported. The study concluded that the ENDOANGEL system is efficient in increasing adenoma yield during routine colonoscopies and is safe for use. It has the potential to improve adenoma detection and decrease the risk of colorectal cancer.

In their study, Liu et al. (2020) examined how the CADe system affected PDR and ADR in colonoscopies. A total of 1026 patients underwent colonoscopies, either with or without the CADe system, using a random scheduling method. The researchers found that the CADe group had a significantly higher adenoma detection rate than the standard group. Furthermore, the CADe system increased the average number of detected adenomas, as well as the number of small adenomas and proliferative polyps, with a statistically significant difference (P<0.001) between the two groups. However, there was no significant difference in the detection of larger adenomas between the two groups (P>0.05). The results suggest that the CADe system is a viable tool to improve the detection of polyps and adenomas during colonoscopies.

The effectiveness and safety of a CADe system in detecting colorectal neoplasias during colonoscopy were examined by Repici et al. (2020). The study randomly assigned 685 patients to either the CADe group or the control group. The CADe system processed colonoscopy images and provided real-time superimposition of suspected lesions on the endoscopy display. The primary outcome was ADR. The results showed that ADR was significantly higher in the CADe group compared to the control group. Furthermore, the CADe system detected more adenomas per colonoscopy, particularly small and medium-sized adenomas. The study concludes that including CADe in real-time colonoscopy can significantly increase ADR and adenomas detected per colonoscopy, without increasing the withdrawal time. This study highlights the potential of deep learning systems for enhancing the detection of colorectal neoplasias during colonoscopy while being safe to use.

Su et al. (2020) developed an automatic quality control system (AQCS) to improve the efficiency of colonoscopy. They conducted a randomized controlled trial involving 659 consecutive patients who underwent routine colonoscopy with or without AQCS assistance. The study found that the AQCS group had significantly higher ADR, PDR, mean number of adenomas and polyps detected per procedure compared to the control group. These results suggest that AQCS can effectively enhance the performance of colonoscopists during the withdrawal phase and significantly increase the detection rates of polyps and adenomas.

In a double-blind randomized trial conducted in China, Wang et al. (2020) aimed to determine the efficacy of a CADe system in detecting colon polyps and adenomas during colonoscopy. The study included consecutive patients aged 18-75 years undergoing diagnostic or screening colonoscopy. A total of 962 patients were included in the analysis, with 484 patients in the CADe group and 478 in the control group. The primary outcome was ADR, and the results showed that the ADR was significantly higher in the CADe group (34%) than in the control group (28%). The authors suggested that a CADe system could improve the detection of polyps and adenomas during colonoscopy, but further research is needed to investigate its impact on interval colorectal cancer.

Wang and colleagues (2020) conducted a randomized trial to investigate the effectiveness of CADe systems in detecting precancerous polyps during colonoscopy and reducing the rate of missed adenomas. Patients were randomly assigned to the CADe and routine groups. The study showed that the adenoma and polyp miss rates were significantly lower in the CADe colonoscopy group compared to the routine colonoscopy group, indicating that the use of CADe during colonoscopy can effectively reduce the risk of missed adenomas.

The study by Kamba et al. (2021) investigated whether the use of CADe system could reduce the risk of missed adenomas during colonoscopy screening and surveillance in Japan. Patients were randomly assigned to either the standard colonoscopy group or the CADe-first group for a tandem procedure The results showed that the CADe-first group had a significantly lower adenoma miss rate, as well as a lower polyp and sessile serrated lesion miss rate. Additionally, the use of CADe system improved the adenoma detection rate during colonoscopy.

Yao et al. (2022) conducted a study to assess the effectiveness of using a CADe system in combination with a CAQ system to improve ADR. The study included 1076 patients who were randomly assigned to four treatment groups. The primary outcome measured was ADR. The results showed that the group receiving both CADe and CAQ systems had a higher ADR compared to the group receiving only CADe, but not when compared to the group receiving only CAQ. The study concluded that the combination of CADe and CAQ systems significantly improved the effectiveness of CADe.The quantitative findings of adenoma and polyp detection in CADe and standard colonoscopy groups are presented in Table 2.

Table 2. Quantitative findings of adenoma and polyp detection in CADe and standard colonoscopy groups. The values are presented as n/N.

Author, Year	**CADe (Adenomas)**	**Standard Colonoscopy (Adenomas)**	**CADe (Polpys)**	**Standard Colonoscopy (Polyps)**
Wang, 2019	262/498	160/269	235/522	156/536
Gong, 2020	58/355	27/349	166/355	118/349
Liu, 2020	250/486	144/248	221/508	144/518
Repici, 2020	187/341	139/344	279/341	214/344
Su, 2020	113/308	56/315	118/308	80/315
Wang, 2020	165/484	132/478	252/484	177/478
Wang, 2020	144/184	120/185	118/184	102/185
Kamba, 2021	111/172	93/174	120/172	106/174
Yao, 2022	205/805	40/271	NR	NR

The total number of studies represented in the CADe and standard group diagnosis of colorectal adenomas is 9. With the random-effects model, the OR was computed to be 1.532 (95% CI=1.125-2.087). There was high heterogeneity in the results (I^2=85.5%), and the findings were significant (P=0.0068) (**Figure 2**).

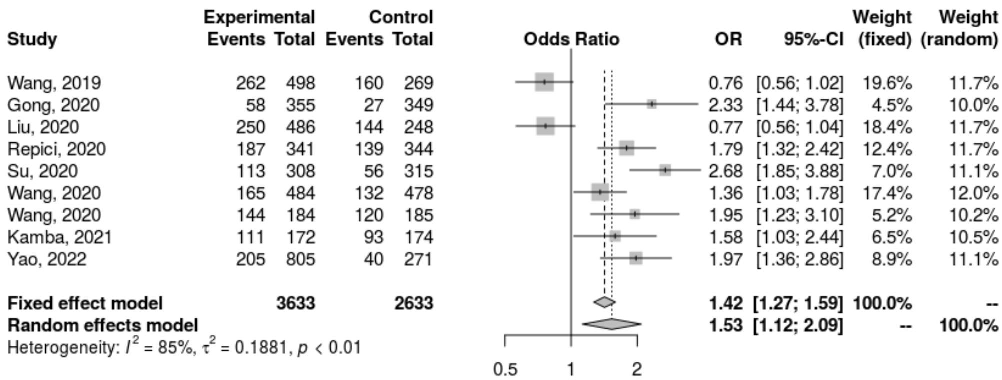

Figure 2. Forest plot depicting the odds ratio of being diagnosed with colorectal adenomas in the CADe group (illustrated as experimental group) versus the standard group (illustrated as the control group).

On assessing the likelihood of diagnosing colorectal polyps with CADe add-on systems compared to standard colonoscopy, the OR was computed as follows: OR=1.893 (95% CI=1.687-2.125). The findings were significant (P< 0.0001). Limited heterogeneity was present in the analytical subset (I^2=9%) (**Figure 3**).

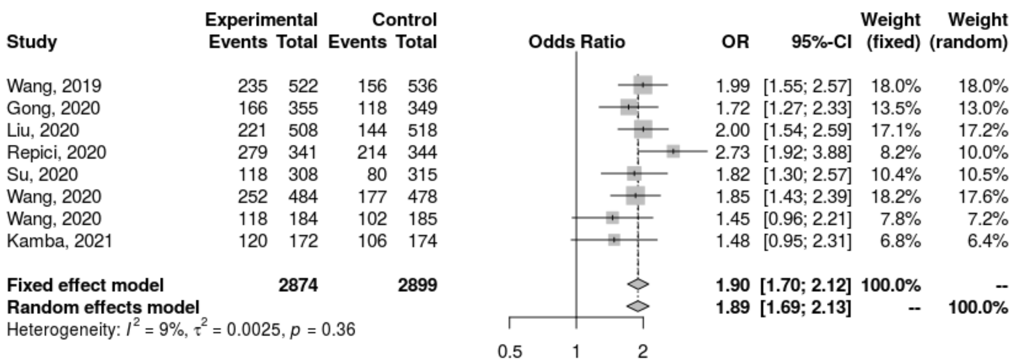

Figure 3. Forest plot depicting the odds ratio of being diagnosed with colorectal polyps in the CADe group (illustrated as experimental group) versus the standard group (illustrated as the control group).

Discussion

In recent years, there has been a significant increase in the use of AI in medical applications. Given that colorectal cancer is the third most common cause of cancer-related death in the United States, one important area where AI can be beneficial is in improving the detection of precancerous lesions in the colon and reducing mortality rates[17]. AI integration in colonoscopies can be particularly advantageous in two main areas: first, by enhancing polyp detection to improve adenoma detection rates and minimize the chances of missed polyps, and second, by characterizing polyps to determine appropriate removal strategies, including resect-and-discard, advanced endoscopic resection, or surgery[18]. Enhancing detection rates for colorectal polyps and adenomas is crucial, as it directly impacts colorectal cancer prevention. Increasing adenoma detection rates allows for early, targeted intervention, thereby mitigating cancer progression risks. Strategies like "resect and discard" or "diagnose and leave" can reduce pathology costs by eliminating non-neoplastic polyps' post-optical diagnosis or by not removing diminutive rectosigmoid hyperplastic polyps. Implementing AI-assisted detection could lead to more effective and economical colorectal cancer prevention strategies.

Real-time support is crucial for the practical application of AI in colonoscopy, unlike in fields like pathology, radiology, and dermatology[19]. The detection of polyps during colonoscopy requires quick action as the lesion may not always be optimally positioned on the screen or under ideal lighting conditions[20]. The significance of screening colonoscopy lies in the identification and removal of precancerous colorectal polyps. However, as colonoscopy is an operator-dependent procedure, there is significant variability in the effectiveness of colonoscopists in preventing colorectal cancer[21]. Therefore, regular performance monitoring of physicians is necessary to improve the quality of colonoscopies. For efficient polyp detection, computer-aided detection should be performed in real-time[12]. Improving the detection of adenomas has been an ongoing effort, with the development of new techniques and devices such as full-spectrum endoscopy, the third eye panoramic cap, and the balloon-colonoscope system[22]. However, their high costs and limited expertise prevent their widespread use. Add-on devices attached to endoscopes are more accessible and provide direct views behind colonic folds, although their effectiveness is mixed[23]. Nevertheless, current guidelines promote their use for improving adenoma and polyp detection.

The impact of adenoma detection on screening surveillance requires further discussion, particularly for patients with high-grade dysplasia who need more intensive surveillance[24]. Those without high-grade dysplasia may consider longer follow-up periods. Two categories of missed adenomas during colonoscopy include those hidden behind mucosal folds or debris and those that are visible but still missed[25]. Solutions proposed for the former include distal scope attachments and panoramic colonoscopy to reduce blind spots. For the latter, a second observer during the procedure has been shown to be beneficial, and computer-aided detection using machine learning or deep learning has shown promise in detecting lesions during colonoscopy[25]. Clinical trials in different countries have successfully applied these technologies both retrospectively and prospectively[26, 27].

The integration of computer-aided detection systems into colonoscopies has been found to enhance the identification of colon polyps and adenomas by providing visual cues during the procedure[28]. These systems offer high detection rates, low false positives, and no reported adverse effects, making them safe and viable for use in real-time colonoscopy practice[29]. The improved polyp and adenoma detection rates observed with computer-aided detection are promising, but additional well-designed randomized trials are necessary to assess their clinical and statistical significance in enhancing the quality indicator ADR. Given the underdiagnosis of 15-20% of colorectal cancer cases, there is a high interest in further integrating computer-aided detection systems in the clinical setting[30].

Conclusion

To improve the detection of adenomas and polyps during colonoscopy, real-time computer-aided detection (CADe) has shown promising results, especially for serrated and neoplastic polyps. However, more extensive studies are required to assess the impact of CADe on the detection of adenomas and serrated polyps, as well as its effects on endoscopists with lower detection rates. Despite the positive results, further studies are needed to confirm these findings, preferably through well-designed randomized controlled trials. These studies should focus on improving the adenoma detection rate, which is currently the most widely accepted quality indicator in colonoscopy. With more widely adopted clinical applications, prospective research can provide greater insight into the role of computer-aided detection to curb mortality and morbidity due to colorectal cancer in gastroenterology.

References

[1] Keum N, Giovannucci E. Global burden of colorectal cancer: emerging trends, risk factors and prevention strategies. *Nat Rev Gastroenterol Hepatol* 2019; 16: 713–732.

[2] Jiang Y, Yuan H, Li Z, et al. Global pattern and trends of colorectal cancer survival: a systematic review of population-based registration data. *Cancer Biol Med* 2022; 19: 175.

[3] Sullivan R, Peppercorn J, Sikora K, et al. Delivering affordable cancer care in high-income countries. *Lancet Oncol* 2011; 12: 933–980.

[4] Viscaino M, Bustos JT, Muñoz P, et al. Artificial intelligence for the early detection of colorectal cancer: A comprehensive review of its advantages and misconceptions. *World J Gastroenterol* 2021; 27: 6399.

[5] Liang F, Wang S, Zhang K, et al. Development of artificial intelligence technology in diagnosis, treatment, and prognosis of colorectal cancer. *World J Gastrointest Oncol* 2022; 14: 124.

[6] Taghiakbari M, Mori Y, von Renteln D. Artificial intelligence-assisted colonoscopy: A review of current state of practice and research. *World J Gastroenterol* 2021; 27: 8103.

[7] Kelly CJ, Karthikesalingam A, Suleyman M, et al. Key challenges for delivering clinical impact with artificial intelligence. *BMC Med* 2019; 17: 1–9.

[8] Wang P, Berzin TM, Brown JRG, et al. Real-time automatic detection system increases colonoscopic polyp and adenoma detection rates: a prospective randomised controlled study. *Gut* 2019; 68: 1813–1819.

[9] Gong D, Wu L, Zhang J, et al. Detection of colorectal adenomas with a real-time computer-aided system (ENDOANGEL): a randomised controlled study. *Lancet Gastroenterol Hepatol* 2020; 5: 352–361.

[10] Liu W-N, Zhang Y-Y, Bian X-Q, et al. Study on detection rate of polyps and adenomas in artificial-intelligence-aided colonoscopy. *Saudi J Gastroenterol Off J Saudi Gastroenterol Assoc* 2020; 26: 13.

[11] Repici A, Badalamenti M, Maselli R, et al. Efficacy of real-time computer-aided detection of colorectal neoplasia in a randomized trial. *Gastroenterology* 2020; 159: 512–520.

[12] Su J-R, Li Z, Shao X-J, et al. Impact of a real-time automatic quality control system on colorectal polyp and adenoma detection: a prospective randomized controlled study (with videos). *Gastrointest Endosc* 2020; 91: 415–424.

[13] Wang P, Liu X, Berzin TM, et al. Effect of a deep-learning computer-aided detection system on adenoma detection during colonoscopy (CADe-DB trial): a double-blind randomised study. *Lancet Gastroenterol Hepatol* 2020; 5: 343–351.

[14] Wang P, Liu P, Brown JRG, et al. Lower adenoma miss rate of computer-aided detection-assisted colonoscopy vs routine white-light colonoscopy in a prospective tandem study. *Gastroenterology* 2020; 159: 1252–1261.

[15] Kamba S, Tamai N, Saitoh I, et al. Reducing adenoma miss rate of colonoscopy assisted by artificial intelligence: a multicenter randomized controlled trial. *J Gastroenterol* 2021; 56: 746–757.

[16] Yao L, Zhang L, Liu J. Effect of an artificial intelligence-based quality improvement system on efficacy of a computer-aided detection system in colonoscopy: a four-group parallel study. *Endoscopy*; 54.

[17] Mattiuzzi C, Sanchis-Gomar F, Lippi G. Concise update on colorectal cancer epidemiology. *Ann Transl Med*; 7.

[18] Ahmed S, Johnson K, Ahmed O, et al. Advances in the management of colorectal cancer: from biology to treatment. *Int J Colorectal Dis* 2014; 29: 1031–1042.

[19] Hardy NP, Mac Aonghusa P, Neary PM, et al. Intraprocedural artificial intelligence for colorectal cancer detection and characterisation in endoscopy and laparoscopy. *Surg Innov* 2021; 28: 768–775.

[20] Rex DK, Bond JH, Winawer S, et al. Quality in the technical performance of colonoscopy and the continuous quality improvement process for colonoscopy: recommendations of the US Multi-Society Task Force on Colorectal Cancer. *Off J Am Coll Gastroenterol ACG* 2002; 97: 1296–1308.

[21] Macken E, Moreels T, Vannoote J, et al. Quality assurance in colonoscopy for colorectal cancer diagnosis. *Eur J Surg Oncol* 2011; 37: 10–15.

[22] Gkolfakis P, Tziatzios G, Dimitriadis GD, et al. New endoscopes and add-on devices to improve colonoscopy performance. *World J Gastroenterol* 2017; 23: 3784.

[23] Facciorusso A, Del Prete V, Buccino RV, et al. Comparative efficacy of colonoscope distal attachment devices in increasing rates of adenoma detection: a network meta-analysis. *Clin Gastroenterol Hepatol* 2018; 16: 1209–1219.

[24] Murthy SK, Feuerstein JD, Nguyen GC, et al. AGA clinical practice update on endoscopic surveillance and management of colorectal dysplasia in inflammatory bowel diseases: expert review. *Gastroenterology* 2021; 161: 1043–1051.

[25] Sekaran A, Dey D, Singh A, et al. Pathology of Malignant Lesions of the Gastrointestinal Tract. In: *Surgical Pathology of the Gastrointestinal System: Volume I-Gastrointestinal Tract*. Springer, 2022, pp. 699–782.

[26] Hassan C, Spadaccini M, Iannone A, et al. Performance of artificial intelligence in colonoscopy for adenoma and polyp detection: a systematic review and meta-analysis. *Gastrointest Endosc* 2021; 93: 77–85.

[27] Mohan BP, Facciorusso A, Khan SR, et al. Real-time computer aided colonoscopy versus standard colonoscopy for improving adenoma detection rate: A meta-analysis of randomized-controlled trials. *EClinicalMedicine* 2020; 29: 100622.

[28] Byrne MF, Shahidi N, Rex DK. Will computer-aided detection and diagnosis revolutionize colonoscopy? *Gastroenterology* 2017; 153: 1460–1464.

[29] Eliakim R, Yassin K, Niv Y, et al. Prospective multicenter performance evaluation of the second-generation colon capsule compared with colonoscopy. *Endoscopy* 2009; 41: 1026–1031.

[30] Couto J, Mc Clure P, McFadden S, et al. Thematic analysis of the competencies of the therapy radiographer practising in the linear accelerator. In: *European Congress of Radiology 2019 (Vienna, Austria, February 27-March3, 2019)*. Springer Open, 2019, pp. S325–S325.