Volume 7, No. 8 August, 2026
p ISSN 2723-6927-e ISSN 2723-4339

Effectiveness of Artificial Intelligence–Assisted Colonoscopy for Adenoma Detection: A Systematic Review and Meta-Analysis

Mutiara Delia Subiyanto*, Laura Subiyanto
Universitas Islam Sultan Agung, Indonesia
Email: mutiaradelia79@gmail.com*, laurasubiyanto21@gmail.com

Keywords:
Artificial Intelligence; Colonoscopy; Adenoma Detection Rate; Colorectal Neoplasia; Computer-Aided Detection.

ABSTRACT

Colorectal cancer remains one of the leading causes of cancer-related morbidity and mortality worldwide. Colonoscopy plays a central role in colorectal cancer screening, and the adenoma detection rate (ADR) is a key quality indicator associated with reduced colorectal cancer risk. Recently, artificial intelligence (AI)-based computer-aided detection (CADe) systems have been developed to assist endoscopists in identifying colorectal lesions during colonoscopy. This research aimed to evaluate the effectiveness of artificial intelligence–assisted colonoscopy in improving adenoma detection compared with conventional colonoscopy. A systematic review and meta-analysis were conducted following PRISMA guidelines. Literature searches were performed in PubMed, the Cochrane Library, and ScienceDirect to identify comparative studies evaluating CADe-assisted colonoscopy versus conventional colonoscopy. The primary outcome was adenoma detection rate. Pooled risk ratios (RRs) with 95% confidence intervals (CIs) were calculated using a random-effects model. Four studies comprising 10,483 colonoscopy procedures were included in the meta-analysis. The pooled results demonstrated that AI-assisted colonoscopy significantly increased adenoma detection compared with conventional colonoscopy (RR = 1.19; 95% CI = 1.07–1.32; $p = 0.002$). Moderate heterogeneity was observed among the included studies ($I^2 = 68\%$). Notably, although overall ADR improved substantially, several studies reported limited or no significant improvement in the detection of advanced colorectal neoplasia, suggesting that the benefit may have been predominantly driven by increased detection of diminutive adenomas. Artificial intelligence–assisted colonoscopy using CADe systems significantly improved adenoma detection rates compared with conventional colonoscopy. However, further large-scale randomized studies are needed to determine whether these improvements translate into clinically meaningful long-term reductions in colorectal cancer incidence and mortality.

INTRODUCTION

Colorectal cancer (CRC) remains a major global health burden and continues to rank among the most frequently diagnosed malignancies worldwide. According to global cancer epidemiology data (Sung et al., 2021), CRC is one of the leading causes of cancer-related morbidity and mortality, contributing substantially to healthcare burdens across both developed and developing regions. The incidence of CRC has increased in several countries, partly due to population aging, changes in dietary and lifestyle patterns, and variations in access to screening programs. Importantly, CRC develops through the well-established adenoma–carcinoma sequence, in which benign precursor lesions gradually progress into malignant tumors over time. This prolonged progression provides an important opportunity for early detection and prevention through screening and removal of precancerous lesions.

Population-based screening programs have therefore become a cornerstone of CRC prevention strategies. Among the available screening modalities, the fecal immunochemical test (FIT) has become one of the most widely implemented noninvasive screening tools due to its practicality, patient acceptability, and cost-effectiveness. FIT detects occult blood in stool, which may indicate the presence of colorectal neoplasia (Imperiale et al., 2014). Individuals with positive FIT results are typically referred for diagnostic colonoscopy (Rabba et al., 2025), which serves as the definitive method for visualizing the colonic mucosa and removing suspicious lesions. Large-scale screening programs using FIT followed by colonoscopy have demonstrated meaningful reductions in CRC incidence and mortality when implemented effectively (Ali et al., 2024).

Colonoscopy is widely regarded as the gold standard for detecting colorectal adenomas and early-stage colorectal cancer. During the procedure, direct visualization of the colonic mucosa enables endoscopists to identify and remove polyps before malignant transformation occurs. Among the quality (M. F. Kaminski et al., 2010) indicators used to evaluate colonoscopy performance, the adenoma detection rate (ADR) is considered the most important metric (Corley et al., 2014). ADR refers to the proportion of colonoscopies in which at least one adenoma is identified and has been strongly associated with the long-term effectiveness of colorectal cancer prevention. Previous research has demonstrated that higher ADRs are correlated with significantly lower rates of interval colorectal cancer and CRC-related mortality, highlighting the clinical importance of maximizing lesion detection during colonoscopy.

Despite its central role in CRC prevention, colonoscopy has several limitations. Studies have shown that some colorectal lesions may still be missed during endoscopic examinations, particularly small, flat, or subtle lesions that are difficult to distinguish from normal mucosa. Several factors contribute to variability in detection, including differences in endoscopist experience, withdrawal technique, bowel preparation quality, patient anatomical characteristics, and lesion morphology. Missed adenomas are considered major contributors to interval colorectal cancers, which develop after a negative colonoscopy but before the next recommended screening interval. Therefore, improving lesion detection during colonoscopy remains a major focus of technological innovation.

Recent advances in artificial intelligence (AI) (Barua et al., 2021) and deep learning technologies have created opportunities to enhance the diagnostic performance of colonoscopy (Hassan et al., 2021). Computer vision algorithms trained on large endoscopic image datasets can identify subtle mucosal abnormalities with high accuracy (Repici et al., 2020). One of the most extensively studied applications of AI in endoscopy is computer-aided detection (CADe), a technology designed to assist endoscopists by automatically highlighting potential polyps during real-time colonoscopy (Wang et al., 2019). By functioning as a "second observer," CADe systems aim to reduce human error and minimize the likelihood of overlooked lesions during mucosal inspection.

Multiple randomized controlled trials have demonstrated that CADe-assisted colonoscopy can significantly improve colorectal adenoma detection compared with conventional colonoscopy. These systems continuously analyze endoscopic video streams and generate visual alerts when suspicious mucosal patterns are detected, prompting endoscopists to examine highlighted areas more carefully. As a result, CADe systems may assist in identifying subtle lesions that might otherwise be missed during routine examinations. The rapid development (R. Kaminski, 2024) of AI-assisted endoscopy has generated considerable interest as a strategy for improving colonoscopy quality indicators and enhancing colorectal cancer screening outcomes.

However, the clinical significance of improvements in ADR associated with CADe remains under debate. Some investigators have suggested that increased detection through AI-assisted colonoscopy is primarily driven by the identification of diminutive or clinically less significant adenomas. Although detecting these lesions contributes to higher ADR values, their direct impact on long-term colorectal cancer prevention may be limited. Therefore, researchers have emphasized the importance of evaluating whether CADe systems also improve the detection of advanced colorectal neoplasia, including advanced adenomas and other high-risk lesions with greater malignant potential.

This distinction is particularly relevant in FIT-positive screening populations. Individuals with positive FIT results have a higher baseline probability of harboring advanced colorectal neoplasia compared with average-risk screening populations. Colonoscopy in FIT-positive individuals therefore plays a critical role in identifying clinically significant lesions requiring therapeutic intervention or closer surveillance. In this high-risk population, improved detection of advanced neoplasia may have substantial implications for screening program effectiveness and long-term cancer prevention.

Several recent studies have investigated the role of AI-assisted colonoscopy in detecting colorectal neoplastic lesions within organized screening programs and real-world clinical settings. Trials conducted in FIT-based screening populations have reported inconsistent findings regarding the effect of CADe on advanced lesion detection. While some studies have demonstrated improvements in overall adenoma detection, others have reported minimal or no significant changes in advanced colorectal neoplasia detection rates. These inconsistencies highlight the need for systematic evaluation of available evidence to determine whether CADe provides clinically meaningful benefits beyond improvements in overall ADR.

Given the increasing adoption of artificial intelligence technologies in gastrointestinal endoscopy and the growing reliance on FIT-based screening programs worldwide, understanding the clinical impact of CADe-assisted colonoscopy is important (Dimopoulou et al., 2025). Therefore, this study aimed to systematically review and synthesize existing evidence comparing artificial intelligence–assisted colonoscopy using computer-aided detection systems with conventional colonoscopy (Maas et al., 2024). Specifically, this meta-analysis evaluated the effect of CADe implementation on adenoma detection rate and related neoplasia detection outcomes to clarify the role of AI-assisted colonoscopy in improving colorectal cancer screening performance.[10] The findings of this study are expected to provide important benefits by consolidating evidence from multiple studies to generate a more robust estimate of AI-assisted colonoscopy effectiveness and support clinical decision-making regarding the adoption of CADe systems in routine practice. Furthermore, the results may assist healthcare policymakers and screening program coordinators in assessing the potential value of integrating AI technology into existing colorectal cancer screening programs. By highlighting differences between the effects of CADe on overall adenoma detection and advanced neoplasia detection, this study contributes to a clearer understanding of the clinical significance of AI-assisted colonoscopy and identifies areas requiring further investigation. Ultimately, this evidence synthesis aims to support the optimization of colorectal cancer prevention strategies and improve patient outcomes through enhanced colonoscopy quality.

METHOD

Study Design and Reporting Guidelines

This research was conducted as a systematic review and meta-analysis to evaluate the effectiveness of artificial intelligence–assisted colonoscopy using computer-aided detection (CADe) systems in detecting colorectal neoplasia compared with conventional colonoscopy. The study methodology was developed in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines to ensure transparency, reproducibility, and methodological rigor throughout the review process.

The review included comparative studies evaluating the impact of CADe-assisted colonoscopy on adenoma detection outcomes. The primary objective of the meta-analysis was to determine whether AI-assisted colonoscopy improved the adenoma detection rate (ADR) compared with conventional colonoscopy without artificial intelligence support.

Search Strategy

A comprehensive literature search was conducted across three electronic databases: PubMed, Cochrane Library, and ScienceDirect. The search strategy combined terms related to artificial intelligence, colonoscopy, and adenoma detection. The following search terms were used in various combinations:

1. artificial intelligence
2. computer-aided detection
3. CADe
4. colonoscopy
5. adenoma detection
6. polyp detection

Boolean operators were applied to refine the search strategy and ensure retrieval of relevant comparative studies. The search was designed to identify studies evaluating the use of AI-assisted colonoscopy systems in the detection of colorectal adenomas or neoplastic lesions.

The database search yielded a total of 1,303 records, consisting of 665 records from PubMed, 360 from Cochrane Library, and 278 from ScienceDirect. All identified studies were exported and screened according to predefined eligibility criteria.

Eligibility Criteria

Studies were selected according to predefined Population–Intervention–Comparator–Outcome (PICO) criteria.

Population

The population of interest included patients undergoing colonoscopy following a positive fecal immunochemical test (FIT) within colorectal cancer screening programs or patients undergoing colonoscopy for screening, surveillance, or diagnostic purposes.

Intervention

The intervention evaluated was artificial intelligence–assisted colonoscopy using computer-aided detection (CADe) systems, designed to provide real-time visual alerts for suspected colorectal lesions during endoscopic examination.

Comparator

The comparator consisted of standard colonoscopy performed without artificial intelligence assistance.

Outcome

The primary outcome of interest was the adenoma detection rate (ADR), defined as the proportion of colonoscopies in which at least one adenoma was detected.

Study Design

Eligible studies included randomized controlled trials and comparative studies evaluating CADe-assisted colonoscopy versus conventional colonoscopy.

Studies were excluded if they:

1. were non-comparative or single-arm studies
2. involved artificial intelligence applications unrelated to colonoscopy detection
3. did not report adenoma detection outcomes
4. included inappropriate populations or irrelevant outcome measures.

Study Selection

All retrieved records underwent a two-stage screening process. In the first stage, titles and abstracts were screened to remove clearly irrelevant studies. During this phase, 1,297 records were excluded, leaving six studies for further evaluation.

In the second stage, duplicate records were identified and removed, resulting in five studies eligible for full-text assessment. Full-text articles were carefully reviewed to determine whether they met all predefined inclusion criteria.

After full-text evaluation, one study was excluded due to inappropriate population and outcome reporting, leaving four studies eligible for inclusion in the systematic review and meta-analysis.

The overall study selection process is illustrated in the PRISMA flow diagram (Figure 1).

Data Extraction

Data extraction was conducted independently using a standardized extraction form to ensure consistency across studies. The following information was extracted from each included study:

1. First author and publication year
2. Study design
3. Study setting and population characteristics
4. Total number of participants in the intervention and control groups
5. Type of artificial intelligence system used
6. Number of detected adenomas in each study group
7. Adenoma detection rate (ADR)
8. Additional outcomes related to colorectal lesion detection when available

Extracted data were verified for accuracy prior to inclusion in the quantitative analysis.

Risk of Bias Assessment

The methodological quality of the included studies was assessed to evaluate potential sources of bias that could influence the reliability of the findings. Because the majority of the included studies were randomized controlled trials, risk of bias assessment focused on key domains including:

randomization process
allocation concealment
blinding of outcome assessment
completeness of outcome data

selective reporting of outcomes.

Each domain was evaluated qualitatively to determine the overall methodological quality of the included studies. Overall, the included studies were considered to have low to moderate risk of bias, reflecting generally robust study designs and appropriate reporting of outcomes.

Statistical Analysis

Meta-analysis was performed using Review Manager (RevMan) software. The primary outcome, adenoma detection rate, was analyzed using the Mantel–Haenszel method to calculate pooled risk ratios (RRs) with 95% confidence intervals (CIs).

A random-effects model was applied to account for potential heterogeneity across studies arising from differences in study populations, colonoscopy indications, and CADe system implementation. Statistical heterogeneity among studies was evaluated using the I^2 statistic and Chi-square test.

Heterogeneity was interpreted according to standard thresholds:

$I^2 < 25\%$ indicating low heterogeneity

I^2 25–50% indicating moderate heterogeneity

$I^2 > 50\%$ indicating substantial heterogeneity.

Statistical significance was defined as $p < 0.05$. The pooled results were presented using forest plots to illustrate individual study estimates and the overall effect size.

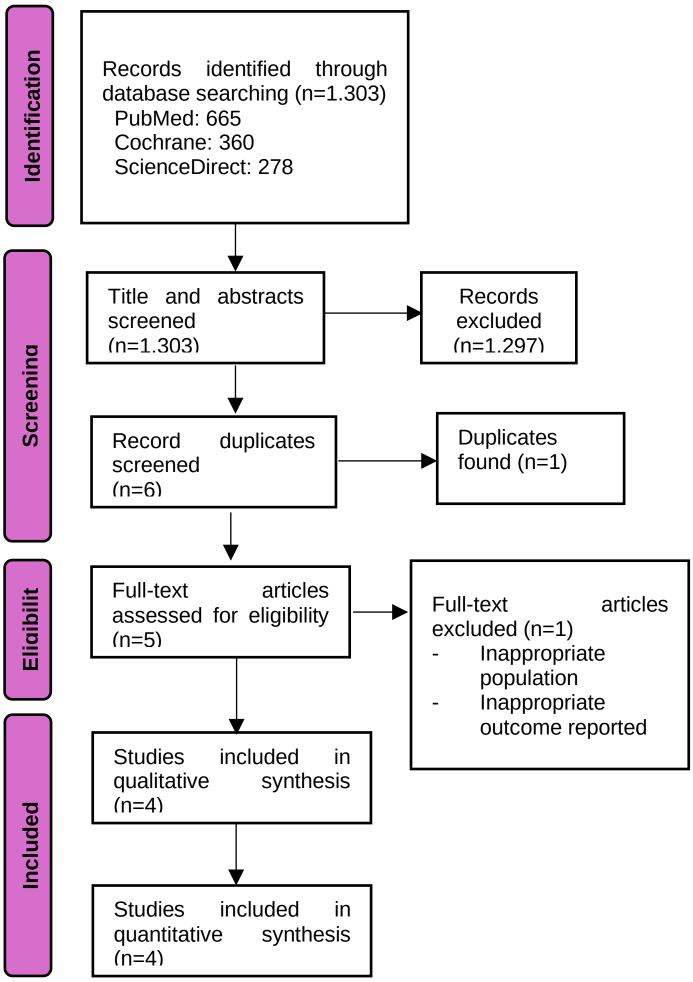

Figure 1. Diagram flow of literature search strategy for this meta-analysis

Source: Adapted from PRISMA 2020 statement

Table 1. Study Summary: Performance of Computer-Aided Detection (CADe) in Colonoscopy

Characteristics	Lui (2023)	Rondonotti (2022)	Thiruvengadam (2024)	Mas-Sanjuan (2023)
Country / Setting	Hong Kong; Queen Mary Hospital, University of Hong Kong	Italy; multicenter FIT-based CRC screening program (5 endoscopy centers)	United States; Riverside University Health System Medical Center (community practice)	Spain; multicenter CRC screening program (6 centers)
Country / Study Setting	Simulation modeling study based on colonoscopy database	Multicenter randomized controlled trial	Pragmatic randomized controlled trial	Multicenter randomized controlled trial
Population Characteristics	Adults undergoing colonoscopy with complete endoscopic and histologic findings (2016-2020); median age 62.6 years; 52.7% male	FIT-positive individuals aged 50-74 years undergoing colonoscopy; median age 61 years; 51.1% male	Adults ≥30 years undergoing colonoscopy; median age 55.5 years; 61% female; predominantly Hispanic population	Adults with positive FIT undergoing screening colonoscopy
FIT Criteria / Threshold	Not specified	FIT positivity cutoff 20 µg Hb/g feces using OC-Hemodia system	FIT-positive patients included but not exclusive	FIT-positive screening population
Number of Samples (AI / Control)	N = 3735 (simulation of CADe effect; no comparator arm)	405 CADe vs 395 standard colonoscopy	550 CADe vs 550 standard colonoscopy	560 CADe vs 553 standard colonoscopy
AI System (CADe Platform)	CADe performance simulated from published meta-analysis	CAD EYE (Fujifilm), deep-learning CADe system	GI Genius (Medtronic), real-time deep-learning CADe	GI Genius (Medtronic), deep-learning CADe system
Colonoscopy Indications	Screening (21.5%) and symptomatic colonoscopy (78.4%)	Colonoscopy following positive FIT screening	Screening, surveillance, FIT-positive, and diagnostic colonoscopy	Colonoscopy following positive FIT screening
Endoscopic Experience	Not reported	Endoscopists ≥300 colonoscopies/year, cecal intubation ≥95%, baseline ADR ≥25%	6 gastroenterologists; each ≥1000 colonoscopies and baseline ADR ≥25%	Experienced screening endoscopists from national CRC screening program
Standard Bowel Preparation	Aronchick scale median 2 (adequate bowel preparation)	Boston Bowel Preparation Scale (BBPS ≥6)	Boston Bowel Preparation Scale (BBPS ≥6 considered adequate)	Adequate bowel preparation required according to screening protocol
Withdrawal Time	Mean withdrawal time 12.2 min	Minimum 6 minutes withdrawal time	Median withdrawal time 12 min (CADe) vs 10 min (control)	Standard screening withdrawal protocol
Definition of Advanced Colorectal Neoplasia	Advanced adenoma: adenoma ≥10 mm, villous histology ≥25%, high-grade dysplasia, or carcinoma; advanced serrated polyp:	Advanced adenoma: adenoma ≥10 mm, villous histology (>25%), high-grade dysplasia, or early invasive cancer	Advanced adenoma: adenoma ≥10 mm, ≥20% villous component, or high-grade dysplasia	Advanced colorectal neoplasia: advanced adenoma or advanced serrated polyp

	serrated lesion ≥10 mm, SSP with dysplasia, or traditional serrated adenoma			
Primary Outcome	Projected change in surveillance intervals after CADe adoption	Primary: ADR; Secondary: APC, advanced ADR, SSL detection	Primary: ADR; Secondary: APC, SSL detection rate	Primary: advanced colorectal neoplasia detection rate
Key Findings	CADe increased polyp detection rate from 50.6% to 64.6% and ADR from 38% to 47.7%, but no increase in advanced adenoma detection; 19.1% of patients would have shortened surveillance intervals under USMSTF guideline	CADe significantly increased ADR (53.6% vs 45.3%; RR 1.18) but no significant difference in advanced adenoma detection (18.5% vs 15.9%)	CADe increased ADR (42.5% vs 34.4%; RR 1.18) and APC but no difference in advanced adenoma detection	No difference in advanced neoplasia detection between CADe and standard colonoscopy
Follow-up / Verification Method	Colonoscopy database with histologic confirmation; modeling via bootstrapping simulation	Histopathology evaluation according to WHO/Vienna classification	Histopathologic confirmation using WHO/Vienna classification	Histopathology confirmation of lesions
Risk of Bias	Moderate	Low	Low	Low
Notes	Simulation study; no direct CADe vs standard colonoscopy comparison; cannot provide pooled effect size	FIT-positive screening population; highly relevant to your PICO	Community-practice pragmatic RCT; mixed indications	One of the few RCTs specifically designed for advanced neoplasia detection

Source: Compiled from Lui et al., 2023; Rondonotti et al., 2022; Thiruvengadam et al., 2024; Mas-Sanjuan et al., 2023

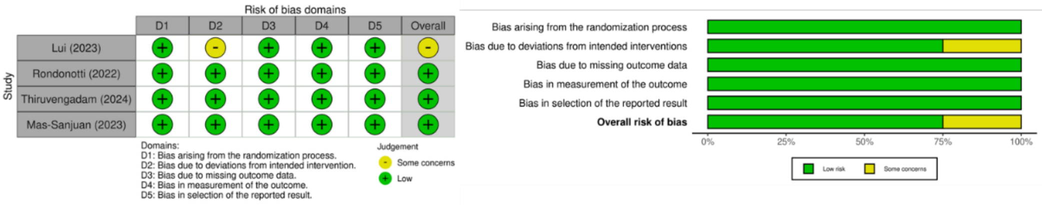

Figure 2. Risk of bias assessment results using RoB-2 Tools from cochrane

Source: Assessment conducted using Cochrane RoB-2. Sterne JAC, et al. BMJ 2019;366:l4898

RESULTS AND DISCUSSION

Study Selection

The systematic literature search was conducted across three major electronic databases: PubMed, Cochrane Library, and ScienceDirect. The search strategy yielded a total of 1,303 records, consisting of 665 records from PubMed, 360 records from the Cochrane Library, and

278 records from ScienceDirect. These records were imported into the screening process and evaluated according to the predefined eligibility criteria.

During the initial title and abstract screening, a substantial proportion of studies were excluded because they were not directly related to the research question. Specifically, studies focusing on artificial intelligence applications in gastrointestinal imaging without colonoscopy, AI-assisted histopathological analysis, capsule endoscopy, computer-aided diagnosis rather than detection systems, and studies unrelated to colorectal neoplasia detection were removed. As a result, 1,297 records were excluded at this stage, leaving six potentially relevant articles for further evaluation.

The remaining studies underwent duplicate screening, during which one duplicate record was identified and removed. This process resulted in five unique articles eligible for full-text assessment. The full texts of these articles were carefully reviewed to determine whether they met the inclusion criteria regarding population, intervention, comparator, and outcome measures.

After full-text evaluation, one article was excluded because it did not meet the eligibility criteria. The excluded study involved an inappropriate population and outcome reporting, which prevented meaningful extraction of the required data for meta-analysis. Consequently, four studies fulfilled all inclusion criteria and were included in the final analysis.

Ultimately, four studies were included in both the qualitative synthesis and quantitative meta-analysis. These studies provided sufficient comparative data on adenoma detection outcomes between AI-assisted colonoscopy (CADe) and conventional colonoscopy. The overall study selection process is summarized in the PRISMA (Page et al., 2021) flow diagram shown in Figure 1, illustrating each stage of identification, screening, eligibility assessment, and final inclusion (Sterne et al., 2019).

Study Characteristics

The present meta-analysis included four studies that investigated the effectiveness of artificial intelligence–assisted colonoscopy using computer-aided detection (CADe) systems compared with standard colonoscopy without AI assistance in detecting colorectal neoplastic lesions. These studies were published between 2022 and 2024, reflecting the relatively recent emergence of deep learning–based CADe technologies in gastrointestinal endoscopy.

Across the four included studies, a total of 10,483 colonoscopy procedures were analyzed, including 5,250 procedures performed with AI-assisted colonoscopy and 5,233 procedures performed using conventional colonoscopy. The studies were conducted in different geographical regions and clinical environments, including organized colorec tal cancer screening programs and real-world community practice settings, thereby providing a diverse representation of colonoscopy practice.

Two of the included studies Rondonotti et al. (2022) and Mas-Sanjuan et al. (2023) were conducted within fecal immunochemical test (FIT)-based colorectal cancer screening programs, enrolling individuals with a positive FIT result who were referred for colonoscopy. These studies are particularly relevant to the present research question because FIT-positive populations represent a higher-risk subgroup with an increased prevalence of colorectal neoplasia, making them an ideal setting for evaluating the potential clinical benefit of AI-assisted detection systems.

Another study, (Thiruvengadam et al., 2024) was designed as a pragmatic randomized controlled trial conducted in a community gastroenterology practice. This study included patients undergoing colonoscopy for a variety of indications, including screening, surveillance, positive

FIT testing, and diagnostic evaluation. The pragmatic design of this trial allowed the investigators to assess the real-world performance of CADe systems outside the controlled conditions typically present in screening trials.

The fourth study, Lui et al. (2023), employed a simulation-based analytical approach using a large colonoscopy dataset to estimate the potential impact of CADe implementation on polyp and adenoma detection outcomes. Although this study did not directly randomize patients to AI-assisted or conventional colonoscopy, it provided valuable insights into the projected changes in detection rates following the adoption of CADe technology.

Across the included studies, CADe systems were integrated into colonoscopy platforms to provide real-time visual alerts highlighting suspected colorectal lesions during endoscopic withdrawal. These systems rely on deep learning algorithms trained on large image datasets to identify subtle mucosal abnormalities that may be overlooked during conventional visual inspection.

The primary outcome evaluated in the present meta-analysis was the adenoma detection rate (ADR), defined as the proportion of colonoscopies in which at least one histologically confirmed adenoma was detected. ADR is widely recognized as a key quality indicator in colonoscopy and has been strongly associated with a reduced risk of interval colorectal cancer. Secondary outcomes reported in some of the included studies included polyp detection rate, serrated lesion detection rate, and advanced neoplasia detection rate, although these outcomes were not consistently reported across all studies.

Overall, the included studies represent a mixture of randomized controlled trials and large observational or simulation-based analyses, providing a comprehensive overview of CADe performance in different clinical settings. The characteristics and main findings of the included studies are summarized in Table 1.

Quantitative Synthesis: Adenoma Detection Rate

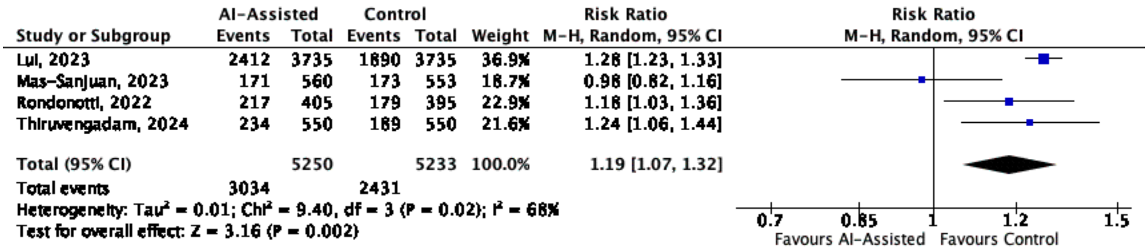

Figure 3. Pooled results for adenoma detection rate (ADR)

Source: Meta-analysis conducted using RevMan. Data from Lui et al., 2023; Rondonotti et al., 2022; Thiruvengadam et al., 2024; Mas-Sanjuan et al., 2023

All four included studies reported data on adenoma detection rate (ADR) comparing AI-assisted colonoscopy with conventional colonoscopy. ADR represents one of the most widely used quality indicators in colonoscopy because it reflects the ability of endoscopists to detect precancerous lesions that may progress to colorectal cancer if left untreated.

In the pooled dataset, 5,250 colonoscopy procedures were performed using CADe-assisted colonoscopy, while 5,233 procedures were conducted using conventional colonoscopy. Across these procedures, 3,034 adenomas were detected in the CADe group, compared with 2,431 adenomas detected in the control group. This difference suggests a higher detection yield when artificial intelligence was incorporated into the colonoscopy procedure.

Meta-analysis was performed using a Mantel–Haenszel random-effects model, which accounts for potential variability among studies arising from differences in study design, population characteristics, and clinical settings. The pooled analysis demonstrated that AI-assisted colonoscopy significantly improved adenoma detection compared with conventional colonoscopy, with a pooled risk ratio (RR) of 1.19 (95% confidence interval [CI]: 1.07–1.32).

This pooled estimate indicates that the use of CADe technology increased the likelihood of detecting at least one adenoma during colonoscopy by approximately 19% relative to conventional colonoscopy. The effect was statistically significant, as indicated by the overall test for effect ($Z = 3.16$, $p = 0.002$).

However, the analysis also revealed moderate to substantial heterogeneity among the included studies, with $I^2 = 68\%$, $\tau^2 = 0.01$, and $\chi^2 = 9.40$ ($df = 3$, $p = 0.02$). This level of heterogeneity suggests that the magnitude (Zhao et al., 2019) of the CADe effect varied across studies, which may be attributable to several factors. These factors include differences in patient populations, colonoscopy indications, baseline adenoma detection rates among endoscopists, and variations in CADe system algorithms and implementation.

Despite the observed heterogeneity, the direction of effect across studies was largely consistent, with all studies demonstrating a tendency toward higher adenoma detection rates in the AI-assisted colonoscopy group. The individual study estimates ranged from modest to moderate increases in detection rates, but the overall pooled estimate consistently favored CADe-assisted colonoscopy.

Among the included studies, (Rittl et al., 2025) contributed the largest weight to the pooled estimate because of its large dataset, followed by (Rondonotti et al., 2022), (Thiruvengadam et al., 2024), and (Mangas-Sanjuan et al., 2023). Although the magnitude of the effect differed among studies, the combined analysis demonstrated a clear overall benefit of AI-assisted colonoscopy in improving adenoma detection.

The results of the meta-analysis are summarized in the forest plot presented in Figure 2, which illustrates the individual study estimates and the pooled effect size. Overall, the findings suggest that the integration of artificial intelligence–based CADe systems into colonoscopy procedures may significantly enhance the detection of adenomas, thereby potentially improving the effectiveness of colorectal cancer screening programs.

Summary of the Main Findings

The present meta-analysis evaluated the effectiveness of artificial intelligence–assisted colonoscopy using computer-aided detection (CADe) systems in improving the detection of colorectal adenomas. By pooling data from four eligible studies comprising 10,483 colonoscopy procedures, this analysis demonstrated that CADe-assisted colonoscopy significantly increased the adenoma detection rate (ADR) compared with conventional colonoscopy. The pooled effect estimate indicated a 19% relative increase in adenoma detection, suggesting that the integration of artificial intelligence into colonoscopic procedures may substantially enhance lesion detection performance.

ADR is widely regarded as the most important quality indicator in colonoscopy because of its well-established association with colorectal cancer prevention. Previous large-scale studies have demonstrated that endoscopists with higher ADRs have significantly lower rates of interval colorectal cancer among their patients. Therefore, improvements in ADR, even relatively modest ones, may translate into meaningful reductions in the long-term risk of colorectal cancer and

CRC-related mortality. The findings of this meta-analysis therefore support the growing body of evidence suggesting that CADe systems can improve colonoscopy quality by assisting endoscopists in detecting adenomas that might otherwise be overlooked.

However, an important observation emerging from the included studies is that improvements in overall ADR were not consistently accompanied by increases in the detection of advanced colorectal neoplasia, including advanced adenomas and other high-risk lesions. This pattern has been increasingly recognized in the literature and suggests that the benefits of CADe systems may primarily involve the detection of smaller or diminutive adenomas rather than lesions with the greatest malignant potential. This distinction has important implications for understanding the true clinical value of artificial intelligence in colorectal cancer screening.

Interpretation of the Findings

The improved adenoma detection observed with CADe-assisted colonoscopy can be explained by several technological and procedural factors. CADe systems utilize deep learning–based computer vision algorithms trained on large datasets of colonoscopic images and videos. These algorithms are capable of analyzing endoscopic frames in real time and identifying patterns consistent with colorectal polyps. When a potential lesion is detected, the system generates a visual alert on the monitor, prompting the endoscopist to examine the highlighted region more closely.

In conventional colonoscopy, lesion detection relies entirely on the endoscopist’s visual perception and attention. Human factors such as fatigue, distraction, variable inspection techniques, and perceptual limitations can contribute to missed lesions. Artificial intelligence systems act as a continuous “second observer,” scanning the entire endoscopic field and potentially identifying lesions that may be overlooked during routine examination.[6] By reducing perceptual errors and improving visual attention to subtle mucosal abnormalities, CADe systems can therefore increase the likelihood that small adenomas are detected and removed.

Another important factor contributing to improved ADR with CADe systems is the enhanced detection of flat and subtle lesions, which can be particularly difficult to recognize during conventional colonoscopy. Flat adenomas often exhibit minimal elevation and subtle color differences relative to the surrounding mucosa, making them challenging to identify even for experienced endoscopists. AI-assisted detection may improve visualization of these lesions by highlighting suspicious areas during withdrawal, allowing the endoscopist to inspect the region more carefully.

Despite these advantages, the impact of CADe on advanced neoplasia detection appears to be less pronounced. Advanced adenomas are typically larger and more morphologically conspicuous than diminutive lesions, making them easier to identify even without AI assistance. Consequently, the incremental benefit of CADe for detecting advanced lesions may be smaller than its benefit for detecting small polyps. This phenomenon may explain why several trials have reported substantial increases in ADR without corresponding improvements in advanced adenoma detection rates.

Comparison with Previous Studies

The results of the present meta-analysis are consistent with findings from previous randomized trials and systematic reviews investigating the role of artificial intelligence in colonoscopy. Early clinical trials evaluating CADe systems demonstrated that real-time AI assistance significantly improved adenoma detection compared with conventional colonoscopy.

These studies suggested that AI-assisted colonoscopy could serve as a valuable tool for improving colonoscopy quality and reducing missed lesions during endoscopic examination.

Subsequent systematic reviews have also confirmed the beneficial effect of AI-assisted colonoscopy on ADR. Pooled analyses of randomized controlled trials have reported improvements in adenoma detection ranging from approximately 10% to 30%, depending on study design, patient populations, and CADe systems used. These findings support the growing consensus that artificial intelligence has the potential to enhance lesion detection during colonoscopy and may contribute to improved colorectal cancer prevention strategies.

However, previous studies have also highlighted the important distinction between overall adenoma detection and advanced neoplasia detection. In several trials conducted within organized colorectal cancer screening programs, CADe systems increased the detection of diminutive adenomas but did not significantly improve the detection of advanced lesions. This observation has raised questions about the clinical significance of AI-driven improvements in ADR.

One possible explanation for this phenomenon is that advanced lesions are already detected at relatively high rates during standard colonoscopy. Because advanced adenomas are typically larger and more visually apparent, experienced endoscopists may already identify these lesions with high accuracy. In contrast, smaller lesions are more susceptible to perceptual errors and therefore benefit more from automated detection systems.

Clinical Implications

The integration of artificial intelligence technologies into colonoscopy practice represents one of the most important recent innovations in gastrointestinal endoscopy. By improving adenoma detection rates, CADe systems may contribute to enhanced colonoscopy quality and potentially reduce the risk of interval colorectal cancer. Given the strong association between ADR and long-term CRC outcomes, technologies that improve detection performance may have meaningful implications for colorectal cancer prevention.

In addition to improving detection performance, CADe systems may help reduce variability in colonoscopy quality among endoscopists. Previous research has demonstrated substantial variation in ADR among practitioners, with lower-performing endoscopists associated with higher rates of interval colorectal cancer. Artificial intelligence systems may help standardize detection performance by providing consistent visual support during colonoscopy, thereby narrowing the gap between high- and low-performing endoscopists.

CADe systems may also serve as valuable educational tools for endoscopists. By repeatedly highlighting subtle lesions during procedures, these systems may reinforce visual recognition patterns and help endoscopists develop improved lesion detection skills over time. This learning effect could potentially contribute to long-term improvements in colonoscopy performance even in the absence of AI assistance.

However, the widespread adoption of AI-assisted colonoscopy also raises several practical considerations. Increased detection of diminutive lesions may lead to higher numbers of polypectomies and potentially greater surveillance colonoscopy demand. In addition, healthcare systems must consider the cost of implementing AI technology and integrating CADe systems into existing endoscopy platforms. These factors should be carefully evaluated to ensure that the benefits of AI-assisted colonoscopy outweigh the associated resource requirements.

Limitations

Several limitations should be considered when interpreting the findings of this meta-analysis. First, the number of included studies was relatively small, which may limit the robustness of the pooled estimates. Although the included studies collectively analyzed more than ten thousand colonoscopy procedures, additional large randomized controlled trials would provide stronger evidence regarding the effectiveness of CADe systems.

Second, moderate heterogeneity was observed among the included studies. Differences in study design, patient populations, colonoscopy indications, and AI system platforms may have contributed to variability in the magnitude of the observed effects. Some studies were conducted in organized FIT-based screening programs, whereas others included broader patient populations undergoing colonoscopy for multiple indications.

Third, one of the included studies used a simulation-based approach rather than a randomized clinical design, which may introduce methodological differences compared with traditional clinical trials. Although simulation studies can provide valuable insights into potential detection improvements, their findings should be interpreted cautiously when pooled with clinical trial data.

Finally, most of the included studies evaluated short-term outcomes such as adenoma detection rate rather than long-term clinical outcomes. As a result, the extent to which improvements in ADR translate into reductions in colorectal cancer incidence and mortality remains to be fully determined.

Future Research

Future research should focus on evaluating the impact of AI-assisted colonoscopy on clinically meaningful outcomes beyond adenoma detection. Large multicenter trials conducted within organized screening programs will be important for determining whether CADe implementation leads to reductions in interval colorectal cancer and long-term CRC mortality.

Additionally, the development of computer-aided diagnosis (CADx) systems may represent the next major advancement in AI-assisted endoscopy. CADx systems are designed to characterize detected lesions in real time, enabling endoscopists to differentiate between neoplastic and non-neoplastic polyps during the procedure. Combining detection and diagnostic capabilities may further enhance the effectiveness of AI-assisted colonoscopy and improve decision-making regarding polyp management.

Ongoing improvements in deep learning algorithms, training datasets, and endoscopic imaging technologies are likely to further enhance the performance of artificial intelligence systems in gastrointestinal endoscopy. Continued evaluation of these technologies will be essential to determine their optimal role in colorectal cancer screening and prevention strategies.

CONCLUSION

This meta-analysis demonstrated that artificial intelligence–assisted colonoscopy using computer-aided detection (CADe) systems significantly improved the adenoma detection rate (ADR) compared with conventional colonoscopy. The pooled analysis showed a meaningful increase in adenoma detection with AI assistance, suggesting that CADe technology can enhance lesion recognition during colonoscopic examinations and potentially improve the overall quality of colorectal cancer screening.

Although CADe-assisted colonoscopy was associated with higher ADR, the available evidence indicated that these improvements were largely driven by increased detection of small or diminutive adenomas rather than advanced colorectal neoplasia. This finding highlighted the need for further research to determine whether AI-assisted colonoscopy can produce clinically meaningful reductions in colorectal cancer incidence and mortality.

Overall, the integration of artificial intelligence into colonoscopy represents a promising technological advancement that may support endoscopists in improving detection performance and standardizing colonoscopy quality across different clinical settings. Future large-scale randomized studies are needed to further evaluate the long-term clinical impact of AI-assisted colonoscopy in colorectal cancer prevention.

REFERENCES

Ali, H., Muzammil, M. A., Dahiya, D. S., Ali, F., Yasin, S., & Hanif, W. (2024). Artificial intelligence in gastrointestinal endoscopy: a comprehensive review. *Annals of Gastroenterology, 37*(2), 133–141. https://doi.org/10.20524/aog.2024.0861

Barua, I., Vinsard, D. G., Jodal, H. C., Løberg, M., Kalager, M., & Holme, Ø. (2021). Artificial intelligence for polyp detection during colonoscopy: a systematic review and meta-analysis. *Endoscopy, 53*(3), 277–284. https://doi.org/10.1055/a-1201-7165

Corley, D. A., Jensen, C. D., Marks, A. R., Zhao, W. K., Lee, J. K., & Doubeni, C. A. (2014). Adenoma detection rate and risk of colorectal cancer and death. *New England Journal of Medicine, 370*(14), 1298–1306. https://doi.org/10.1056/NEJMoa1309086

Dimopoulou, K., Spinou, M., Ioannou, A., Nakou, E., Zormpas, P., & Tribonias, G. (2025). Artificial intelligence in colonoscopy: Enhancing quality indicators for optimal patient outcomes. *World Journal of Gastroenterology, 31*(40), 111499. https://doi.org/10.3748/wjg.v31.i40.111499

Hassan, C., Spadaccini, M., Iannone, A., Maselli, R., Jovani, M., & Chandrasekar, V. T. (2021). Performance of artificial intelligence in colonoscopy for adenoma and polyp detection: a systematic review and meta-analysis. *Gastrointestinal Endoscopy, 93*(1), 77-85.e6. https://doi.org/10.1016/j.gie.2020.06.059

Imperiale, T. F., Ransohoff, D. F., Itzkowitz, S. H., Levin, T. R., Lavin, P., & Lidgard, G. P. (2014). Multitarget stool DNA testing for colorectal-cancer screening. *New England Journal of Medicine, 370*(14), 1287–1297. https://doi.org/10.1056/NEJMoa1311194

Kaminski, M. F., Regula, J., Kraszewska, E., Polkowski, M., Wojciechowska, U., & Didkowska, J. (2010). Quality indicators for colonoscopy and the risk of interval cancer. *New England Journal of Medicine, 362*(19), 1795–1803. https://doi.org/10.1056/NEJMoa0907667

Kaminski, R. (2024). *Poverty Alleviation Strategies: Pathways to Sustainable Development*. DevelopmentAid.org. https://www.developmentaid.org/news-stream/post/182680/poverty-alleviation-strategies

Maas, M. H. J., Rath, T., & Spada, C. (2024). A computer-aided detection system in the everyday setting of diagnostic, screening, and surveillance colonoscopy: an international, randomized trial. *Endoscopy, 56*(11), 843–850. https://doi.org/10.1055/a-2328-2844

Mangas-Sanjuan, C., de-Castro, L., Cubiella, J., Díez-Redondo, P., Suárez, A., & Pellisé, M. (2023). Role of Artificial Intelligence in Colonoscopy Detection of Advanced Neoplasias: A Randomized Trial. *Annals of Internal Medicine, 176*(9), 1145–1152. https://doi.org/10.7326/M22-2619

Page, M. J., McKenzie, J. E., Bossuyt, P. M., Boutron, I., Hoffmann, T. C., Mulrow, C. D., Shamseer, L., Tetzlaff, J. M., Akl, E. A., Brennan, S. E., Chou, R., Glanville, J., Grimshaw, J. M., Hróbjartsson, A., Lalu, M. M., Li, T., Loder, E. W., Mayo-Wilson, E., McDonald, S., … Moher, D. (2021). The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. *BMJ, 372*, n71. https://doi.org/10.1136/bmj.n71

Rabba, W., Asif, F., Younis, M. Y., Nasrullah, H., Fatima, L., & Arif, M. A. (2025). Artificial Intelligence in Colonoscopy: A Systematic Review of Adenoma Versus Polyp Detection Rates. *Cureus*, *17*(12), e98528. https://doi.org/10.7759/cureus.98528

Repici, A., Badalamenti, M., Maselli, R., Correale, L., Radaelli, F., & Rondonotti, E. (2020). Efficacy of Real-Time Computer-Aided Detection of Colorectal Neoplasia in a Randomized Trial. *Gastroenterology*, *159*(2), 512-520.e7. https://doi.org/10.1053/j.gastro.2020.04.062

Rittl, L. G. F., Zaman, A., & de Oliveira, F. H. (2025). Digital Transformation in Waste Management: Disruptive Innovation and Digital Governance for Zero-Waste Cities in the Global South as Keys to Future Sustainable Development. *Sustainability (Switzerland)*, *17*(4). https://doi.org/10.3390/su17041608

Rondonotti, E., D, D. P., Rizzotto, E. R., Alvisi, C., Buscarini, E., & Spadaccini, M. (2022). Efficacy of a computer-aided detection system in a fecal immunochemical test-based organized colorectal cancer screening program: a randomized controlled trial (AIFIT study). *Endoscopy*, *54*(12), 1171–1179. https://doi.org/10.1055/a-1849-6878

Sterne, J. A. C., Savović, J., Page, M. J., Elbers, R. G., Blencowe, N. S., Boutron, I., Cates, C. J., Cheng, H.-Y., Corbett, M. S., Eldridge, S. M., Emberson, J. R., Hernán, M. A., Hopewell, S., Hróbjartsson, A., Junqueira, D. R., Jüni, P., Kirkham, J. J., Lasserson, T., Li, T., … Higgins, J. P. T. (2019). RoB 2: a revised tool for assessing risk of bias in randomised trials. *BMJ*, *366*, l4898. https://doi.org/10.1136/bmj.l4898

Sung, H., Ferlay, J., Siegel, R. L., Laversanne, M., Soerjomataram, I., & Jemal, A. (2021). Global Cancer Statistics 2020: GLOBOCAN Estimates of Incidence and Mortality Worldwide for 36 Cancers in 185 Countries. *CA: A Cancer Journal for Clinicians*, *71*(3), 209–249. https://doi.org/10.3322/caac.21660

Thiruvengadam, N. R., Solaimani, P., Shrestha, M., Buller, S., Carson, R., & Reyes-Garcia, B. (2024). The Efficacy of Real-time Computer-aided Detection of Colonic Neoplasia in Community Practice: A Pragmatic Randomized Controlled Trial. *Clinical Gastroenterology and Hepatology*, *22*(11), 2221-2230.e15. https://doi.org/10.1016/j.cgh.2024.02.021

Wang, P., Berzin, T. M., Glissen Brown, J. R., Bharadwaj, S., Becq, A., & Xiao, X. (2019). Real-time automatic detection system increases colonoscopic polyp and adenoma detection rates: a prospective randomised controlled study. *Gut*, *68*(10), 1813–1819. https://doi.org/10.1136/gutjnl-2018-317500

Zhao, S., Wang, S., Pan, P., Xia, T., Chang, X., & Yang, X. (2019). Magnitude, Risk Factors, and Factors Associated With Adenoma Miss Rate of Tandem Colonoscopy: A Systematic Review and Meta-analysis. *Gastroenterology*, *156*(6), 1661-1674.e11. https://doi.org/10.1053/j.gastro.2019.01.260