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Enhancing Early Detection: An Analysis of Screening Methods for Colorectal Cancer

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Abstract

Colorectal cancer (CRC) remains a leading cause of cancer-related deaths globally, but its incidence and mortality have significantly decreased with proactive screening. Nevertheless, effective screening methods, such as colonoscopy, stool DNA, and FIT, have not been widely adopted, particularly among marginalized communities. Understanding how to implement these screening methods, the barriers to their utilization, and the potential of new approaches to expand screening is essential. This study aimed to assess the effectiveness of existing CRC screening methods, identify obstacles to their broader use, and evaluate new methods that could enhance early-stage diagnosis rates. A structured narrative literature review was conducted, drawing on peer-reviewed studies, clinical trial reports, and published screening guidelines from PubMed, Scopus, and Web of Science. The evidence was organized thematically around three key areas: the effectiveness of screening methods, barriers to implementation, and emerging diagnostic technologies. The review found that colonoscopy offers the highest diagnostic yield and the singular advantage of immediate polypectomy, but its invasiveness, cost, and endoscopic capacity requirements substantially limit uptake, particularly in low-income populations. Non-invasive alternatives—principally FIT and multi-target stool DNA testing—demonstrate sufficient cancer detection performance to serve as effective primary screening tools, with considerably higher patient participation rates in population-based programs. Structural and socioeconomic barriers, including cost, limited healthcare access, and low health literacy, remain the primary determinants of screening inequity. Emerging technologies, such as blood-based circulating tumor DNA assays and wireless capsule endoscopy, show early clinical promise but require further prospective validation and cost reduction prior to large-scale adoption. This review concludes that no single modality simultaneously fulfills all clinical, economic, and equity requirements for an effective population-wide CRC screening programme. A risk-stratified, multi-modal

approach—integrating non-invasive primary screening with targeted colonoscopy for confirmatory assessment and high-risk surveillance—represents the most clinically defensible and equitable strategy. Sustained investment in health education, subsidized access, and emerging diagnostic technologies is essential to reducing CRC-attributable mortality at a global scale.

Subject Areas

Oncology

Keywords

Colorectal Cancer (CRC), Cancer Screening, Colonoscopy, Fecal Immunochemical Test (FIT), Stool DNA Testing, Early Detection, Molecular Diagnostics, Health Equity

1. Introduction

Colorectal cancer (CRC) is among the most prevalent malignancies worldwide, ranking third in incidence and second in cancer-related mortality globally. According to the American Statistics Chart, CRC is the third most commonly diagnosed cancer in the United States, accounting for more than 140,000 new cases in 2018 [1]. According to epidemiological figures, almost a million cases of cancer are newly diagnosed and approximately 601,000 succumb to this disease [2]. CRC is a debilitating disease that is more common in developed countries; however, the increasing number of cases in younger populations calls for quick action in applying regular measures [3].

CRC is a significant form of cancer that can be properly managed. The CRC audit process is usually lengthy, and it takes years for malignancy to develop after the formation of adenomatous polyps [3]. The removal of such polyps, especially before they evolve into malignant tumors, can greatly reduce the chances of cancer, with more than 90% of survivors surviving if CRC is detected in the early stages [3]. Without screening, symptoms often emerge only at advanced stages, significantly reducing treatment efficacy [4] [5].

Significant technological progress over the past two decades has broadened the range of available CRC screening modalities and improved the feasibility of early-stage detection. Colonoscopy, flexible sigmoidoscopy, guaiac-based faecal occult blood testing (gFOBT), and faecal immunochemical testing (FIT) have each contributed to measurable reductions in CRC incidence and disease-specific mortality in populations where screening programs have been systematically implemented [1] [6]. More recently, multi-target stool DNA testing and blood-based molecular assays have further expanded the diagnostic landscape. These modalities differ substantially in their sensitivity, invasiveness, procedural requirements, cost, and patient acceptability—differences that carry significant clinical and public health implications. A systematic comparative evaluation of these methods,

drawing on the published evidence from January 2000 to December 2024, is presented in Section 2.

The development and refinement of CRC screening strategies have advanced in parallel with broader healthcare system reforms that increasingly prioritize preventive medicine over reactive treatment.

Early detection not only improves patient survival but also substantially reduces the high costs associated with treating late-stage colorectal cancer. Modelling analyses show that CRC screening programs generate significant cost savings compared to no screening, largely by decreasing the number of advanced-stage cases that require intensive and expensive treatment [5] [7]. Despite these developments, barriers such as limited public awareness, the absence of health insurance coverage, and low screening uptake continue to restrict the reach of CRC screening programs [8] [9]. Hence, there is always a need to focus on extending barriers, lowering prices, and enhancing awareness to minimize the burden of colorectal cancer on communities. This study sought to assess current colorectal cancer screening practices, the reasons for their limited use, and demonstrate how new healthcare technologies could be used to facilitate detection and treatment, particularly in vulnerable populations.

2. Literature Review

2.1. Overview of Existing Screening Methods

The effectiveness of colorectal cancer (CRC) screening in early malignant cases greatly depends on the accepted screening methods, such as colonoscopy, stool occult blood test (FOBT), and flexible sigmoidoscopy [8]. Colonoscopy is the most widely used examination for screening and is commonly regarded as the "gold standard". Colonoscopy involves the identification and removal of tissue structures known as polyps during the procedure. Subsequently, the practice has been linked to a considerable decrease in the rates of CRC development and death from CRC owing to its ability to detect precancerous growths and prevent them from developing into widespread malignancy [10]. However, its high cost, invasive nature, and need for sedation make it less available and adherent to patients. Flexible sigmoidoscopy is a less invasive variant of colonoscopy that enables endoscopic examination of the distal colon; however, its scope is limited to the rectum and sigmoid colon, precluding assessment of the proximal colon, where a significant proportion of CRC lesions arise [10].

Among noninvasive tests, guaiac-based fecal occult blood testing and more advanced fecal immunochemical tests have become popular for CRC screening. The gFOBT, a form of screening for hidden blood in stool, has been estimated to reduce CRC mortality by up to 16% [8] [11]. This method is limited in scope because it has low sensitivity in diagnosing adenomas. Compared with gFOBT, FIT offers several practical advantages: it does not require dietary restrictions prior to sample collection, does not necessitate multiple sampling days, and is simpler to perform independently at home. Crucially, FIT is also substantially more analytically sen-

sitive and specific for human haemoglobin, making it a superior detection tool for occult blood in stool samples [8] [10]. Research supports these results, stating that FITs exhibit improved rates of detection of both CRC and advanced adenomas, coupled with higher patient compliance owing to the noninvasive nature of the test and the absence of dietary preparatory requirements [10] [11].

Beyond these established methods, two other approaches are gaining increasing attention: CT colonography (virtual colonoscopy) and stool DNA testing. CT colonography is considerably less invasive than traditional colonoscopy, but it still requires bowel preparation and is less sensitive at detecting small polyps [12]. Stool DNA testing identifies cancer-associated genetic and epigenetic alterations in cells shed from the colonic epithelium. Multi-target stool DNA tests have demonstrated high sensitivity for established colorectal cancers and for large, high-grade advanced adenomas; however, their sensitivity for early-stage, non-advanced adenomas—lesions smaller than 10 mm lacking high-grade dysplasia—is substantially lower than that achievable through direct colonoscopic visualization [13] [14]. This distinction between cancer detection performance and adenoma detection performance is clinically important and is reflected in the comparative ratings in **Table 1**.

Nonetheless, these technologies being rather new have not found widespread use in terms of economic accessibility in terms of cost.

A clinically important distinction emerges from the published evidence when comparing these modalities: colonoscopy is unique in combining detection with immediate therapeutic intervention. Unlike non-invasive tests, which identify biological markers of existing disease or advanced precancerous changes, colonoscopy enables the direct visualization and removal of adenomatous polyps at the point of identification, thereby interrupting the adenoma-to-carcinoma sequence before malignant transformation occurs [8] [10]. This distinction—between cancer detection and active cancer prevention through polypectomy—is critical for interpreting the comparative performance data presented in Section 2.2 and informs the clinical implications discussed in Section 4.2.

2.2. Comparative Effectiveness of Different Screening Methods

Direct comparative studies consistently demonstrate that colonoscopy achieves the highest detection rates for both adenomas and established colorectal cancers among all currently available screening modalities. This is because it is possible to identify and remove adenomas during the procedure. Studies indicate that CRC incidence rates decrease by up to 90% among individuals chronically screened using colonoscopy [15]. Nevertheless, the need for colonoscopy invasiveness and a higher cost limit the widespread use of this screening method in some populations, including low-income populations [8].

Among non-invasive approaches, FIT has consistently outperformed gFOBT in both sensitivity and specificity, demonstrating higher detection rates for established CRC and advanced adenomas in direct comparative studies [8] [15]. It has

Table 1. Comparative summary of CRC screening modalities.

Modality	Cancer Detection	Adenoma Detection	Patient Uptake	Major Harms	Follow-up Requirement	Risk Group Suitability
Colonoscopy	High (gold standard)	High; direct polypectomy	Lower; bowel prep required	Perforation ~0.085 - 0.1/1000; Bleeding ~1.64/1000	10-year interval (average risk)	All risk groups; preferred for high risk
Flexible Sigmoidoscopy	Moderate; distal colon only	Moderate; distal only	Moderate	Lower than colonoscopy	5 years; colonoscopy if positive	Average risk; limited for proximal lesions
gFOBT	Moderate; reduces CRC mortality ~16%	Low sensitivity	High; home-based	Nil direct procedural harm	Annual colonoscopy if positive	Average risk in low-resource settings
FIT	Higher than gFOBT; sensitive for Hb	Moderate; better than gFOBT	High; no dietary restriction	Nil direct procedural harm	Annual; colonoscopy if positive	Average risk; well-suited for population screening
Stool DNA	High for cancer; higher than FIT	Lower for adenomas	Moderate	Nil direct procedural harm	1 - 3 years; colonoscopy if positive	Average risk; higher false-positive rate
CT Colonography	Moderate; less sensitive for small lesions	Moderate	Moderate; requires bowel prep	Low radiation exposure	5 years; colonoscopy if positive	Average risk; useful when colonoscopy is contraindicated
WCE/Molecular (ctDNA, miRNA)	Promising; under clinical validation	Under validation	Variable; cost limits access	Minimal (WCE); non-invasive (molecular)	Emerging; intervals not yet standardized	High risk or colonoscopy ineligibility; research settings

*Adenoma detection ratings refer specifically to sensitivity for non-advanced, early-stage adenomas (lesions < 10 mm in diameter without high-grade dysplasia), where inter-modality differences are most clinically consequential. All modalities demonstrate comparatively higher sensitivity for advanced adenomas (diameter ≥ 10 mm, high-grade dysplasia, or villous architecture). Colonoscopy uniquely enables immediate therapeutic polypectomy at the point of detection, providing a primary cancer prevention function not replicable by detection-only non-invasive tests. FIT performance data reflect haemoglobin concentration thresholds applied in population-based screening programs. ADR = Adenoma Detection Rate.

been shown that FIT brings higher participation rates in screening programs and improves the diagnostic yield of advanced neoplasia compared to gFOBT [8] [15]. Although not as extensive as colonoscopy, flexible sigmoidoscopy can achieve greater efficacy than colonoscopic screening in detecting CRC in the distal colon when performed periodically with FIT [15]. Comparative analyses of participation rates have consistently favoured FIT over colonoscopy in population-based settings [11] [16].

Newer techniques, such as stool DNA testing and CT colonography, are also becoming available, yet they differ in their effectiveness.

Stool DNA tests are a well-validated non-invasive method for CRC detection and demonstrate high sensitivity for advanced neoplasia; however, their sensitivity for early-stage, non-advanced adenomas—the pre-malignant lesions most amenable to preventive removal—is substantially lower than that achievable through

colonoscopy, limiting their contribution to primary cancer prevention in this specific lesion category [12]-[14]. This limitation is most clinically significant in younger patients and in populations with a higher prevalence of non-advanced adenomas. Colon CT scans for anatomical imaging are also promising; however, they are less sensitive than colonoscopy, especially in identifying minute lesions, and require further invasive examination through colonoscopy to obtain histopathological confirmation [12].

2.3. Age and Risk Factors Influencing the Need for Screening

Age, in particular, is one of the major risk factors for CRC, with the incidence being higher in those aged > 50 years. The majority of screening guidelines, therefore, suggest that average-risk people should start stool testing at approximately 50 years of age, although some recent guidelines have endorsed commencing at the earlier age of forty-five [4] [17]. Factors such as a family history of CRC, hereditary syndromes such as Lynch syndrome, and other risk factors, including diet and tobacco use, also determine recommendations for screening [10]. Individuals in high-risk groups with a history of CRC or inflammatory bowel disease need more regular surveillance and can often be considered for screening colonoscopy at an earlier age [12]. In such high-risk individuals, colonoscopy is the recommended primary screening modality and should be initiated at an earlier age and with a shorter inter-examination interval than guidelines specify for average-risk populations, owing to the substantially elevated probability of malignant transformation [12] [18].

2.4. Recent Technological Advancements in Screening and Detection

New technologies have been targeting the improvement of non-invasive techniques and promoting the early detection of CRC. A cutting-edge prospect is the search for new genetic IgG and IgM biomarkers. such as circulating miRNAs, which have demonstrated the non-invasive abilities of biomarkers for CRC diagnosis at earlier stages [13]. For instance, plasma-based miRNA assays achieve high operating characteristics, thus offering a better option than invasive procedures [10] [13]. Studies have shown that microRNA-29a and microRNA-92a are among the specific microRNAs for which CRC and high-grade dysplastic adenoma detection may soon be available [13].

More recent studies have built on these findings. In particular, circulating tumor DNA (ctDNA) assays have progressed significantly since the early proof-of-concept work. Current multi-analyte blood-based tests that combine ctDNA with protein biomarkers have achieved sensitivities exceeding 83% for stage I–III colorectal cancer in prospective cohort studies. This suggests a promising path toward practical blood-based screening for the general population ([14]; and subsequent validation studies). Comparative reviews of these next-generation molecular tools increasingly position them not as direct replacements for colonoscopy, but as useful risk-stratification tools. By helping to identify individuals who truly

need further investigation, they could make referrals for invasive procedures more efficient—especially in under-resourced settings.

Importantly, these studies also revealed the potential of stool DNA in lower-staging cancers, which, internally or within tissues, are already evidence of disease. Multi-target stool DNA tests, while emerging as more accessible alternatives to colonoscopy in certain populations, have limited sensitivity for detecting smaller, non-advanced adenomas [10] [13], given that the molecular alterations they identify—somatic gene mutations and epigenetic modifications—are most reliably present in established colorectal cancers and large advanced lesions, rather than in early-stage pre-malignant polyps.

2.5. Gaps in Literature

Though there have been such improvements in CRC screening, various gaps exist in the literature. Colonoscopy remains the highest-performing screening modality; however, it is frequently inaccessible in low-resource settings owing to its high cost, procedural complexity, and the substantial endoscopic capacity required for population-wide deployment [15]. It is worth mentioning that noninvasive techniques, such as FIT and stool DNA tests, are promising; however, they raise some concerns about their use for CRC prevention because of their lower sensitivity for adenoma detection [11]. Further studies are needed to validate the large-scale use of potential biomarkers, such as miRNAs [13]. Collectively, these gaps in the literature underscore the need for continued research to improve the sensitivity of non-invasive screening tools, expand the accessibility of all modalities across diverse healthcare settings, and better characterize the barriers that prevent eligible populations from participating in screening programs—all in service of reducing the global burden of CRC-attributable mortality.

3. Methodology

3.1. Research Design

This study is a structured narrative literature review. A narrative approach was chosen because the goal is to synthesize and compare a wide range of evidence across different screening methods, populations, and healthcare settings. This kind of broad, flexible synthesis isn't well suited to the strict inclusion criteria of a systematic review or meta-analysis. The review draws entirely on existing published sources—peer-reviewed studies, clinical guidelines, and epidemiological reports—to evaluate how effective current colorectal cancer screening methods are, identify the main barriers to their use, and explore how emerging technologies could help expand access.

3.2. Data Collection

Search Strategy

In this research, data were gathered from different secondary sources, including peer-reviewed journals, clinical studies, medical association guidelines, and epi-

demiological studies on CRC screening. The main sources of the data are as follows:

- Three major academic databases were searched—Pub Med, Scopus, and Web of Science—for publications from January 2000 to December 2024. This time frame was selected to focus on the modern era of colorectal cancer screening, including the widespread use of FIT, the introduction of stool DNA testing, and more recent advances in molecular diagnostics.

Search terms were grouped into three thematic clusters:

- Screening modalities: Colorectal cancer screening, colonoscopy effectiveness, fecal immunochemical test (FIT), stool DNA testing, CT colonography, and flexible sigmoidoscopy.

- Access and barriers: Barriers to CRC screening, screening adherence, low-income populations and health equity in colorectal cancer.

- Emerging technologies: Capsule endoscopy for colorectal cancer, circulating tumor DNA in colorectal cancer, and microRNA as colorectal cancer biomarkers.

For this structured narrative review, sources were identified through targeted database searches of PubMed, Scopus, and Web of Science. Searches used the thematic clusters of terms described above (Section 3.2a). Rather than applying the exhaustive deduplication and staged screening protocol of a PRISMA-compliant systematic review, this narrative approach employed purposive sampling: sources were evaluated iteratively for their relevance to the three core review questions, methodological rigour, and representativeness of the existing evidence base.

Ultimately, 24 peer-reviewed publications and clinical guidelines published between January 2000 and December 2024 were selected and cited in this review. Selection prioritized high-impact journals (New England Journal of Medicine, Gastroenterology, The Lancet), authoritative guidelines from the American Cancer Society (ACS), the US Multi-Society Task Force (MSTF) on Colorectal Cancer, and the World Health Organization (WHO), and studies covering a diversity of geographic contexts, population risk groups, and screening modalities. Sources were excluded if they focused exclusively on post-treatment surveillance without a screening comparison, reported no CRC-relevant outcomes, were not available as full-text peer-reviewed articles in English, or focused solely on paediatric populations.

3.3. Data Analysis

Thematic analysis was employed to identify recurring patterns and themes related to CRC screening effectiveness, barriers to access, and opportunities for new technologies. The data were organized into the following broad themes for analysis:

- Effectiveness: Studies were reviewed to compare the sensitivity, specificity, and overall diagnostic yield of screening methods such as colonoscopy, fecal immunochemical testing (FIT), CT colonography, and stool DNA testing.
- Barriers to Implementation. The analysis showed data on the implementation of CRC screening in the general population, especially in the underserved pop-

ulation. This involved examining cost-related matters, geographical concerns, and compliance.

- Emerging Technologies. The data gathered were reviewed for possibilities of new screening modalities, particularly WCE and diagnostic techniques involving circulating tumor DNA (ctDNA) and microRNA biomarkers.
- Comparative Insights. The review integrated study reports across studies to enable comparisons of different screening techniques as well as new innovative technologies in developed and developing countries.

3.4. Inclusion and Exclusion Criteria

Studies were selected based on the following pre-defined inclusion and exclusion criteria:

- **Population:** Studies involving adult populations (aged 18 years and older) undergoing colorectal cancer (CRC) screening in any healthcare setting were selected. Studies limited to pediatric populations or those focused solely on post-treatment surveillance (without a screening comparison) were excluded.
- **Screening modality:** Eligible studies examined at least one of the following: colonoscopy, flexible sigmoidoscopy, guaiac-based fecal occult blood test (gFOBT), fecal immunochemical test (FIT), stool DNA testing, CT colonography, wireless capsule endoscopy (WCE), or molecular biomarkers (such as ctDNA and miRNA). Studies that focused only on treatment outcomes unrelated to the screening pathway were excluded.
- **Study design:** Randomized controlled trials (RCTs), prospective and retrospective cohort studies, cross-sectional studies, modelling studies, and clinical practice guidelines from major organizations (American Cancer Society [ACS], American College of Gastroenterology [ACG], United States Preventive Services Task Force [USPSTF], and World Health Organization [WHO]) were included. Case reports, editorials, and opinion pieces were excluded.
- **Outcomes:** Studies were included if they reported on at least one of the following: cancer detection rate, adenoma detection rate, sensitivity, specificity, patient participation or adherence, complication rates, cost-effectiveness, or issues related to access and equity. Studies that did not report any relevant CRC screening outcomes were excluded.
- **Language and publication type:** Only English language, peer-reviewed publications were included. Conference abstracts without full-text data were excluded.

3.5. Ethical Considerations

As this research relies on secondary data, there are no direct ethical concerns related to participant involvement. However, ethical regulations have not been neglected to the extent of ensuring that all the works employed in the research were cited and acknowledged, whereas the data accrued were within the scope of academic ethics.

3.6. Limitations

However, this methodology has a few limitations.

- **Dependence on secondary data:** This research is dependent on previously published studies, which, to some extent, might hinder the advancement of new empirical evidence.
- **Generalization:** Although the research has a wide scope encompassing different CRC screening methods, the results cannot be extrapolated to all populations, especially in areas or settings that are quite different from those presented in the literature.

4. Analysis and Discussion

4.1. Analysis

The evidence synthesized in Section 2 reveals three consistent, cross-cutting themes that underpin the discussion that follows.

First, the superiority of colonoscopy in detecting and simultaneously removing adenomatous polyps—thereby actively interrupting malignant progression—is consistently documented across the literature [15] [19]. This dual diagnostic-therapeutic function is not replicated by any non-invasive alternative. However, this clinical advantage is substantially offset by colonoscopy's well-documented barriers to uptake: procedural invasiveness, the requirement for bowel preparation and sedation, and the associated cost burden that disproportionately excludes low-income populations from access [20] [21].

Second, non-invasive tests—particularly FIT and multi-target stool DNA testing—demonstrate sufficient cancer detection performance for the distinct role they are designed to fulfil in population-based screening. Their markedly higher patient participation rates and lower logistical requirements constitute genuine public health advantages in settings where endoscopic capacity is limited [5] [11]. These tests are not underperforming alternatives to colonoscopy; they are appropriate primary tools for a different phase of the screening pathway, with colonoscopy reserved for confirmatory follow-up and high-risk surveillance.

4.2. Discussion

4.2.1. Effectiveness of Screening Methods

The comparative evidence reviewed in Section 2 supports a risk-stratified approach to CRC screening—one that moves beyond the question of which modality is clinically 'best' in isolation toward the more practically meaningful question of which modality is most appropriate for a given population, risk context, and resource environment.

For average-risk populations, the collective evidence positions FIT and multi-target stool DNA testing as the most clinically and operationally appropriate primary screening tools. Their superior patient participation rates relative to colonoscopy are not a trivial consideration: at the population level, a modality with moderate sensitivity but high uptake may prevent substantially more cancers than

one with high sensitivity and low uptake. Published modelling analyses corroborate this, demonstrating that FIT-based programs with high participation can equal or exceed colonoscopy programs in population-level mortality reduction [5] [7]. The acknowledged trade-off—reduced sensitivity for early-stage, non-advanced adenomas—is a genuine limitation that can be substantially mitigated by ensuring that all positive non-invasive results trigger timely diagnostic colonoscopy.

For high-risk populations—individuals with confirmed hereditary CRC syndromes such as Lynch syndrome, a personal history of advanced adenomas, or long-standing inflammatory bowel disease—the clinical calculus shifts decisively toward colonoscopy as the primary modality [4] [17]. In these groups, the elevated baseline risk of malignant transformation justifies the procedural burden of colonoscopy, and the ability to remove lesions at the point of detection provides a preventive benefit that no detection-only test can replicate.

Stool DNA testing occupies an intermediate position: its higher cancer detection sensitivity relative to FIT, achieved at the cost of a greater false-positive rate and higher unit cost, makes it an appropriate option for individuals who decline colonoscopy and require a more sensitive alternative to annual FIT [14]. The clinical utility of its false-positive rate—and its downstream consequences for unnecessary follow-up colonoscopy—warrants explicit discussion in any program implementing stool DNA as a primary screen.

This stratification framework—matching modality to risk profile rather than applying a single test universally—represents the most clinically defensible and resource-efficient approach to CRC screening policy. Its implementation requires standardized, validated risk-assessment protocols to ensure that individuals are systematically directed to the appropriate modality at the appropriate screening interval.

4.2.2. Accessibility and Cost-Related

Equitable access to CRC screening remains one of the most consequential unresolved challenges in global cancer control. The evidence reviewed in Section 2.5 identifies cost, geographic distance from endoscopy facilities, and limited health literacy as the three primary structural barriers to screening uptake—barriers that operate largely independently of which modality is clinically recommended and that disproportionately affect low-income, rural, and ethnically marginalized populations [8] [21].

Critically, these structural barriers do not apply equally across modalities. Colonoscopy requires clinical infrastructure, trained endoscopists, anesthesiologists, and post-procedure recovery capacity—resources that are finite even in well-resourced healthcare systems and that are largely unavailable in low-income settings [21] [22]. The documented endoscopic capacity shortfall in the United States, one of the world's most resource-rich healthcare environments, illustrates the impracticality of colonoscopy-dependent universal screening at scale. In low- and middle-income countries, where the global burden of CRC is rising most rapidly, this

capacity gap is far more severe.

Home-based non-invasive testing—particularly FIT—removes the majority of these structural barriers. It requires no clinical facility, trained endoscopy personnel, bowel preparation, or sedation; it can be self-administered and returned by post, making it operationally feasible in settings with minimal healthcare infrastructure [11] [14]. The policy implication is direct: in any setting where colonoscopy capacity is insufficient to meet population needs, FIT-based primary screening with colonoscopy reserved for positive results maximizes both detection and resource efficiency.

Beyond modality selection, the literature identifies several complementary strategies for improving screening equity: Government-subsidized or publicly funded screening programs with active outreach to underserved communities; community health worker-led education campaigns targeting populations with low screening literacy; and the integration of screening reminders, risk counselling, and results communication into primary care workflows [5] [8]. Telehealth platforms, as noted in the literature, offer a cost-effective mechanism for pre-screening consultations and follow-up coordination in remote populations, reducing the geographic barrier without requiring additional physical infrastructure [5].

The fundamental insight from this body of evidence is that the barriers to equitable CRC screening are not primarily clinical—they are structural and economic. Their resolution therefore requires coordinated policy investment rather than new diagnostic technology. No clinical advance in screening methodology will achieve meaningful population-level impact in the absence of the systemic infrastructure needed to deliver it equitably.

4.2.3. Emerging Technologies

Regarding the topics identified for CRC screening, emerging technologies are centrally directed toward increasing the rates of detection or the adhesion of patients without increasing expenses accordingly. One such positive practice is wireless capsule endoscopy (WCE), which offers the possibility of examining a person's gastrointestinal tract in a noninvasive manner without the administration of anaesthesia [23]. WCE has demonstrated the capacity to detect adenomatous polyps and early-stage colorectal cancer without requiring sedation or bowel insufflation; however, its clinical adoption remains limited owing to the high per-unit cost of the capsule device, the need for specialist image-review equipment, and the current absence of standardized reporting and quality assurance protocols [23].

There are also new developments related to the molecular characterization of distant cancer cells, such as ctDNA and miRNA biomarkers, which create prospects for CRC screening in a noninvasive manner. Such tests can determine gross genomic or epigenomic changes that are relevant to the development of CRC and are more efficient than conventional methods for the early detection

of the disease [24].

Early validation studies have reported that ctDNA and microRNA assays demonstrate high analytical sensitivity and specificity for CRC detection, including at early disease stages; however, their clinical performance in unselected, average-risk screening populations remains less well established than that of colonoscopy or FIT, and prospective validation in large community-based cohorts is still required [10] [13]. These technologies are not yet in routine clinical use owing to high per-test costs and the absence of standardized, validated protocols for broad deployment [10]. As these barriers are addressed, molecular biomarker tests may prove particularly valuable in settings where conventional colonoscopy-based screening is logistically or economically unfeasible, enabling earlier risk stratification and more efficient targeting of confirmatory endoscopy.

5. Conclusion and Recommendations

5.1. Conclusion

This review draws several key conclusions from a comparative analysis of available colorectal cancer (CRC) screening modalities. Colonoscopy maintains its established position as the most clinically effective screening tool, owing to its unparalleled diagnostic sensitivity and its unique therapeutic capability: the identification and resection of adenomatous polyps—the recognized precursors of CRC—in a single procedure. This dual function substantially reduces disease-specific morbidity and mortality in populations with access to regular colonoscopic surveillance. However, colonoscopy's limitations in terms of cost, procedural invasiveness, and patient acceptability—particularly in low-income and underserved communities—constrain its viability as a universal primary screening modality.

Non-invasive tests, particularly FIT and multi-target stool DNA testing, are well-validated for detecting established colorectal cancer and advanced neoplasia, and their superior patient participation rates make them operationally effective in population-based programs. However, unlike colonoscopy, they cannot directly visualize or remove premalignant lesions, which limits their independent contribution to primary cancer prevention—particularly in individuals with high-grade or rapidly progressing precancerous adenomas.

Emerging technologies, including wireless capsule endoscopy and molecular diagnostic approaches such as circulating tumor DNA assays and microRNAs, hold considerable promise for improving CRC detection, particularly in populations unable to access conventional endoscopy. However, limited clinical availability and high per-test costs remain significant barriers to their widespread adoption. Ultimately, the most effective approach to CRC prevention and early detection will require integrated, risk-stratified strategies that combine the clinical thoroughness of colonoscopy with the population-level reach of non-invasive screening while systematically addressing the structural and economic barriers that currently limit equitable access.

5.2. Recommendations

1) Increased Accessibility to Colonoscopy: Governments and healthcare institutions can assist in addressing the lack of colonoscopy in certain populations by endorsing financial support. There should be health care insurance so that colonoscopy services are offered everywhere, which will go a long way to prevent the advancement of CRC.2.

2) Promote Noninvasive Screening Methods: Promote the use of stool culture or stool DNA test as a primary diagnostic method. This is especially true for populations with no health resources or populations that are averse to certain procedures. Health education programs on noninvasive methods of screening for women's health are imperative to improve participation.

3) Leverage Emerging Technologies: Further advances in CRC screening clearly require further investments in R&D of modern technologies such as WCE and Molecular Diagnostics. These emerging technologies should be made more affordable to comply with the present-day demands among high-risk groups or areas where it is impossible to perform colonoscopy.

4) Telehealth for Screening Awareness: Although telehealth is not commonly used in the conceptualization of CRC screening programs, especially in its delivery phase, there is merit in incorporating it for the purposes of education, prescreening, and post-care, especially for remote populations. In particular, with the aid of telehealth, the link between patients and providers for access to care has the potential to be enlarged and help people screen within the guidelines.

5) Implementing a Multi-Tiered Screening Approach: During screening, healthcare providers must apply a multi-tiered approach that ensures there is a correspondence between the method of screening suggested and the individual's risk profile and the resources at hand.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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