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ABDOMINAL IMAGING

ORIGINAL ARTICLE

Diagnostic sensitivity and specificity of enhanced computed tomography in colorectal tumors: a meta-analysis and systematic review

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PURPOSE

Early detection of colorectal cancer (CRC) is crucial for improving patient prognosis and survival outcomes. In contemporary clinical practice, computed tomography (CT) has become an established diagnostic modality and a reference standard for CRC evaluation. This meta-analysis systematically evaluates the diagnostic performance of contrast-enhanced CT imaging in detecting and characterizing colorectal neoplasms, providing evidence-based recommendations to optimize clinical decision-making and therapeutic strategies in CRC management.

METHODS

A systematic literature search was performed across multiple electronic databases, including PubMed, Medline, EMBASE, the Cochrane Library, ClinicalTrials.gov, CNKI, Wanfang, and Weipu, covering studies from database inception through November 25, 2024. The search strategy was designed to identify all relevant studies investigating the diagnostic accuracy of contrast-enhanced CT imaging in colorectal neoplasms. For each eligible study, diagnostic performance parameters—specifically, sensitivity and specificity—were extracted and analyzed. All statistical analyses were conducted using RevMan software.

RESULTS

A total of nine studies involving 4,857 patients were included. The meta-analysis revealed that the pooled sensitivity of enhanced CT imaging for diagnosing colorectal tumors was 76% [95% confidence interval (CI): 70%–79%] and the pooled specificity reached 87% (95% CI: 84%–89%). Furthermore, the area under the curve for the diagnostic test was 0.89 (95% CI: 0.85–0.92), indicating strong discriminatory capability in differentiating colorectal tumors. Subgroup analysis revealed no statistically significant differences in diagnostic sensitivity and specificity between intravenously administered and orally administered contrast agents in enhanced CT scans.

CONCLUSION

Contrast-enhanced CT imaging is an effective and reliable method for the clinical diagnosis of colorectal tumors.

CLINICAL SIGNIFICANCE

Contrast-enhanced CT scanning demonstrates high sensitivity and specificity in the diagnosis of CRC.

KEYWORDS

Clinical, computed tomography, colorectal tumor, diagnosis, treatment

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Colorectal cancer (CRC) is a globally prevalent malignant neoplasm of the digestive system, with incidence and mortality rates among the highest compared with all malignant tumors.[1,2] Global cancer statistics indicate that in 2020, approximately 1,932 million new CRC cases were reported worldwide, resulting in nearly 935,000 fatalities.[3,4] Over the past decade, the global incidence of CRC has increased, with a marked rise in cases in devel-

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oping regions such as China and Southeast Asia.[5] In China, CRC has become the second most frequently occurring malignant tumor, with an annual incidence of approximately 517,100 cases—307,700 in men and 209,400 in women.[6,7]

Risk factors associated with CRC include advanced age, being a man, unhealthy dietary habits (such as high consumption of fats, sugars, alcohol, red meat, and processed meats), obesity, tobacco use, and physical inactivity.[8] Notably, the lifetime risk of developing and dying from gastrointestinal cancers is estimated at 8.20% and 6.17%, respectively, with CRC posing the highest risk, accounting for 38.5% of the incidence risk and 28.2% of the mortality risk among gastrointestinal cancers.[9] Patients with early-stage CRC who undergo radical surgery have improved long-term survival rates and better prognoses, considerably enhancing their survival prospects.[10] Conversely, patients with late-stage CRC, who often forgo surgical intervention, rely predominantly on chemotherapy and radiotherapy—treatments with limited efficacy that require frequent hospital visits and consume substantial medical resources.[11,12] Therefore, early diagnosis of CRC is crucial for improving patient outcomes and conserving healthcare resources.

For early-stage CRC, the prognosis following diagnosis and surgical intervention is relatively favorable. However, the five-year survival rate for patients with advanced metastatic disease remains low.[13,14] Enhanced computed tomography (CT), known for its non-invasive and rapid imaging capabilities, is widely used in the early diagnosis of CRC.[15] However, significant heterogeneity exists in the literature regarding the diagnostic performance of contrast-enhanced CT for colorectal neoplasms, particularly in terms of reported sensitivity and specificity values. This study adopts an evidence-based medicine approach to systematically evaluate the diagnostic efficacy of contrast-enhanced CT imaging in detecting colorectal tumors, aiming to establish a strong evidence base for optimizing clinical decision-making in CRC diagnosis and management.

Main points

- Enhanced computed tomography (CT) scanning with contrast agents is recognized for its high sensitivity and specificity in diagnosing colorectal cancer.
- There is no statistically significant difference in diagnostic sensitivity and specificity between intravenously and orally administered contrast agents.
- When performing contrast-enhanced CT scans for patients with suspected colorectal tumors, orally administered contrast agents should be given preferential consideration due to their comparable diagnostic efficacy.

Methods

This meta-analysis was conducted in strict accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses guidelines.[16] Given the nature of our study as a meta-analysis, neither ethical approval nor patient consent was required.

Inclusion and exclusion criteria

This study explicitly defined the inclusion and exclusion criteria to ensure the homogeneity of the included studies and the reliability of the results. The specific criteria were as follows: (1) Study type: the study included diagnostic trials that utilized enhanced CT imaging technology for the diagnosis of CRC. To ensure data extractability and comparability, only studies providing fourfold table (2 × 2 contingency table) data were included. There was no lower age limit for study participants; however, participants had to be over 18 years of age, with no restrictions on gender or ethnicity, to enhance the generalizability of the study results. (2) Diagnostic test methods: the study focused on CT imaging techniques enhanced with intravenous and oral contrast agents. Both methods are commonly used radiological tools for diagnosing CRC, providing vital information about tumor location, size, and the extent of invasion. (3) Measurement indicators: the primary measurement indicators in this study included sensitivity, specificity, and the diagnostic odds ratio. Sensitivity and specificity are core indicators for evaluating the accuracy of diagnostic tests, reflecting the test's ability to identify genuine cases and exclude non-cases, respectively. The diagnostic odds ratio integrates information from both sensitivity and specificity, providing a metric for the overall performance of the diagnostic test.

Literature search

This study followed a predefined literature search strategy to ensure the comprehensiveness and accuracy of the data collected. The search strategy, which incorporated Boolean operators, was as follows: ("computed tomography" or "CT") and ("colorectal tumors" or "rectal cancer" or "colon cancer") and ("diagnosis" or "sensitivity" or "specificity"). Searches were conducted across PubMed, Medline, EMBASE, the Cochrane Library, ClinicalTrials.gov, CNKI, Wanfang, and Weipu databases, covering studies from the database inception to November 25, 2024. Additionally, we reviewed the references of included articles and relevant systematic reviews to identify additional relevant studies, ensuring a broader scope of related research within our analysis.

Literature screening and data extraction

In this study, a cross-checking methodology was employed for the comprehensive evaluation and selection of literature. Adhering to predefined inclusion and exclusion criteria, we systematically reviewed the titles, abstracts, and full texts of the identified studies, making inclusion decisions based on this sequential assessment. For the selected articles, an exhaustive data extraction process was conducted, capturing fundamental information such as author details, study locations, publishing journals, and study populations—key elements in understanding the research context. Furthermore, for diagnostic data, we extracted fourfold tables (2 × 2 contingency tables) and implemented a dual-reviewer cross-checking mechanism to ensure the precision and reliability of the extracted data.

Quality assessment of included studies

This study employed the Quality Assessment of Diagnostic Accuracy Studies (QUADAS) tool,[17] as recommended by the Cochrane Library, to systematically evaluate the methodological quality of diagnostic accuracy studies. The QUADAS-2 instrument encompasses four key domains: patient selection, index test, reference standard, and flow and timing, collectively comprising 18 items. Within these domains, reviewers assessed the risk of bias for each, with the first three also undergoing an evaluation of clinical applicability. During the assessment process, reviewers categorized the risk of bias as "low," "high," or "unclear" based on responses to domain-specific questions, which could be "yes," "no," or "unclear." This methodological approach helped identify potential biases within the studies and provided an objective assessment of their reliability. By applying the QUADAS-2 tool, this study conducted a meticulous analysis of the methodological quality of diagnostic accuracy research, ensuring the scientific rigor and validity of the conclusions drawn.

Statistical analysis

This meta-analysis utilized RevMan software for data analysis (Review Manager,

RevMan, The Cochrane Collaboration, Nordic). Statistical heterogeneity was assessed using the I^2 statistic and Cochran's Q test. Studies were considered to exhibit significant heterogeneity if the I^2 value exceeded 50% or if Cochran's Q test yielded statistically significant results ($P < 0.05$). In such cases, a random-effects model was employed to account for the observed variability.

We calculated the sensitivity, specificity, and area under the summary receiver operating characteristic curve for enhanced CT scans in diagnosing colorectal tumors. Additionally, studies were stratified into two subgroups based on the route of contrast agent administration: intravenous and oral. Sensitivity and specificity were calculated for each subgroup, followed by a comparative analysis to determine whether differences existed between them. Egger's regression test was conducted to assess publication bias in the synthesized outcomes. In this study, a *P* value of less than 0.05 was considered the threshold for statistical significance.

Results

As indicated in Figure 1, an initial electronic search identified 694 articles relevant to the study's theme. After reviewing abstracts and titles, 626 articles were excluded for not meeting the inclusion criteria. Further examination of full texts led to the exclusion of an additional 36 studies that did not fulfill the research requirements. Ultimately, nine studies met all eligibility criteria and were included in this analysis.

As summarized in Table 1, this meta-analysis includes nine studies[18-26] involving 4,857 patients. These articles were published between 2000 and 2019, with sample sizes ranging from 71 to 2,541 participants. Among the nine included studies, five used intravenous contrast enhancement, and four employed oral contrast enhancement. These data provide an overview of the application of different contrast enhancement techniques in studies diagnosing colorectal tumors and form the basis for subsequent analysis.

In this diagnostic meta-analysis, the QUADAS tool was used to assess the quality of the included studies, which were collectively rated as moderate in quality (Figures 2 and 3). Regarding patient selection, most studies provided consecutive or random patient samples, thereby reducing potential biases associated with case–control designs and minimizing inappropriate patient exclusions. However, some studies did not fully blind the interpretation of diagnostic test results from the reference standard, potentially introducing performance bias. In terms of the reference standard, most studies employed methods capable of accurately classifying the target condition, but in some cases, the interpretation of results was conducted with knowledge of the diagnostic test outcomes, potentially affecting the accuracy of the findings.

With respect to flow and timing, although all patients underwent reference standard testing, inconsistencies were observed in the intervals and interventions between the index test and the reference standard across different studies. Overall, despite some methodological limitations, the included studies demonstrated a reasonable level of reliability in assessing diagnostic accuracy, and these moderately rated studies provided valuable data for this meta-analysis.

In this diagnostic meta-analysis, we selected the sensitivity and specificity of enhanced CT imaging as the primary evaluation metrics. Statistical findings revealed that the I^2 values for sensitivity and specificity were 93.8% and 89.0%, respectively—both exceeding 50%—and that Cochran's Q test results were statistically significant (all $P <$ 0.009), indicating substantial heterogeneity among the included studies. Consequently, a random-effects model was employed to account for this heterogeneity in the pooled analysis. The results of the meta-analysis demonstrated that the pooled sensitivity of enhanced CT imaging for the diagnosis of colorectal tumors was 76% [95% confidence interval (CI): 70%–79%], as shown in Figure 1; the pooled specificity was 87% (95% CI: 84%–89%), as depicted in Figure 4. Furthermore, the area under the diagnostic test's receiver operating characteristic curve (AUC) was 0.89 (95% CI: 0.85–0.92), as illustrated in Figure 5, suggesting that enhanced CT imaging possesses good accuracy in diagnosing colorectal tumors. The Egger's regression test demonstrated no significant evidence of publication bias across the synthesized outcomes ($P = 0.082$).

Based on the contrast methods used, we stratified the included studies into two subgroups for analysis. For studies utilizing intravenous contrast-enhanced CT scans, sensitivity was 0.65 (95% CI: 0.60–0.72) and specificity was 0.86 (95% CI: 0.82–0.90). By contrast, for studies employing oral contrast-enhanced CT scans, sensitivity was 0.78 (95% CI: 0.74–0.81) and specificity was 0.86 (95% CI: 0.84–0.87).

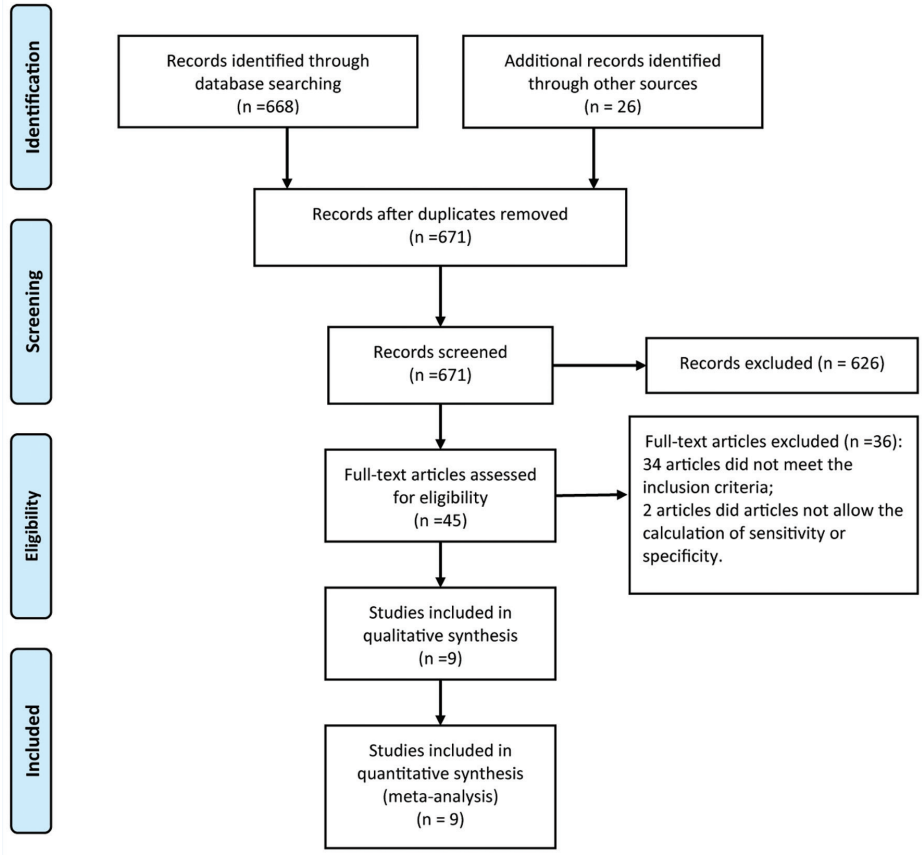

Figure 1. PRISMA flow diagram of the study selection. PRISMA, Preferred Reporting Items for Systematic Reviews and Meta-Analyses.

Table 1. Characteristics of the included studies

Study ID	Country	Cases	Diagnostic gold standard	Enhanced CT scanning		True positive	False positive	False negative	True negative	Enhanced method for CT imaging
				Sensitivity	Specificity					
Cao et al.[18] (2016)	China	120	Colonoscopy	0.65	0.66	24	28	13	55	Intravenous contrast agents
Dai[19] (2019)	China	205	Colonoscopy	0.84	0.83	38	27	7	133	Oral contrast agents
Fletcher et al.[20] (2000)	USA	180	Colonoscopy	0.88	0.72	114	14	16	36	Oral contrast agents
Hoppe et al.[21] (2004)	Switzerland	92	Colonoscopy	0.76	0.88	26	7	8	51	Intravenous contrast agents
Johnson et al.[22] (2008)	USA	2541	Colonoscopy	0.66	0.89	193	248	99	2001	Oral contrast agents
Kim et al.[23] (2008)	Korea	214	Colonoscopy	0.69	0.89	37	21	17	166	Intravenous contrast agents
Miao et al.[24] (2003)	UK	201	Colonoscopy	0.24	0.89	14	16	45	126	Intravenous contrast agents
Pickhardt et al.[25] (2003)	USA	1233	Colonoscopy	0.89	0.80	149	217	19	848	Oral contrast agents
Wong et al.[26] (2002)	China	71	Colonoscopy	0.59	0.93	16	3	11	41	Intravenous contrast agents

CT, computed tomography; USA, United States of America; UK, United Kingdom of Great Britain and Northern Ireland.

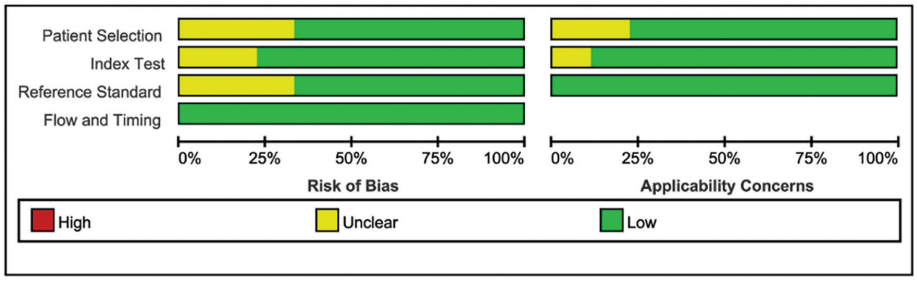

Figure 2. Cumulative bar plot of risk of bias and applicability concerns across all studies.

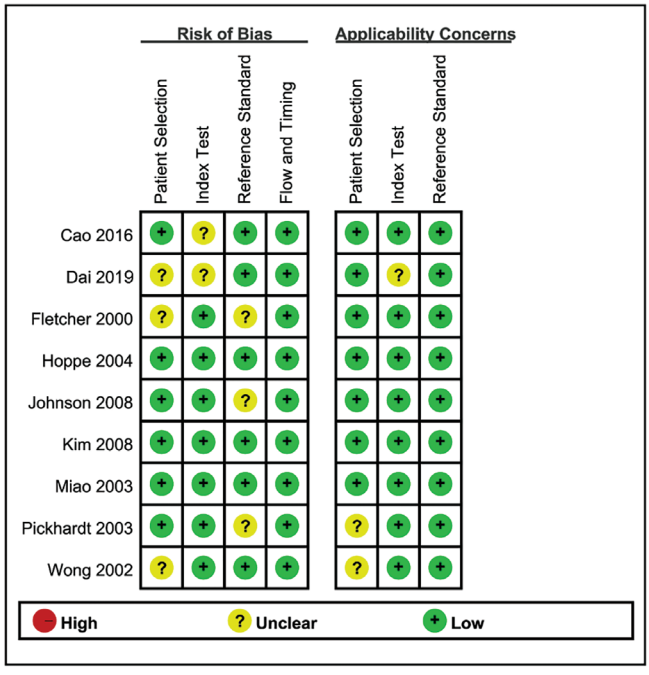

Figure 3. Summary of risk of bias and applicability concerns.

Comparing sensitivity (P = 0.152) and specificity (P = 0.230) between the two contrast methods, we found no statistically significant differences. These findings suggest that both contrast methods exhibit similar diagnostic accuracy, each demonstrating a reasonable level of reliability.

Discussion

Over the past decade, the global incidence of CRC has shown an upward trend, particularly in developing regions such as China and Southeast Asia, where cases have increased considerably.[27] CRC ranks fourth among new cancer cases worldwide, accounting for 11% of all cancer diagnoses, with approximately 1,096 million new cases of colon cancer and 704,000 new cases of rectal cancer, totaling 1.8 million new CRC cases.[28] The incidence rate of CRC is higher in men than in women and is more common in developed countries than in developing ones, with age-standardized incidence rates of 30.1 per 100,000 for men and 16.3 per 100,000 for women.[29] Moreover, the incidence of CRC among women in Southeast Asia has increased notably, with mortality rates also rising in this region, particularly among women.[5] These trends may be associated with rapid economic development in these regions, which in turn affects lifestyle and dietary habits.[30] For instance, there has been a shift from a grain-based diet to one richer in protein.[31] Given the high incidence

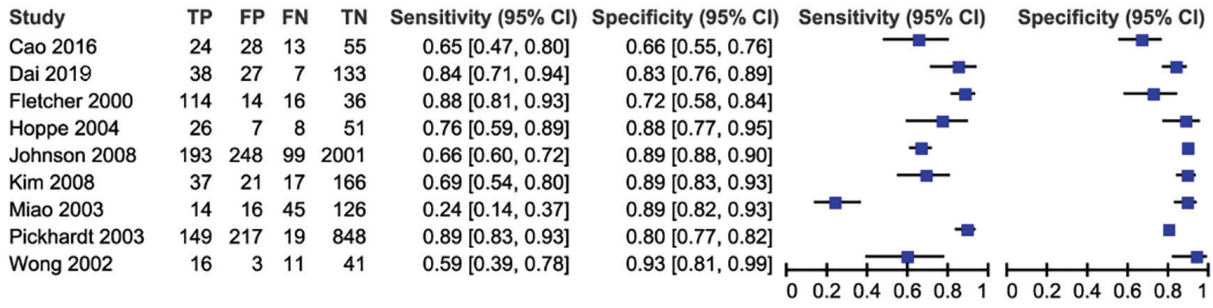

Figure 4. Forest plot of the sensitivity and specificity of enhanced CT in the diagnosis of colorectal tumors. CT, computed tomography; CI, confidence interval.

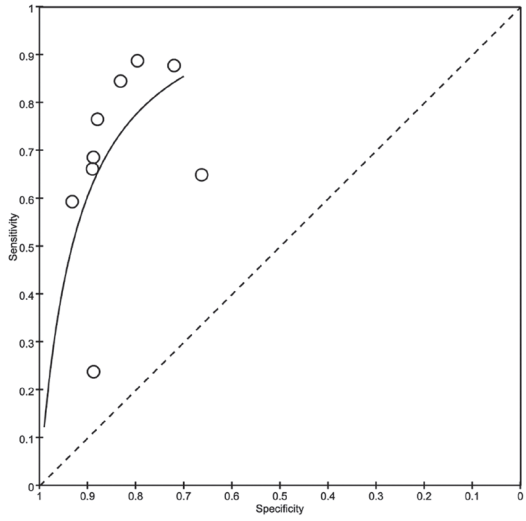

Figure 5. SROC plot curve of the sensitivity of enhanced CT in the diagnosis of colorectal tumors. SROC, summary receiver operating characteristic; CT, computed tomography.

and increasing prevalence of CRC in younger populations, early screening in the general population or large-scale settings becomes particularly important.[32]

Patients diagnosed with CRC at an early stage can undergo potentially curative surgical treatment, leading to higher long-term survival rates and better prognoses, thereby significantly improving survival.[33] By contrast, patients presenting with advanced-stage CRC are typically ineligible for surgical intervention, with treatment primarily limited to palliative chemotherapy and radiotherapy, which demonstrate limited therapeutic efficacy.[34] These patients frequently require repeated hospital admissions, resulting in substantial healthcare resource consumption. Consequently, early CRC detection is crucial not only for optimizing patient prognosis but also for enhancing healthcare resource utilization efficiency.

Enhanced CT scanning, characterized by its speed, non-invasiveness, and relatively low cost, has become a crucial tool for the early diagnosis of CRC.[35] In addition to assessing the location of CRC and its relationship with surrounding tissues, enhanced CT provides essential diagnostic information and valuable details for surgical assessment.[36,37] However, heterogeneity in study design, population demographics, and the technical parameters of CT imaging protocols among different diagnostic trials has resulted in considerable variability in reported outcomes. Our meta-analysis demonstrates that contrast-enhanced CT imaging exhibits superior diagnostic performance in CRC detection, with high sensitivity and specificity, thereby establishing its clinical utility as a reliable diagnostic modality.

These findings align with the existing literature. A previous investigation evaluating the diagnostic efficacy of multi-slice spiral CT enhancement in lung cancer differentiation reported enhanced scanning parameters with 91.4% sensitivity, 88.1% specificity, and 90.0% accuracy, demonstrating statistically significant improvements over non-enhanced scanning protocols.[38] Additionally, fecal DNA methylation testing, a non-invasive molecular method, has been applied to the early diagnosis of CRC. One study showed that the combined detection of SDC2/ADHFE1/PPP2R5C methylation predicted CRC with a sensitivity of 84.8%, a specificity of 98.0%, and an AUC of 0.930 (95% CI: 0.889–0.970).[39] These data further confirm the value of enhanced CT imaging in the early diagnosis of CRC and demonstrate its high accuracy and potential in comparison to other non-invasive screening methods. Therefore, enhanced CT imaging plays an indispensable role in early CRC diagnosis, significantly contributing to improved patient survival rates and reduced healthcare resource consumption.

Enhanced CT scanning plays a pivotal role in the diagnosis of CRC, offering considerable advantages while also presenting certain limitations. Its utility is underscored by its ability to accurately delineate the location and extent of CRC, providing crucial data for tumor staging and size assessment.[40,41] It enhances tumor detection rates and minimizes missed diagnoses by offering detailed insights into lesion vascularity, which is instrumental in characterizing pathology.[42] As a non-invasive diagnostic modality, it employs specialized X-ray equipment to generate cross-sectional images that reveal internal structures with high diagnostic value.

The strengths of enhanced CT scanning include its high sensitivity and specificity, particularly for detecting larger colonic adenomas and tumors over 10 mm, with sensitivity reaching up to 90%.[43] Its rapid imaging capability reduces the impact of respiratory and bowel motion artifacts, yielding clear images.[44] Technological advancements in resolution, image reconstruction, and scanning speed further enhance the accuracy of CRC diagnosis with CT. However, the use of ionizing radiation in CT scans poses risks, particularly for patients requiring multiple scans or long-term follow-ups.[45] Additionally, its ability to detect small lesions (≤1 cm)

is limited, making accurate differentiation of T1–2 stage intestinal wall layers challenging.

Potential for misdiagnosis and missed diagnoses exist due to factors such as inadequate bowel preparation or peritoneal fat turbidity, which may lead to confusion between pathological and physiological stenosis or misinterpretation of tumor invasion.[46] Furthermore, assessing lymph node metastasis remains a limitation, as CT primarily relies on lymph node size, which is prone to diagnostic errors.[47] Although enhanced CT scanning is invaluable for tumor localization, staging, and vascular assessment in CRC, its limitations in detecting small lesions, radiation risks, and accurate lymph node metastasis assessment must be considered.[48,49]

This meta-analysis investigating the diagnostic utility of contrast-enhanced CT scanning in CRC identification has several inherent limitations that warrant consideration. The primary limitation stems from the substantial heterogeneity observed in sensitivity and specificity metrics across the included studies, likely due to variations in diagnostic protocols, reference standards, and imaging parameters. Although we implemented a random-effects model to account for this heterogeneity, its potential impact on the overall findings remains non-negligible.

Furthermore, dataset limitations prevented a comprehensive stratified analysis of CT diagnostic efficacy across different CRC stages, constraining our ability to evaluate stage-specific diagnostic performance. Methodologically, the predominance of cohort studies, particularly those conducted within the Chinese population, may affect the generalizability of our conclusions, as these study designs generally provide lower levels of clinical evidence compared with prospective diagnostic trials. These limitations highlight the need for future large-scale, prospective multicenter studies to further validate the diagnostic role of contrast-enhanced CT scanning in CRC, thereby strengthening the evidence base for clinical decision-making in CRC diagnosis and management.

In conclusion, this meta-analysis demonstrates that contrast-enhanced CT scanning exhibits superior diagnostic performance in CRC detection, with high sensitivity and specificity, thereby establishing its clinical utility as a reliable diagnostic modality. Notably, our findings reveal comparable diagnostic efficacy between intravenous and oral contrast administration ($P > 0.05$), suggesting that oral contrast agents may serve as a preferable alternative in clinical practice. The preferential use of oral contrast agents offers multiple advantages, including reduced healthcare expenditures, streamlined examination procedures, and maintained diagnostic accuracy while also improving therapeutic efficiency and alleviating patient financial burdens.

Looking ahead, future research should focus on three key areas: (1) optimizing contrast-enhanced CT protocols for CRC detection across different disease stages; (2) developing integrated diagnostic frameworks that combine CT with emerging modalities such as artificial intelligence-based image analysis and molecular biomarkers; and (3) exploring multimodal imaging strategies to enhance tumor characterization and improve precision in therapeutic decision-making. These advancements have the potential to revolutionize CRC diagnosis and management, ultimately improving patient outcomes.

Footnotes

Conflict of interest disclosure

The authors declared no conflicts of interest.

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