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Role of Artificial Intelligence in Detecting Colorectal Cancer Recurrence After Surgery

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Abstract: Colorectal cancer (CRC) recurrence after surgery is a major concern for patient prognosis and survival, making accurate and timely detection necessary. While imaging, biomarker analysis, and colonoscopies are important post-operative surveillance techniques, their sensitivity and specificity are often constrained. In recent years, artificial intelligence (AI) has emerged as a powerful tool for improving the identification and prognosis of colorectal cancer recurrence. Artificial intelligence (AI) algorithms, particularly ones built on machine learning (ML) and deep learning (DL), have shown great promise in the analysis of complicated medical data, including genetic profiles, histological slides, medical imaging, and patient clinical histories. By identifying subtle patterns that may be prone to be overlooked by clinicians, these systems have the potential to increase diagnostic accuracy and detect recurrences early. This study reviews recent developments, applications, and difficulties in the use of AI in the post-operative surveillance of colorectal cancer. It highlights AI-powered methods across genetics, pathology, and radiology, emphasising their potential incorporation into clinical practice for predictive and individualized recurrence monitoring. Additionally, the paper addresses the prospects of AI technology in the battle against colorectal cancer recurrence, as well as its ethical and regulatory considerations essential for their effective implementation into clinical practice.

Keywords: *Artificial Intelligence, Machine Learning, Deep Learning, Colorectal Cancer, Recurrence, Detection.*

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I. INTRODUCTION

In clinical practice, colorectal cancer is a malignant tumor that has a high rate of morbidity and the third-highest death rate of all tumours. [1]. Roughly half of the 1.4 million new cases deteted every year are in the progressive stage. The 5-year survival rate is 30% to 40%, with a median survival of 7 months, attributing, mostly, to surgical recurrence and metastasis. Of these, 10% to 30% are abdominal cavity metastases. In China, colorectal cancer ranks third in terms of incidence and fifth in terms of death among systemic tumours. Despite advancements in surgical techniques, recurrence continues to be a major problem in the management of patients with colorectal cancer. [2]

Recurrence, thus, must be detected early in order to improve patient outcomes. However, conventional techniques like imaging and tumor markers prevalently fall short in this regard. The use of artificial intelligence (AI) has shown promise regarding improving the identification and treatment of colorectal cancer recurrence. This study discusses the potential use of AI to enhance the identification of colorectal cancer recurrence following surgery, as well as the developments, advantages, and difficulties related to its implementation.

II. ADVANCEMENTS IN AI FOR CRC RECURRENCE DETECTION

AI, particularly machine learning (ML) and deep learning (DL) techniques, have shown significant potential in analyzing complex datasets, including imaging, genetic, and clinical data, to detect CRC recurrence with higher accuracy and sensitivity. Machine learning (ML) algorithms are further classified into supervised, unsupervised and reinforcement learning. [3]

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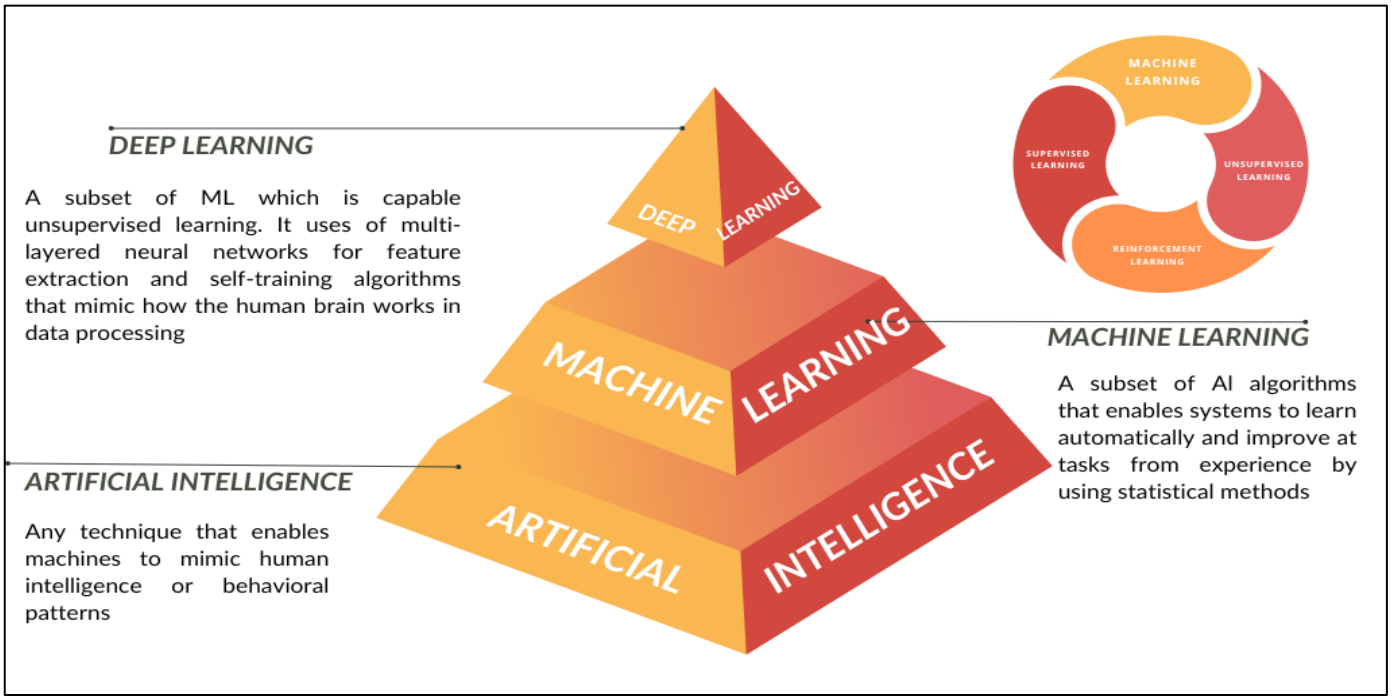

Fig 1 An Overview of the Differences Between Artificial Intelligence (AI), Machine Learning (ML), and Deep Learning (DL)

Algorithms driven by artificial intelligence (AI) may analyze various radiological images, including CT, MRI, and PET scans, to find recurrence-indicating patterns that may be overlooked by human radiologists. To minimize diagnostic errors and enable identification of early signs of recurrence, convolutional neural networks (CNNs)- a family of deep learning models- have shown great accuracy in differentiating recurrent colorectal cancer (CRC) from other pathologies on imaging tests. Furthermore, AI systems may also evaluate patient data that goes beyond imaging, such as genetic profiles and blood biomarkers to forecast the chance of recurrence. By integrating multiple data sources as such, personlized monitoring plans may be developed, allowing clinicians greater oversight in management of high-risk patients.

A recent (2025) retrospective study by Li, Z., Aihemaiti, Y., Yang, Q. et al. has shown the utility of survival-based machine learning models in predicting postoperative recurrence risk among T1 colorectal cancer patients. These models incorporate clinicopathologic and procedural data to forecast recurrence more accurately than conventional risk calculators, supporting stratified follow-up planning after both endoscopic and surgical treatment. [4]

AI-assisted postoperative surveillance systems have shown promise in identifying early signs of colorectal cancer recurrence by analyzing longitudinal imaging data and tumor markers. Integration of AI into follow-up care workflows allows earlier detection of recurrence, potentially improving re-intervention success rates and survival outcomes. [5]

Furthermore, the use of multi-modal Al models combining imaging, histopathology, genomics, and clinical data to enhance predictive accuracy for recurrence. These models provide a comprehensive understanding of patient risk profiles, surpassing single-modality approaches, and support the transition toward more personalized and timely interventions in colorectal cancer follow-up care. [6]

III. CLINICAL APPLICATIONS AND BENEFITS

One of the key advantages of AI in detecting CRC recurrence is the capacity to process large volumes of data quickly and with precision. Artificial intelligence is increasingly being applied in the surveillance phase of colorectal cancer management. Machine learning models can process heterogeneous data such as CEA levels, radiologic findings, and clinical parameters to identify recurrence patterns, offering a level of accuracy comparable to or better than traditional clinical follow-up. [7] AI models trained on extensive datasets from diverse patient populations can discern subtle patterns in imaging studies that human clinicians may find difficult to recognize, improving early detection and reducing the need for invasive follow-up procedures.

AI plays a vital role across the full continuum of colorectal cancer (CRC) management, beginning with early diagnosis and extending through treatment planning and post-surgical surveillance. When applied to histopathology slides and medical imaging, advanced AI systems can accurately identify tumors and malignant cells, improve diagnostic precision, and enable earlier intervention. [8] Beyond diagnosis, AI's ability to evaluate diverse patient data—including genetic profiles, biomarkers, and medical histories—facilitates correct prognostication and risk stratification. This supports clinicians in forecasting recurrence or metastasis and in crafting individualized treatment regimens tailored to tumor characteristics and prior therapeutic responses. [3]

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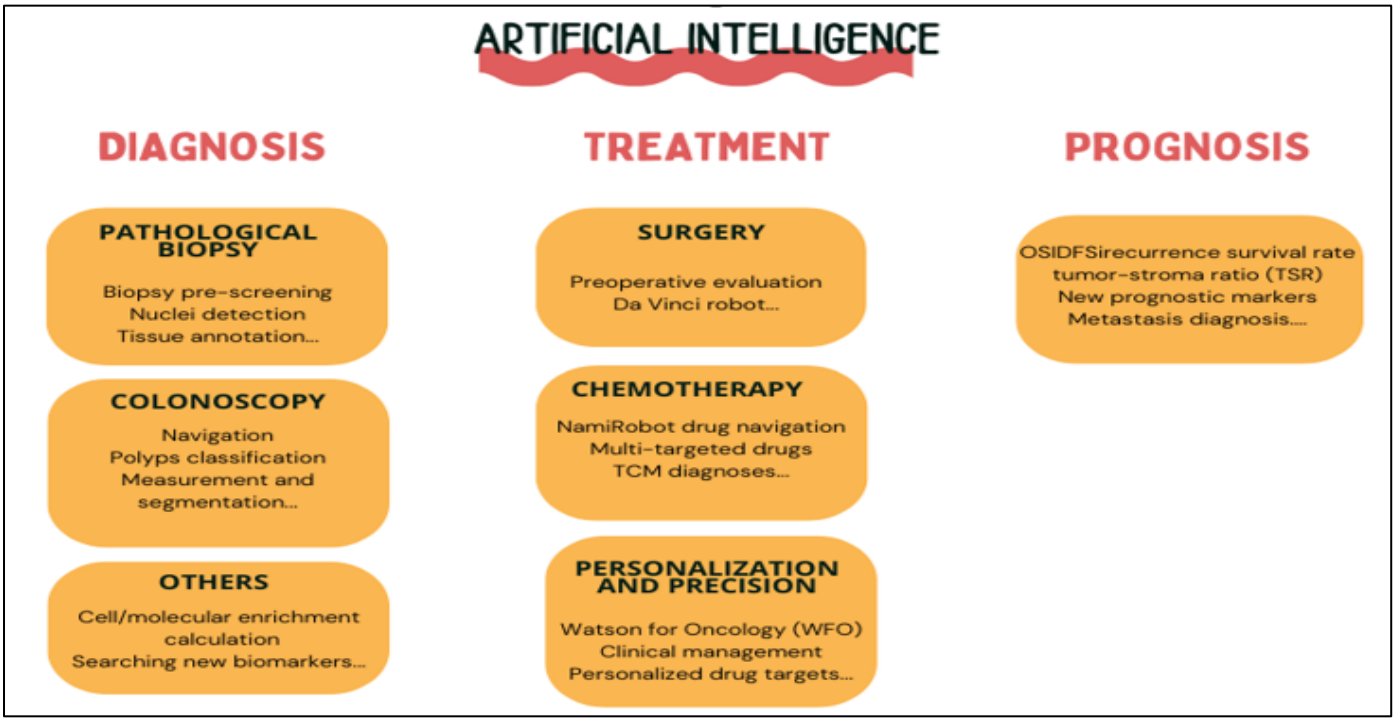

Fig 2 The Application of AI in CRC Diagnosis, Treatment, and Recurrence

In a 2024 study by Xiao, H., Weng, Z., Sun, K. et al., a deep learning model trained on histopathology images was able to accurately predict 5-year recurrence risk in colorectal cancer patients. By extracting spatial and morphological features beyond the capability of traditional pathology review, the system enhanced prognostic precision and helped guide post-surgical decision-making.[9]

In post-operative settings, AI contributes significantly to early recurrence detection by consistently analyzing surveillance imaging and identifying subtle changes that may escape human observation. These systems also provide predictive analytics that guide clinicians in adjusting follow-up intensity based on evolving risk. Recent studies show that deep learning algorithms can detect subtle imaging changes and biochemical trends preceding clinical recurrence. These tools not only enhance the sensitivity of recurrence detection but also enable risk stratification for individualized surveillance planning. [10]

Furthermore, recent advancements have extended AI's applications into intraoperative decision-making. Tools designed for real-time risk stratification, complication prediction, and operative strategy customization are increasingly being integrated into surgical workflows with coloectal surgeons. This evolution marks a shift toward end-to-end AI support across colorectal cancer care, with the potential to reduce intraoperative risks and improve long-term outcomes, while also detecting recurrence early. [11]

Altogether, this integrated and dynamic use of AI enhances diagnostic accuracy, personalizes patient care, and contributes to more efficient and effective colorectal cancer management.

IV. CHALLENGES AND LIMITATIONS

The broad use of AI for CRC recurrence detection still faces several obstacles, despite the encouraging developments. The requirement for sizable, diversified, and high-quality datasets for AI algorithm training is one of the main obstacles. For AI models to achieve accuracy and broad applicability, these datasets must not only hold imaging data but also clinical information, genetic profiles, and patient outcome reports. The interpretability of AI models is another difficulty. Despite reaching great accuracy, Deep learning models are typically considered "black boxes" because of their intricate decision-making processes. [12] This lack of openness may make clinical adoption difficult as it is vial for medical practitioners to trust and understand the reasoning behind AI-driven judgments. In addition, incorporating AI into clinical settings requires regulatory approval, establishment of standardised protocols, and collaborative efforts from AI developers and heathcare professionals. Successful implementation depends greatly on ensuring that AI tools are validated and substantiated and fit seamlessly into existing workflows.

Moreover, recent AI-driven prediction systems incorporate circulating tumor DNA (ctDNA), molecular markers, and radiogenomic, allowing for non-invasive recurrence detection with high sensitivity that can precede visible imaging changes, improve early detection, and enable real-time surveillance. Such approaches could potentially reshape colorectal cancer follow-up protocols and set the stage for proactive, rather than reactive, oncologic care. [13] [14]

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V. CONCLUSION

AI has the potential to revolutionize the detection of CRC recurrence after surgery by improving diagnostic accuracy, enabling earlier detection of any cancer recurrence, while paving way for tailored patient care. Its integration into clinical practice may offer significant benefits, including reduced recurrence rates, improved survival outcomes, and more efficient healthcare delivery. However, challenges such as the need for diverse training datasets, model interpretability, and regulatory approval must be addressed before AI can become a routine part of post-surgical CRC care. With ongoing advancements, as such, AI holds great promise in the future of CRC management and surveillance.

RECOMMENDATION FOR FUTURE RESEARCH

Future studies should concentrate on completing extensive clinical trials to confirm the effectiveness of AI-based methods in CRC recurrence detection, increasing model openness, and broadening datasets to include a larger range of patient demographics. Furthermore, collaborations among researchers, physicians, and AI developers will also be crucial to ensure that AI technologies are precise and meet the requirements of healthcare practitioners.

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