

Integrating artificial intelligence techniques for advancements in colorectal cancer management: navigating past and predicting future direction

Zeeshan Raza, Sabah Uddin Saqib, Adeel Ahmad Bajwa

Abstract

Artificial Intelligence (AI) in the last few years has emerged as a valuable tool in managing colorectal cancer, revolutionizing its management at different stages. In early detection and diagnosis, AI leverages its prowess in imaging analysis, scrutinizing CT scans, MRI, and colonoscopy views to identify polyps and tumors. This ability enables timely and accurate diagnoses, initiating treatment at earlier stages. AI has helped in personalized treatment planning because of its ability to integrate diverse patient data, including tumor characteristics, medical history, and genetic information. Integrating AI into clinical decision support systems guarantees evidence-based treatment strategy suggestions in multidisciplinary clinical settings, thus improving patient outcomes. This narrative review explores the multifaceted role of AI, spanning early detection of colorectal cancer, personalized treatment planning, polyp detection, lymph node evaluation, cancer staging, robotic colorectal surgery, and training of colorectal surgeons.

Keywords: Artificial Intelligence, Colorectal Surgery, Clinical Neoplasm Staging, Precision Medicine, Robotic surgery, Colonoscopy, Colorectal Neoplasms, Magnetic Resonance Imaging, Lymph Nodes, Tomography, X-Ray, cancer, telemetry surgery, virtual learning.

DOI: <https://doi.org/10.47391/JPMA.AKU-9S-26>

Introduction

In the last few years, Artificial Intelligence (AI) has emerged as a new frontier in managing colorectal cancers (CRC), affecting all aspects of the disease from early detection to diagnosis, treatment planning, and individualized treatment. Regarding early detection and diagnosis, AI has taken advantage of its capabilities in medical imaging analysis, scrutinizing CT scans, MRI, and

colonoscopy images to identify suspicious lesions like polyps and tumors. This assists clinicians in making timely and accurate diagnoses, facilitating the initiation of treatment at earlier stages.^{1, 2} Moreover, AI aids pathologists by analyzing histopathological slides, contributing to quicker and more precise pathology reports and risk stratification.³ This diagnostic aptness helps improve the accuracy of cancer staging and its outcomes.

GeoAI can synthesize diverse patient data through data mining to formulate personalized treatment plans, including tumor characteristics, medical history, and genetic information. This leads to more efficient data management, including real-time analysis of diagnostic data, improved patient outcomes, and better-informed decision-making in both clinical and research settings, ultimately improving treatment outcomes⁴.

AI assists with tracking the course of colorectal cancer management, identifying complications, and improving follow-up care by analyzing data from various sources, including imaging, laboratory testing, and clinical records. Furthermore, by predicting treatment outcomes, AI models enable doctors to select the best courses of action for specific patients, guaranteeing a more focused and efficient approach to cancer care. Additionally, the technology is proving fundamental to the monitoring and follow-up care of patients with colorectal cancer, both during and after treatment.⁵

AI is a critical component of clinical decision support systems, offering evidence-based treatment strategy suggestions based on patient-specific data and the most recent medical knowledge. This guarantees that professionals in a multidisciplinary clinical setting have thorough information when making crucial patient care decisions.

Artificial Intelligence (AI) expedites the development of new treatments for colorectal cancer by predicting the effectiveness of new medications and accelerating the identification of prospective therapeutic targets. AI also impacts clinical trial matching, which helps match eligible patients with colorectal cancer with appropriate trials

.....
Department of Surgery, in Colorectal Surgery, University Hospital Coventry and Warwickshire Trust UK

Correspondence: Sabah Uddin Saqib

Email: sabahuddin.bajwa@uhcw.nhs.uk

ORCID ID. 0000-0002-1103-181X

according to their features. This advances cancer research and provides patients with improved access to cutting-edge therapies. Furthermore, AI models analyse patient data to forecast long-term results in survival prediction and prognostication. This helps healthcare providers estimate prognosis and make well-informed decisions regarding continued care. The technology's ability to monitor patients remotely expands its uses; it makes it possible to follow patients receiving therapy for colorectal cancer quickly and promptly.

In this narrative review, we have highlighted the present application of artificial intelligence to colorectal cancer management. We have also discussed how AI has revolutionized colorectal cancer surgery and its impact on the education and training of colorectal surgeons. Finally, we have outlined the possible risks associated with AI adoption and possible solutions to tackle those risks.

AI in diagnosis, staging, and prevention of colorectal cancer

Artificial intelligence (AI) has demonstrated considerable promise in diagnosing and staging colorectal cancer by utilizing cutting-edge algorithms and technology. AI can identify and categorize colorectal tumours by analysing radiological images from CT, MRI, and colonoscopy procedures. To do this, radiometric properties and textures in medical images are analysed to obtain more information about the characteristics of the tumour.

Furthermore, AI can also automatically detect and segment tumours in medical images, increasing productivity and lessening the workload for radiologists. This is especially helpful for locating tiny or subtle lesions that would be difficult to find by hand. In the same way, AI can improve virtual colonoscopy processes by identifying and describing polyps on its own. This facilitates early intervention and increases the accuracy of colorectal cancer screening.

AI can combine information from multiple sources, including clinical records, pathology reports, and imaging, to present a complete picture of the patient's state. This all-encompassing method helps ensure precise staging and diagnosis. These algorithms offer a more accurate evaluation of tumour features and can help with early detection. AI can analyse colorectal tissue sample histopathology slides. AI algorithms can help pathologists diagnose cancer and determine the stage of the disease by spotting cellular patterns and irregularities.

Artificial intelligence (AI) can help stage colorectal cancer by automatically categorizing tumours based on the classification scheme of TNM (tumour, node, and

metastasis). This aids in assessing the severity of the illness and directs the formulation of a treatment strategy.

In the general population, AI models can analyse patient data, including clinical history and genetic information, to anticipate the risk of developing colorectal cancer. Early intervention and individualized preventive actions may benefit from this. These systems might offer evidence-based recommendations based on patient data and the most recent medical literature⁵.

AI in the detection of colorectal polyps

Artificial Intelligence (AI) has shown significant potential in detecting colorectal polyps, particularly in colonoscopy and medical imaging. Based on the principle of face detection, a large dataset of colonoscopy pictures can be used to train AI tools. Acting as an extra set of eyes for endoscopists raises the detection rate overall. Artificial intelligence can identify polyps and accurately locate and segment them in endoscopic pictures or video frames. AI models can give the endoscopist feedback in real time, letting them know if there are any problematic lesions. It can also classify detected polyps based on their likelihood of being neoplastic (cancerous) or non-neoplastic. This can guide endoscopists in determining the appropriate management strategy. Through continuous learning and refinement, AI algorithms can help reduce false positives (identifying non-polyp structures as polyps) and false negatives (missing actual polyps). This instantaneous response can boost the examination's effectiveness and raise the possibility of finding polyps, improving the accuracy of polyp detection.⁶

AI can be integrated with various imaging modalities, such as Narrow Band Imaging (NBI) or magnification endoscopy, to enhance the detection of subtle or flat lesions that may be challenging to identify with conventional white-light endoscopy alone.

AI tools can be integrated seamlessly into the endoscopy workflow, providing real-time analysis without causing significant disruptions. This ensures that the use of AI in polyp detection is practical and user-friendly, and it can be employed in large-scale colorectal cancer screening programs to handle the substantial volume of data generated. AI can optimize the efficiency of screening processes by assisting in identifying polyps.⁷

AI in the detection of preoperative lymph nodes in colorectal cancer

The use of artificial intelligence (AI) to help identify preoperative lymph nodes in colorectal cancer is growing. Precise identification and description of lymph nodes are essential for designing suitable treatment approaches

and staging the illness. Artificial intelligence (AI) systems can autonomously recognize and describe lymph nodes from medical imaging data, including computed tomography (CT) and magnetic resonance imaging (MRI) scans. This entails evaluating their dimensions, form, and additional characteristics that could suggest malignancy.

In imaging investigations, this is accomplished by automatically separating lymph nodes from surrounding tissues, which is crucial for accurate measurement and analysis of lymph node features. AI models can extract relevant features from imaging data, such as texture, density, and shape of lymph nodes. These features can then be used for classification, helping to distinguish between benign and malignant lymph nodes. Also, AI can integrate imaging data with pathology reports to enhance the accuracy of lymph node detection and classification. Combining information from both modalities provides a more comprehensive understanding of the disease. AI algorithms can provide real-time decision support during image interpretation by highlighting suspicious lymph nodes for the radiologist or oncologist. This assists in expediting the diagnostic process and improving the accuracy of lymph node detection. Moreover, AI can provide quantitative measurements of lymph node characteristics, helping clinicians assess factors such as size, volume, and enhancement patterns. This information contributes to a more detailed and objective evaluation.

AI can also be employed to reconstruct three-dimensional models of lymph nodes based on imaging data. This can aid in visualizing the spatial relationships and better understanding the distribution of lymph nodes within the body. Deep learning techniques, such as convolutional neural networks (CNNs), are commonly used for image analysis tasks. These models can be trained on large datasets to recognize complex patterns and variations in lymph node appearance.

Based on imaging features, AI models can be trained to predict the likelihood of lymph node metastasis. This information is valuable for treatment planning and determining the extent of surgical intervention. Accurate detection of preoperative lymph nodes through AI can contribute to more precise surgical planning, which can determine the extent of lymphadenectomy, ensuring the removal of affected lymph nodes while minimizing unnecessary procedures.

AI in colorectal cancer registry

By using it to improve data management, analysis, and decision-making, colorectal cancer registries can benefit greatly from artificial intelligence (AI). AI can help

automate the gathering and combining many data sources, including pathology reports, imaging data, and electronic health records. This contributes to the upkeep of an extensive and current colorectal cancer registry. Artificial Intelligence algorithms have the potential to enhance data quality by detecting mistakes, discrepancies, or absent details. This guarantees the accuracy and uniformity of the data in the registry.

AI algorithms can analyse patient data to find trends and forecast the likelihood that colorectal cancer may manifest. For tailored preventative care and early intervention, this can be helpful. Artificial intelligence (AI)-driven solutions can track cases of colorectal cancer in real-time, spot patterns, and identify trends. Better planning and resource allocation for public health are made possible by this.

AI can assist in matching eligible individuals with suitable clinical trials based on their features and medical history by creating sizable colorectal cancer registries. This facilitates patient access to cutting-edge medicines and quickens clinical trial recruitment. Similarly, AI models can be used to evaluate past data to predict patient outcomes and survival rates. Policymakers and medical experts may find this information helpful in assessing the efficacy of various treatment modalities.

In Natural language processing (NLP), AI can extract valuable information from unstructured data sources such as clinical notes, pathology reports, and research articles. This enhances the depth and completeness of the data in the registry. It can also improve the security and privacy of patient data within the colorectal cancer registry by implementing robust encryption, access controls, and anomaly detection mechanisms.

AI in Robotic Surgery and Telesurgery

Artificial Intelligence (AI) is at the forefront of transforming the landscape of robotic surgery and telesurgery, introducing advancements that significantly enhance precision, decision-making, and overall surgical outcomes.⁸ Through real-time data analysis, machine learning algorithms provide feedback to robotic systems, allowing for more accurate movements and minimizing the risk of errors. This heightened precision is precious in intricate surgeries, such as those involving colorectal cancer, where surgical accuracy is paramount for successful outcomes.

AI provides real-time insights and decision help during robotic surgeries, functioning as an intelligent assistant. AI also makes some degrees of autonomy possible in robotic surgery. Though complete autonomy is still

uncommon, AI-powered systems can independently carry out some tasks—like cutting or suturing tissues. By automating repetitive parts of the process, surgeons can focus on more complex and essential parts of the operation.

Innovations in augmented reality and image recognition signal the entry of AI into robotic surgery. In the surgical field, computer vision algorithms can recognize and highlight essential structures, giving surgeons augmented images that facilitate navigation and decision-making.

Telesurgery, enabled by AI, allows surgeons to control robotic systems remotely. AI algorithms play a crucial role in compensating for communication delays and ensuring the stability of the robotic system during remote procedures. This capability expands access to expert surgeons, enabling them to assist with complex surgeries regardless of geographical distances.⁹

AI in robotic surgery also enables real-time monitoring of physiological parameters, providing instant feedback to the surgical team. This continuous monitoring helps detect anomalies early, allowing prompt intervention and enhancing patient safety. The technology's learning and adaptation capabilities mean that AI systems can refine their algorithms based on experiences from multiple surgeries, contributing to the continuous improvement of surgical techniques and outcomes.

Moreover, by automating routine tasks and providing intelligent assistance, AI contributes to the overall efficiency of robotic surgery. This efficiency could reduce the workload on surgeons and support staff, allowing

them to focus more on critical decision-making aspects of the procedure. As technology continues to evolve, the integration of AI in robotic surgery and telesurgery is poised to bring about further enhancements in patient care, accessibility to specialized expertise, and the overall efficiency of surgical procedures.

AI and surgical training

Artificial Intelligence (AI) is bringing new advancements to improve performance evaluation, individualized learning, and skill acquisition, changing the surgical training style. Trainees can practice procedures in a controlled environment by using realistic surgical environments created by AI-driven virtual reality and simulation platforms¹⁰. These AI-guided simulations provide a risk-free environment for surgeons to hone their abilities. This has the potential to change the old Concept of surgical training of "see one, do one, and teach one" to what we now call "simulated training, proctored training, and independent practice by high fidelity simulators and modern, sophisticated surgical tools like robots. (Figure). Artificial Intelligence (AI) facilitates personalized learning paths by analysing individual surgeon performance data and customizing training programs to meet their needs. This guarantees that surgeon concentrates on areas that need development while moving at their speed. AI is a real-time guide during surgical procedures, providing trainees with decision support and procedural direction. AI-powered adaptive learning platforms continuously modify the training program according to the surgeons' progress, adding new challenges and changing the degree of difficulty.

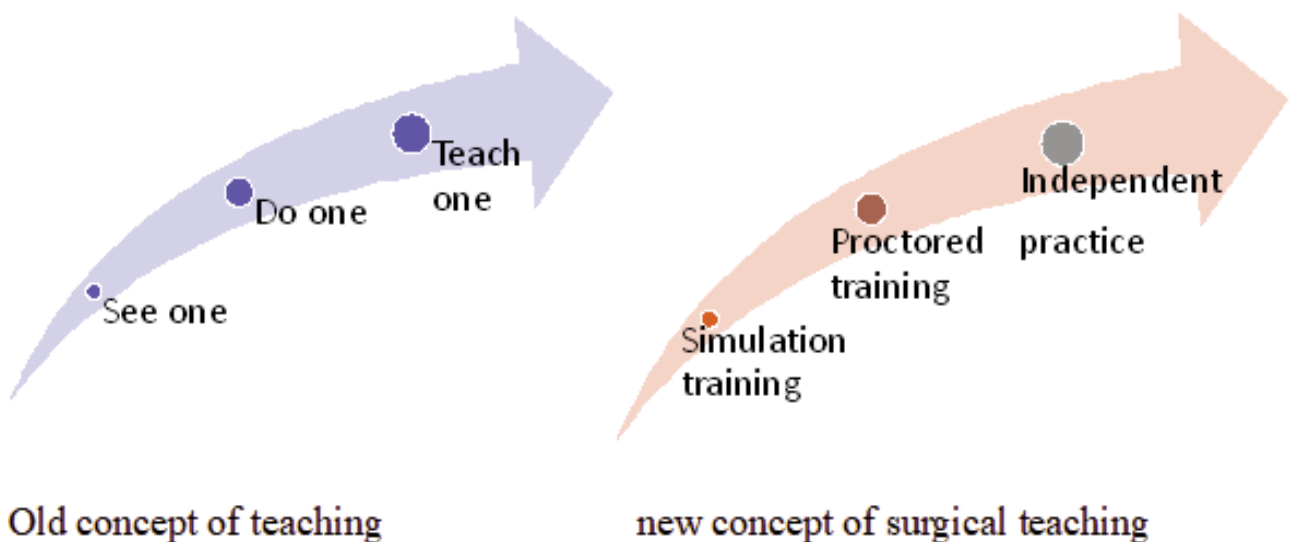


Figure: Shows that teaching and training concepts are being changed with advanced surgical tools like high-fidelity simulators and modern surgical equipment.

Additionally, AI facilitates tele-mentoring and remote training, allowing learners to get advice from knowledgeable mentors no matter how far away they live. AI is used in surgical training to monitor skills retention, evaluate long-term competency, and suggest refresher courses as necessary. AI-driven developments in surgical education can lead to a more effective, individualized, and patient-focused strategy that improves surgical care quality for patients and surgeons.

Establishing Boundaries by Using Artificial Intelligence

The integration of AI in colorectal cancer management marks a transformative shift in the landscape of cancer care, but it comes with notable drawbacks and challenges that warrant attention. One primary concern is the reliance on data quality and the potential for bias. AI models heavily rely on the data they are trained on, and if the data is biased or lacks diversity, the algorithms may produce skewed results, potentially leading to disparities in diagnosis and treatment recommendations among different patient groups. Ensuring diverse and representative training datasets is crucial to mitigate this issue.

The interpretability of AI models is another problem. Many advanced AI systems and intense learning models are regarded as "black boxes" because of their intricate decision-making procedures. The medical community is concerned about how AI determines specific diagnoses or therapy suggestions because of the need for more openness. Informed clinical decision-making depends on patients and healthcare providers being able to grasp the reasoning behind AI-generated judgments, which is why interpreted AI models are so important. Furthermore, continuous validation and integration with clinical processes are necessary to guarantee the dependability and efficiency of AI applications for diagnosing and staging colorectal cancer. Maintaining its efficacy over time also necessitates ongoing model monitoring and updating based on real-world performance and developing medical knowledge. Similarly, collaboration between radiologists, pathologists, and AI developers is vital for successfully implementing AI in clinical practice.

Lastly, ethical and legal issues also pose significant challenges. AI in healthcare raises concerns about patient privacy, consent, and the responsible handling of sensitive medical data. Additionally, legal frameworks and

regulations regarding the liability for AI-driven decisions are still evolving, introducing uncertainties about accountability in the event of adverse outcomes. It's crucial to address ethical and privacy considerations to ensure responsible and secure implementation in colorectal cancer management¹¹.

Conclusion

AI contributes to more precise, efficient, and patient-centric healthcare delivery, from early detection and personalized treatment planning to drug development and ongoing patient monitoring. We conclude that rigorous validation of AI models, transparency, and a focus on ethical considerations will remain critical in maximizing the potential of AI in future.

Disclaimer: None.

Conflict of Interest: None.

Funding disclosure: None.

References

1. Mitsala A, Tsalikidis C, Pitiakoudis M, Simopoulos C, Tsaroucha AK. Artificial Intelligence in Colorectal Cancer Screening, Diagnosis and Treatment. *A New Era. Curr Oncol* 2021;28:1581-607. doi: 10.3390/curroncol28030149.
2. Goyal H, Mann R, Gandhi Z, Perisetti A, Ali A, Aman Ali K, et al. Scope of Artificial Intelligence in Screening and Diagnosis of Colorectal Cancer. *J Clin Med* 2020;9:3313. doi: 10.3390/jcm9103313
3. Wang KS, Yu G, Xu C, Meng XH, Zhou J, Zheng C, et al. Accurate diagnosis of colorectal cancer based on histopathology images using artificial intelligence. *BMC Med* 2021;19:76. doi: 10.1186/s12916-021-01942-5
4. Lorenzovici N, Dulf EH, Mocan T, Mocan L. Artificial Intelligence in Colorectal Cancer Diagnosis Using Clinical Data: Non-Invasive Approach. *Diagnostics (Basel)* 2021;11:514. doi: 10.3390/diagnostics11030514
5. Quero G, Mascagni P, Kolbinger FR, Fiorillo C, De Sio D, Longo F, et al. Artificial Intelligence in Colorectal Cancer Surgery: Present and Future Perspectives. *Cancers (Basel)* 2022;14:3803. doi: 10.3390/cancers14153803
6. Barua I, Vinsard DG, Jodal HC, Løberg M, Kalager M, Holme Ø, et al. Artificial intelligence for polyp detection during colonoscopy: a systematic review and meta-analysis. *Endoscopy* 2021;53:277-84. doi: 10.1055/a-1201-7165
7. Nazarian S, Glover B, Ashrafian H, Darzi A, Teare J. Diagnostic Accuracy of Artificial Intelligence and Computer-Aided Diagnosis for the Detection and Characterization of Colorectal Polyps: Systematic Review and Meta-analysis. *J Med Internet Res* 2021;23:e27370. doi: 10.2196/27370
8. Hakamada K, Mori M. The changing surgical scene: From the days of Billroth to the upcoming future of artificial intelligence and telerobotic surgery. *Ann Gastroenterol Surg* 2021;5:268-9. doi: 10.1002/ags3.12466

9. Niu H. Application and Prospect of Telesurgery: The Role of Artificial Intelligence. In: Stawicki SP, Engelbrecht A, eds. Artificial Intelligence in Medicine and Surgery - An Exploration of Current Trends, Potential Opportunities, and Evolving Threats. London, UK: IntechOpen Limited; 2023. DOI: 10.5772/intechopen.111494
10. Saqib SU, Bajwa AA. The role of Da Vinci Xi robotic simulation curriculum in enhancing skills in robotic colorectal surgery. Ann Med Surg (Lond) 2023;85:6001-7. doi: 10.1097/MS9.0000000000001342
11. Alawad M, Yoon HJ, Gao S, Mumphy B, Wu XC, Durbin EB, et al. Privacy-Preserving Deep Learning NLP Models for Cancer Registries. IEEE Trans Emerg Top Comput 2021;9:1219-30. doi: 10.1109/tetc.2020.2983404.

DISCLAIMER

Articles published in JPMA and Supplements of JPMA do not represent the views of the editor or editorial Board. Authors are solely responsible for the opinions expressed and the accuracy of the data. The contribution of each author towards the published research included in this supplement is the responsibility of the authors and their institutions. It is expected to be in accordance and compliance with the ICMJE Guidelines. Any questions/queries raised by readers should be directed to the corresponding author.