Preliminary exploration and thinking on artificial intelligence in accelerated rehabilitation management after colorectal cancer surgery

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Abstract：Colorectal cancer is one of the most common malignant tumors in the world, and accelerated recovery after surgery is crucial to the patient's prognosis and quality of life. The traditional accelerated recovery surgical pathway is effective, but it lacks the ability to meet the individual needs of patients and cannot fully adapt to the unique situation of each patient. With the development of artificial intelligence technology, AI has significantly improved the accuracy and efficiency of ERAS work through personalized data analysis and intelligent monitoring. In preoperative evaluation, intraoperative management, and postoperative rehabilitation monitoring, AI can predict the risk of postoperative complications, optimize the rehabilitation pathway, provide accurate treatment plans, and improve patients' diagnosis and treatment experience and prognosis. However, AI still faces problems such as data privacy, algorithm transparency, and limited promotion in its application. These challenges need to be further addressed to comprehensively improve the level of medical services and the quality of patient rehabilitation.

Keywords：Artificial Intelligence; Enhanced Recovery Surgery; Colorectal Cancer; Personalization; Postoperative Management

Introduction：

Colorectal cancer is the second leading cause of cancer-related deaths globally. In 2020, there were an estimated 1.9 million new cases of colorectal cancer and over 930,000 deaths worldwide (Wei, et al., 2024). It is projected that by 2040, the number of new cases will rise to 3.2 million annually (a 63% increase), with 1.6 million deaths (a 73% increase). The aging population and unhealthy lifestyles present additional challenges for the prevention and treatment of colorectal cancer. Currently, the main treatment methods for colorectal cancer include surgery, chemotherapy, and radiotherapy, with curative surgery being the most effective treatment (Cianci & Restini, 2021). However, the trauma-induced stress response, risk of complications, and variations in recovery speed during postoperative rehabilitation are crucial factors influencing patient survival and quality of life. Therefore, scientific and efficient perioperative rehabilitation management is essential for improving patient outcomes.

Enhanced Recovery After Surgery (ERAS) is an optimized perioperative management model that, through multidisciplinary collaboration and evidence-based practices, significantly shortens hospital stays, reduces the incidence of postoperative complications, and improves recovery quality (Celotto, et al., 2024). In the treatment of colorectal cancer, the ERAS pathway includes comprehensive management before, during, and after surgery, such as optimizing preoperative preparation, precise anesthesia, postoperative pain management, early diet, and activity interventions. Research shows that the application of ERAS can significantly reduce postoperative complications such as infections and bowel obstruction in colorectal cancer patients and effectively reduce medical costs. However, traditional ERAS pathways have limitations in addressing personalized patient needs and real-time adjustments to recovery paths, make it difficult to meet the precise rehabilitation needs of different patients (Avram, Lazăr, Mariş, & Olariu, 2023).

The rapid development of Artificial Intelligence (AI) offers new opportunities for the personalized optimization of the ERAS pathway. AI technologies, particularly machine learning and deep learning, can process and analyze large-scale medical data to provide efficient data support for clinical decision-making by setting up complex models. AI has shown tremendous potential in areas such as disease diagnosis, image analysis, and drug development, significantly improving the precision and efficiency of medical services (Zhu, et al., 2025). In postoperative rehabilitation management, AI can track patients in real-time, predict early complications, dynamically optimize recovery paths, and provide precise, personalized intervention recommendations to both patients and medical teams. In particular, in the postoperative management of colorectal cancer, AI can complement the shortcomings of traditional ERAS pathways and provide more accurate and scientific rehabilitation support for patients (Pal, 2025).

This article aims to explore the preliminary applications and potential of AI technology in the ERAS management of colorectal cancer patients. The focus is on analyzing specific examples of AI technology in preoperative personalized assessment, intraoperative real-time monitoring, and postoperative risk prediction and recovery path optimization. It delves into the advantages and challenges of AI technology in addressing the limitations of traditional ERAS pathways and looks ahead to the future trends of scientific and intelligent development of AI technology in postoperative rehabilitation management. The goal is to provide higher-quality rehabilitation services for colorectal cancer patients (Quero, et al., 2022).

1 Application of artificial intelligence in personalized preoperative assessment

Preoperative assessment is one of the core elements of colorectal cancer Enhanced Recovery After Surgery (ERAS) management. Its primary goal is to thoroughly evaluate the patient's physical health, identify potential risks, and understand their rehabilitation needs (Celotto, et al., 2025). Through a systematic and personalized evaluation, healthcare professionals can obtain a comprehensive understanding of the patient’s health status before surgery. This thorough evaluation process forms the foundation for developing an optimized treatment plan, which can significantly improve the quality of postoperative recovery (Xu, et al., 2023). Accurate preoperative assessment not only aids in tailoring personalized treatment strategies but also plays a crucial role in reducing the incidence of postoperative complications, shortening hospital stays, and lowering overall medical costs (Marques, et al., 2022).

The importance of a detailed preoperative assessment cannot be overstated, as it allows healthcare providers to take proactive measures in addressing potential issues before they arise (Nasu, et al., 2013). By evaluating comorbidities, nutritional status, psychological health, and other patient-specific factors, clinicians can identify high-risk patients who may require special attention. Early intervention is key to improving patient outcomes, as targeted strategies such as enhanced nutritional support or psychological counseling can be implemented. These measures, tailored to the individual patient's needs, help create more favorable conditions for postoperative rehabilitation and recovery (Zain, et al., 2024).

The assessment of nutritional status is particularly significant in colorectal cancer patients, as malnutrition is common in this population. Nutritional deficiencies and weight loss can impair immune function, delay wound healing, and increase the risk of postoperative complications (Chen, Chen, & Zhang, 2025). By identifying patients at risk for malnutrition or sarcopenia (the loss of muscle mass), healthcare providers can initiate preoperative nutritional interventions that may improve surgical outcomes. Addressing psychological health before surgery can reduce anxiety and stress, both of which are known to negatively impact recovery after surgery. Interventions in these areas can significantly improve overall patient well-being and recovery times (Mazaki, et al., 2021).

Advancements in Artificial Intelligence have provided a strong technological support system for preoperative assessment. AI-driven personalized preoperative assessment models can analyze vast and multidimensional data, including Electronic Health Records (EHR), medical imaging, genomic data, and information regarding patient behavior and lifestyle (Chadebecq, et al., 2020). By employing machine learning algorithms, these models can mine complex datasets and accurately predict the risks of postoperative complications. Factors such as the patient's age, Body Mass Index (BMI), the type of surgery to be performed, and preoperative laboratory results can be used to predict the likelihood of various postoperative complications (Joseph et al., 2021). By offering predictions based on robust data analysis, these AI models provide healthcare providers with actionable insights to refine preoperative preparations and intraoperative management strategies (Van De Graaf, et al., 2019).

If a patient is identified as being at high risk for postoperative infection, the healthcare team can develop and implement an early anti-infection protocol, potentially preventing or mitigating the impact of infection. For patients who are at higher risk of bowel obstruction, a more conservative postoperative diet transition plan can be devised. These targeted approaches, driven by AI analysis, help to effectively reduce the incidence of postoperative complications, ultimately improving patient outcomes and reducing the overall cost of care.

AI-driven preoperative assessment tools have demonstrated their potential in several research studies. In one study examining postoperative complications in colorectal cancer patients, a machine learning-based predictive model was developed by analyzing clinical data from 1,244 patients (Alouthah, et al., 2024; Lam, et al., 2022).

The model incorporated various variables, such as medical history, preoperative laboratory results, and imaging data. The results showed that the model could provide predictions with a certain level of accuracy regarding the likelihood of postoperative complications. Based on this predictive model, healthcare providers can customize preoperative intervention plans for high-risk patients. Patients identified as high-risk for infection or complications related to surgery can receive personalized nutritional support strategies and other interventions (Achilonu, et al., 2021). However, the predictive accuracy of such models can vary across different datasets. In some cases, the model may not show high levels of accuracy when applied to certain patient populations or datasets. This variability highlights the need for caution when using AI technology in clinical decision-making and underscores the importance of external validation and the use of larger, multi-center datasets to enhance model performance and generalizability (Andras, et al., 2024).

In the realm of nutritional assessment, AI has proven to be particularly valuable. A retrospective observational study involving 586 colorectal cancer patients demonstrated the utility of AI-assisted L3 Computed Tomography (CT) for assessing nutritional status and diagnosing sarcopenia. The patients in the study underwent endocrine and nutritional assessments, and the AI system was used to analyze their CT images (Wolthuis, et al., 2016). The results revealed that a significant portion of the patients were malnourished or had sarcopenia. AI analysis showed that certain thresholds for skeletal muscle index and muscle area could be used to predict the risk of low fat-free mass and reduced appendicular skeletal muscle mass, which are key indicators of malnutrition and sarcopenia. These findings provided a more objective and quantitative approach to assessing nutritional and sarcopenia risk before surgery. The use of AI in this context offers the potential for earlier detection of these conditions, which allows healthcare providers to intervene with appropriate nutritional interventions that may improve surgical outcomes (Hassan, et al., 2023).

Despite the promising applications of AI in preoperative assessment, the technology still faces significant challenges that must be addressed before it can be widely adopted in clinical practice (Yu & Helwig, 2021). One of the primary challenges is the insufficient quality and diversity of data used to train AI models. Many models rely on data from single medical centers or specific regions, which can limit their generalizability and accuracy when applied to different patient populations. To overcome this limitation, it is essential to gather data from a broader range of sources, to ensure that AI models are trained on diverse and representative datasets.

Another challenge is the lack of interpretability in many AI models. The "black box" nature of many machine learning algorithms makes it difficult for healthcare providers to understand how predictions are made (Kudo, et al., 2021). This lack of transparency can lead to a lack of trust in the system and may hinder widespread adoption. Improving the interpretability of AI models is crucial to gaining the confidence of healthcare providers and ensuring that these tools are used effectively in clinical decision-making (Kim & Kim, 2020; Huang, et al., 2020).

AI models often struggle to incorporate subjective factors such as a patient's psychological state, lifestyle, and personal preferences. These factors are difficult to quantify but can have a significant impact on preoperative risk and recovery. The ability to incorporate these non-quantitative elements into AI models would improve their accuracy and make them more comprehensive. However, the integration of such subjective factors into AI-driven models presents both technical and ethical challenges, which must be addressed as AI technology continues to evolve (Tian, et al., 2024).

The issue of data privacy and ethics remains a major concern in the development and deployment of AI in healthcare. Legal regulations regarding data privacy and sharing are still in development, and there are concerns about the potential risks to patient confidentiality. Striking a balance between leveraging the power of AI to improve patient outcomes and protecting patient privacy is a critical issue that will need to be resolved through legislation and ethical guidelines (Aftab, et al., 2025).

Despite these challenges, the potential benefits of AI-driven preoperative assessment are undeniable. As research progresses and technology improves, it is likely that these tools will become increasingly sophisticated and accurate (Ignjatovic, et al., 2012). By addressing the current limitations, AI has the potential to revolutionize preoperative care, offer healthcare providers more accurate, efficient, and personalized treatment plans for colorectal cancer patients, ultimately improving patient outcomes and reducing the burden on healthcare systems (Dresen, et al., 2009).

2 Application of artificial intelligence in intraoperative management and real-time monitoring

In colorectal cancer surgery, the quality of intraoperative management directly impacts postoperative recovery outcomes and the incidence of complications (Spinelli, et al., 2023). Surgical precision, timing, and proper management of the perioperative environment are all crucial in influencing patient recovery. Common challenges encountered during surgery include control bleeding, protecting vital organs and tissues, ensuring optimal anesthesia management, and promptly addressing any intraoperative complications that may arise. Imprecise surgical techniques can cause excessive tissue damage, which leads to increased postoperative complications. Poor management of fluids, body temperature, and anesthesia can further delay recovery, increase patient discomfort, and prolong hospital stays. Achieving efficient and precise intraoperative management is essential to optimize patient recovery, reduce complications, and support the principles of Enhanced Recovery After Surgery (ERAS), which aims to minimize the stress of surgery and promote faster recovery (Chen, et al., 2023).

AI-driven real-time monitoring systems have shown considerable potential in improving surgical precision and safety during colorectal cancer surgery. These systems leverage machine learning and deep learning algorithms to process large datasets in real-time provide valuable insights to surgeons and anesthesiologists that can significantly improve patient outcomes. One such innovation is the development of a real-time bleeding point detection system. In this system, deep learning algorithms are used to analyze endoscopic surgical images and automatically identify and label bleeding areas in real-time (Maeda, et al., 2025). This capability allows surgeons to quickly pinpoint bleeding points and perform precise hemostasis. The introduction of such technology has proven to reduce surgery time, minimize intraoperative blood loss, and lower the postoperative infection rate, all of which contribute to improved recovery times and outcomes for patients. The AI-driven system is more accurate and efficient compared to traditional methods, where bleeding points may go unnoticed or require more time to identify (Jayakumar, et al., 2021).

Other AI applications in colorectal cancer surgery involve the use of real-time medical imaging, such as CT scans, to guide surgeons in accurately identifying tumor boundaries and determining resection margins. These systems can analyze CT data during surgery, highlight the boundaries of the tumor and ensure that healthy tissues are preserved while achieving complete tumor removal (Watanabe, et al., 2012). AI algorithms also aid in minimizing the risk of leaving behind tumor remnants, which is a major concern in cancer surgeries. This enhanced accuracy in tumor localization and tissue protection improves the surgical outcome and reduces the need for additional surgeries or postoperative treatments.

Anesthesia management is another critical aspect of colorectal cancer surgery where AI has shown substantial promise. AI-powered systems can integrate real-time patient data, to assist anesthesiologists in making more precise and personalized adjustments to anesthesia dosage. This personalized approach helps maintain the patient's optimal physiological state during surgery, prevent issues such as hypotension, bradycardia, and excessive sedation (Fadlallah, et al., 2024). A clinical trial conducted on colorectal cancer patients demonstrated that an AI-assisted anesthesia management system could dynamically adjust anesthesia dosages, significantly reducing postoperative anesthesia-related complications. In this study, patients who underwent AI-assisted anesthesia management had a complication rate of 15%, compared to 27% in the traditional anesthesia management group ($P < 0.01$), which highlights the potential of AI in improving patient safety and recovery outcomes (Pacella, et al., 2023).

Another AI application in intraoperative management is optimizing fluid infusion plans. AI algorithms can analyze a patient's fluid parameters, such as blood volume, electrolytes, and hydration status, to determine the most appropriate fluid infusion plan. This helps in preventing fluid overload, a common complication in postoperative care, which can lead to conditions such as pulmonary edema, kidney dysfunction, or prolonged recovery (Liao, Tsuei, & Chu, 2022). A study showed that AI-based fluid management systems reduced the incidence of postoperative fluid overload complications to 8%, compared to 20% in the traditional fluid management group ($P < 0.05$). This reduction in complications contributes to faster recovery and shorter hospital stays for patients, which supports the goals of ERAS protocols (Granata, et al., 2023).

AI's role in intraoperative management is expected to become even more sophisticated and integrated into the surgical workflow. One of the key developments is the ability of AI systems to combine preoperative evaluation data with real-time intraoperative monitoring information. This integration can provide surgeons with personalized surgical recommendations based on the patient's medical history, real-time surgical data, and even potential complications that may arise during surgery. AI can predict intraoperative challenges, such as sudden drops in blood pressure, changes in oxygen saturation, or unforeseen complications related to the patient's specific health conditions. By suggesting preventive measures in real-time, AI has the potential to improve surgical outcomes by allowing surgeons to take proactive steps before problems escalate (Alouthah, et al., 2024).

AI is likely to be deeply integrated with robotic-assisted surgical systems in the future. Robotic surgery has already revolutionized the precision and minimally invasive nature of many surgical procedures, and the incorporation of AI will enhance these systems further. An AI-driven robotic surgery system could continuously monitor the patient's condition during surgery, adjust the robotic arm's operating angles in real-time, and optimize the force applied during surgery to avoid unnecessary tissue damage. Such systems have the potential to significantly increase surgical accuracy and efficiency, reduce complications, and minimize recovery times. These technologies could allow for highly customized, real-time interventions, adapt to the nuances of individual patients and their specific anatomical and physiological characteristics (Li, et al., 2025).

The application of AI in intraoperative management is not without its limitations and challenges. Despite the promising potential, several factors still need to be addressed for AI systems to become fully integrated into clinical practice. One primary issue is the performance of AI systems in complex clinical environments. Factors such as lighting conditions in the operating room, equipment obstructions, variations in tissue morphology, and the dynamic nature of surgeries can affect the accuracy of AI-based image recognition and data analysis. The ability of AI algorithms to process and interpret real-time data under these conditions may still require refinement to ensure consistent accuracy (Wang, et al., 2022).

Another challenge is the robustness and generalizability of AI algorithms. Most current AI systems are trained on specific datasets from particular hospitals or regions, which may limit their applicability in other settings with different patient populations, surgical practices, or medical equipment. For AI to be broadly useful, it must be capable of adapting to varying conditions and performing accurately across diverse healthcare settings. This will require further development of algorithms that can handle diverse data sources and be validated across different institutions, surgical practices, and patient demographics.

The requirement for real-time decision-making during surgery presents another challenge. In order to provide timely and accurate recommendations, AI systems must have access to significant computational power and stable data transmission capabilities. Many operating rooms, however, are not equipped with the necessary infrastructure to support the intensive computational requirements of real-time AI processing. The speed and reliability of data transmission networks must be improved to ensure that AI systems can operate without delay or interruption, which could potentially hinder decision-making during critical moments of surgery.

Despite these challenges, the continued advancement of AI technologies holds immense promise for transforming intraoperative management into colorectal cancer surgery. As AI systems become more sophisticated, better integrated with robotic systems, and capable of handling diverse and complex clinical environments, their application in surgery will likely expand. The potential to improve surgical precision, minimize complications, and personalize patient care offers a significant opportunity to enhance the quality of colorectal cancer surgery, reduce recovery times, and improve patient outcomes. Through continued research, development, and the resolution of existing challenges, AI could revolutionize the way colorectal cancer surgeries are performed, make them safer, more efficient, and more effective in the long term.

3 Application of artificial intelligence in postoperative rehabilitation monitoring and intervention

Postoperative rehabilitation management is a critical component of recovery for colorectal cancer patients, as it directly influences long-term prognosis and quality of life. While traditional postoperative monitoring typically relies on periodic follow-ups and clinical examinations, this approach has limitations. The periodic nature of these assessments may fail to capture early signs of complications. These issues may not be addressed promptly, which leads to delayed interventions that could worsen recovery outcomes (Hardacre, et al., 2025). The diversity of patients' postoperative needs means that standardized rehabilitation pathways often fail to provide tailored care, particularly for those with complex or coexisting conditions such as malnutrition, sarcopenia, or anxiety. In these cases, personalized rehabilitation programs become essential to address the unique recovery challenges faced by individual patients.

AI technology is playing an increasingly vital role in addressing these challenges by improving the effectiveness of postoperative rehabilitation monitoring and intervention. One notable example is the machine learning-based postoperative complication prediction model developed by Shen et al. (2024), which integrates preoperative data, intraoperative data, and postoperative physiological indicators to predict the risk of complications like anastomotic leakage. This model has demonstrated an 85% accuracy rate in clinical trials, which allows healthcare providers to intervene early and reduce the incidence of severe postoperative complications. By predicting the likelihood of complications, the model helps tailor interventions to the patient's specific needs, optimizing recovery and reducing unnecessary hospital readmissions.

Remote monitoring platforms are another promising AI application in postoperative rehabilitation. These platforms collect real-time data from patients' home environments, which allow healthcare providers to monitor patients continuously, even after they have been discharged from the hospital. Convolutional Neural Networks (CNNs) used in radiomics can help manage surgical complications like lymphedema, a common issue following colorectal cancer surgeries. By analyzing medical images such as CT scans or MRIs, AI systems can track changes in fluid accumulation and tissue condition, enable timely interventions to prevent further complications. Integrating robotic systems with AI algorithms in physical rehabilitation settings allows for real-time adaptive control, optimize muscle fiber recruitment and improve rehabilitation outcomes (Al-Remawi & Aburub, 2024). These robotic rehabilitation systems adjust their movements based on the patient's progress, provide a personalized and responsive rehabilitation experience that can help accelerate recovery.

AI-driven platforms also play a significant role in offering personalized psychological and nutritional support. Given the emotional toll cancer treatment and recovery can take on patients, AI systems are increasingly being used to provide tailored psychological interventions, such as Cognitive-Behavioral Therapy (CBT) programs or stress-reduction exercises. These programs can be customized to address each patient's specific emotional state, help to improve mental health during the rehabilitation process. Nutritionally, AI can help create personalized dietary plans by analyzing patient-specific data, to suggest the most appropriate food choices that support recovery. These personalized interventions enhance the overall care of cancer survivors by addressing the physical, mental, and emotional aspects of rehabilitation.

AI can assist in rehabilitation treatment by accumulating real-time medical records and analyzing this data through machine learning algorithms. By continuously monitoring and analyzing data from various sources, these platforms can detect trends and predict outcomes, help healthcare providers make informed decisions about treatment adjustments. The platform may suggest changes to a patient's rehabilitation regimen based on their progress or highlight the need for a more intensive intervention if early signs of complications are detected. The interface of these platforms not only provides detailed statistics on similar patients, but also offers valuable benchmarks, but also outputs the best treatment combinations for each patient, based on historical data and clinical outcomes. This data-driven approach ensures that patients receive the most effective rehabilitation strategies, tailored to their unique needs and conditions, thus improving functional recovery.

In optimizing personalized rehabilitation pathways, researchers like Demir et al. (2012) have developed AI systems that analyze microcirculation data to assess tissue perfusion accurately. Their algorithm is capable of automatically extracting the microvascular network and quantitatively measuring changes in microcirculation. This technology holds significant potential for postoperative rehabilitation, especially for patients who have undergone major surgeries that may affect their tissue perfusion or healing capabilities. By providing continuous and real-time feedback on blood flow and tissue health, AI can alert clinicians to potential issues, enable timely interventions to improve healing and prevent complications such as ischemia or delayed wound healing.

Another research team has designed an AI-driven rehabilitation platform that recommends the most suitable exercise plans for patients based on their recovery status. This system uses the OpenPose human keypoint detector, a deep learning-based tool that analyzes patients' movements by recognizing the posture and angle of rehabilitation exercises. By analyzing two-dimensional images, the system can ensure that patients are performing exercises correctly, address issues such as unclear rehabilitation processes or lack of professional guidance. This technology enables patients to continue their rehabilitation outside the hospital, where they can perform exercises at home with real-time feedback on their movements. The system also collects rehabilitation data from these home exercises, which helps physicians conduct a comprehensive analysis of recovery progress and adjust treatment plans accordingly.

Despite the clear advantages of AI technology in postoperative rehabilitation, there are still several challenges that must be overcome before it can be widely adopted. One of the most significant challenges is ensuring the continuity and completeness of data collection. Postoperative patients often engage in home-based monitoring, which can be affected by various factors. These issues can compromise the real-time performance and accuracy of AI models, potentially leading to delayed interventions or incomplete assessments. Developing more robust and reliable remote monitoring systems is critical for the successful implementation of AI in postoperative care.

Another challenge is the need for multi-source data to develop truly personalized rehabilitation plans. AI models require data from a variety of sources to make accurate predictions and recommendations. The current mechanisms for data sharing and integration are not fully developed, which could limit the training and optimization of AI models. Interoperability issues between different healthcare systems, as well as variations in data quality and formats, pose significant barriers to effective AI implementation. Overcoming these challenges will require advancements in data standards, improved sharing mechanisms, and collaboration between healthcare institutions to ensure that AI models have access to the necessary data to provide optimal care.

Ethical and privacy concerns continue to pose barriers to the widespread adoption of AI technology in healthcare. The collection, storage, and analysis of sensitive patient data raise significant privacy and security risks. Ensuring that AI systems comply with legal and ethical standards is essential to building trust among patients and healthcare providers. Legal regulations regarding data protection and patient consent are still evolving, and there is a need for clear guidelines on how to balance the benefits of AI-driven healthcare with the protection of patient privacy. Addressing these concerns will require robust data security measures, transparent data usage policies, and continued efforts to safeguard patient confidentiality.

While AI has the potential to greatly enhance postoperative rehabilitation for colorectal cancer patients, challenges such as data continuity, multi-source data integration, and ethical considerations must be addressed before AI systems can be widely implemented in clinical settings. As AI technology continues to evolve and overcome these obstacles, it holds great promise for improving the rehabilitation process and ultimately enhancing the quality of life for cancer survivors.

4 Application of artificial intelligence in patient health education and self-management

Health education plays a crucial role in the recovery process of patients. Through systematic and scientific health education, patients can understand the basic requirements for postoperative care, preventive measures for complications, and rehabilitation goals and methods, thereby increasing their participation and compliance in the rehabilitation process. Effective health education helps patients learn proper postoperative exercise techniques, recognize complications such as infections, follow appropriate diets, and adhere to medication regimens, which can significantly reduce postoperative complications and promote recovery. Health education can alleviate patients' anxiety and psychological stress, enhance recovery outcomes and quality of life.

Traditional health education faces several challenges, including one-way information transmission and overly standardized content, which fail to meet individual patient needs. AI-driven intelligent health education tools are changing this scenario. AI-based educational platforms analyze patients' medical histories, postoperative rehabilitation data, and behavioral patterns to provide personalized health education content (Yin, et al., 2023; Singh, 2023). A research team developed an intelligent education application that combines postoperative rehabilitation data and psychological health assessments to create tailored care plans for patients, including postoperative diets, medication management, and exercise regimens. In clinical trials, patients using this application had a 20% reduction in readmission rates, and their quality-of-life scores at six weeks post-surgery were significantly higher than those of the control group who did not use the platform. AI-driven educational tools not only enhance patients' knowledge of rehabilitation but also boost their self-management abilities and confidence (Mitsala, et al., 2021). AI also demonstrates unique advantages in real-time interactive health education. A study involving colorectal cancer postoperative patients monitored vital signs continuously for five days using wearable wireless sensors, combining remote phone consultations to form a comprehensive virtual care intervention system (Aburub & Agha, 2024). The results indicated a very high feasibility of this home-monitoring technology, with a success rate of 99% in measuring vital signs trends across 105 cases. Patients also had high acceptance of this new rehabilitation method, with a satisfaction score of 8 out of 10 (Okagawa, et al., 2022). The consistency between AI-based vital signs trend assessments and phone consultations was 68%. Although 16% of assessments were incomplete due to data loss, no urgent cases requiring contact with the surgeon occurred. This indicates that AI technology has a certain level of accuracy and reliability in postoperative rehabilitation monitoring (Al-Remawi & Aburub, 2024).

Another pilot study conducted in two tertiary hospitals in the UK remotely monitored postoperative abdominal wound conditions in 200 patients using a wound assessment tool installed on their smartphones for 30 days (Mansur, et al., 2023). The results showed that 83% of patients used the tool, and 74% completed experience questionnaires. Within 30 days post-surgery, the surgical site infection rate was 16.5%, with 73% of infections diagnosed after discharge (Raza, Saqib, & Bajwa, 2024). The reliability, interface quality, ease of use, patient satisfaction, and practicality ratings were all high. While some patients desired more personalized interactions, most felt that this service provided greater benefits compared to conventional care (Wang, Liang, Cao, Cai, & Fan, 2023).

Dynamic adjustment of health education content is another major advantage of AI technology. An AI health education system can analyze data from a patient's rehabilitation progress and dynamically adjust the educational content accordingly (Avram, et al., 2023). When the system detects that a patient is recovering slowly in a specific aspect, it will push additional guidance or remind the patient to contact healthcare providers. This feature enhances the flexibility and precision of health education, to ensure that healthcare guidance is always highly aligned with the patient's current condition (Alouthah, et al., 2024).

AI's role in health education and self-management will further expand. Combining Virtual Reality (VR) technology with AI education platforms can provide patients with an immersive learning environment, where they can simulate postoperative care procedures, to master proper postoperative care methods. This interactive health education not only makes the learning process more flexible and engaging but also significantly improves patients' operational skills and confidence. Smart devices combined with AI can track real-time physiological data and behavioral data, provide personalized feedback to healthcare providers. Real-time monitoring, combined with health education, can help patients more effectively complete their rehabilitation plans and improve postoperative recovery outcomes.

AI-driven health education tools still face several limitations in practical applications. The equity of technological application is an important issue. Some patients, especially the elderly or low-income populations, may be unable to benefit from these technologies due to insufficient digital literacy or difficulty accessing smart devices (Pattanshetty & Khan, 2022). The accuracy and safety of personalized educational content depends on the quality of data, and the lack of patient privacy protection and data-sharing mechanisms may limit the continuous upgrading and optimization of these systems (Yu & Helwig, 2021). Current AI systems lack the ability to handle complex, emotionally charged conversations, which could affect the effectiveness of education and the user experience.

5 Challenges and ethical considerations of artificial intelligence in postoperative rehabilitation management of colorectal cancer

AI technology in postoperative colorectal cancer rehabilitation management has demonstrated significant potential but also faces a range of challenges, particularly in the areas of data privacy and algorithm transparency. AI systems typically rely on large amounts of patient data, including physiological indicators, behavioral patterns, and electronic health records, all of which must adhere strictly to privacy regulations (Al-Akayleh, et al., 2024). A research team developed a postoperative rehabilitation management platform that uses real-time monitoring data to predict postoperative complication risks, but low patient participation due to privacy concerns has been a key issue in clinical applications. This indicates that while technology has potential, data privacy concerns directly impact its practical utility and adoption.

To address these issues, data protection technologies have gradually been introduced. In recent years, some AI developers have adopted federated learning methods, which train models locally on patient devices rather than relying on centralized data storage, which can avoid the direct transmission of sensitive data. Google's federated learning technology has been successfully applied in Google Cloud's AI medical imaging platform, balance patient privacy protection with model performance. This method significantly reduces the risk of data breaches and provides a feasible solution for using sensitive medical data.

Algorithm transparency is also an urgent issue. Due to the complexity of deep learning models, healthcare professionals and patients often find it difficult to understand the underlying logic of AI decisions (Rasa, 2024). In a study involving a deep learning model for predicting postoperative complications, despite achieving an accuracy rate of 85%, its "black box" nature led to a lack of trust from clinicians in the predictions. To address this, explainable AI technologies have gained attention in recent years. A study on AI applications in postoperative rehabilitation introduced XAI techniques, which generate human-understandable decision-making explanations. This significantly increased clinicians' acceptance and trust in AI tools, promote their practical application.

Ethical considerations are also crucial, with data security and patient informed consent being two core issues. Protecting personal health data is particularly important, especially in cases where AI systems involve cross-institutional data sharing. In a multi-center collaborative study, patient data was leaked during transmission due to the lack of unified encryption standards, which leads the participating institutions to suspend the study. To address this, international data protection regulations, such as the European General Data Protection Regulation (GDPR) and the U.S. Health Insurance Portability and Accountability Act (HIPAA), have been developed to guide patient data protection. These regulations require encryption during data collection, storage, and sharing, and the explicit signing of agreements. Additionally, patient informed consent is equally crucial. To address this, user-friendly informed consent interfaces can be developed to help patients understand how their data will be used, the potential risks, and the specific scenarios in which it will be applied, thereby enhancing trust in AI systems (Ameen, et al., 2022).

The establishment of policy and regulatory frameworks is vital for the safe application of AI technology. Countries have gradually developed relevant standards for AI applications in healthcare. The World Health Organization (WHO) has mandated that AI medical devices undergo rigorous safety and efficacy certification before being used. The U.S. Food and Drug Administration (FDA) also requires AI medical tools to undergo clinical trials to verify their stability and accuracy. These regulations ensure the safe promotion of AI technology in the medical field. Data protection laws like GDPR and HIPAA not only require patient data to be used with patient authorization but also ensure that privacy protection is considered as a core issue in the system design stage.

Although policy and technological developments have supported the application of AI in colorectal cancer postoperative rehabilitation management, there are still some limitations. issues with data quality and fairness constrain the further improvement of technology performance. Many AI models are trained using data from specific populations, which may reduce the prediction accuracy for other demographic groups. Obstacles in data sharing and cross-institutional cooperation, such as a lack of standardization and legal restrictions, remain significant barriers to expanding AI applications. Current AI tool designs and applications often prioritize technical performance while neglecting the psychological and ethical needs of patients. When faced with highly technical rehabilitation management platforms, patients may feel alienated or anxious, which can impact their compliance and rehabilitation outcomes (Watanabe, et al., 2019).

6 Conclusion

AI technology plays an important role in the perioperative rehabilitation management of colorectal cancer patients, and has shown obvious advantages in preoperative risk assessment, intraoperative decision-making, and personalized optimization of postoperative rehabilitation pathways. We designed a flowchart of AI-assisted accelerated rehabilitation management for postoperative colorectal cancer patients (Figure 1), which details the entire process of postoperative rehabilitation management. By integrating AI technology into key stages before, during, and after surgery, the efficiency of rehabilitation work for colorectal cancer patients can be improved, and personalized services can be achieved.

Despite the numerous benefits that AI technology brings to the healthcare sector, there are still several challenges in its practical application. The limited generalization ability of models, partly due to the homogeneity of data sources, restricts the widespread use of AI technology across different regions and populations. concerns regarding personal privacy protection and the transparency of AI technology may affect patients' acceptance of this technology. There is still room for improvement in integrating AI technology with clinical practice, including the establishment of standardized processes and training healthcare professionals in the use of AI technology. These are key issues that need to be addressed.

In the future, AI technology should further optimize personalized models, incorporating genomics, multi-omics data, and real-time monitoring technologies to improve predictive accuracy and the relevance of comprehensive rehabilitation recommendations. Privacy protection technologies should be developed to enhance patients' trust in AI technology. By promoting data sharing among multiple institutions through standardization and policy support, and strengthening training for healthcare professionals, we can ensure that AI tools are effectively integrated into clinical practice, which support the goals of precision medicine and personalized rehabilitation.

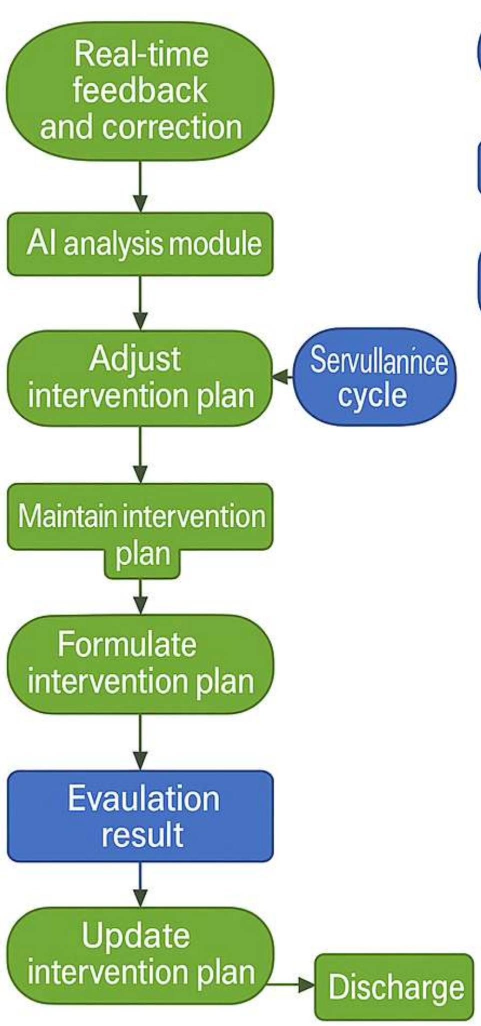

Figure 1 Flowchart of artificial intelligence-assisted accelerated rehabilitation management for patients with colorectal cancer after surgery

Reference

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