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Review

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Outcomes of Laparoscopic Versus Open Surgery for the Treatment of Colorectal Cancer: A Literature Review

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Abstract

The treatment of colorectal cancer (CRC) by laparoscopic and open surgery shows significant differences in clinical and postoperative outcomes. This study aims to consolidate existing knowledge on the outcomes of both surgical techniques in the treatment of CRC. Through a comprehensive review of major medical databases, including PubMed, Scopus, and Web of Science, research from the past decade was prioritized. The results highlight that laparoscopic surgery offers numerous advantages, including fewer postoperative complications, less blood loss, and shorter hospital stays, while maintaining comparable long-term oncologic outcomes to open surgery. However, challenges remain in patient management and the effectiveness of laparoscopic surgery in complex cases. We conclude that ongoing research and health policy improvements are needed to optimize the management and outcomes of CRC patients undergoing laparoscopic and open surgery, and suggest new directions for future research and updates to clinical guidelines.

Keywords: Colorectal cancer; Laparoscopic surgery; Open surgery; Oncological outcomes; Postoperative recovery

Introduction

The treatment of colorectal cancer (CRC) has significantly evolved with the increasing recognition of laparoscopic surgery as an alternative to traditional open surgery. This shift holds important implications for patient outcomes, including survival rates, recurrence, postoperative complications, and overall quality of life. Understanding the comparative benefits and limitations of these surgical approaches is crucial for optimizing global health outcomes in CRC treatment [1].

Laparoscopic surgery, defined as a minimally invasive technique, has been categorized as a preferable option for many patients due to its multiple benefits. These include fewer postoperative complications, less intraoperative blood loss, and shorter hospital stays compared to open surgery. Open surgery, on the other hand, remains a standard approach, particularly in cases where the technical complexity of laparoscopy could present challenges [1].

The surgical techniques involved in laparoscopic and open surgery present distinct mechanisms of action. Laparoscopic surgery utilizes small incisions and camera assistance to guide the surgeon, resulting in less body invasion, thus less trauma and quicker recovery. However, it requires a steeper learning curve and greater technical expertise. Open surgery, although more invasive, allows the surgeon direct access and full visualization of the affected area, which can be advantageous in certain complex cases [2].

Globally, the incidence and prevalence of CRC vary significantly according to age, sex, and ethnicity. Older adults and men have higher prevalence and incidence rates compared to women and younger adults. Additionally, the incidence of CRC is rising among young adults in several countries, underscoring the need for targeted early screening programs. Mortality rates also vary considerably across regions, with the highest rates observed in Eastern Europe and the lowest in South Asia [2].

The impact of CRC on morbidity and mortality is significant, affecting not only patients' physical health but also their socioeconomic well-being. Surgical treatment choices are influenced by factors such as access to healthcare, availability of trained surgeons, and patient preferences. Laparoscopic surgery, by offering quicker recovery and fewer complications, can reduce downtime and the costs associated with prolonged medical care [2].

Recently, several clinical trials and comparative studies have explored the outcomes of laparoscopic and open surgeries. These studies have demonstrated that laparoscopic surgery is not inferior to open surgery in terms of long-term oncological outcomes and offers significant advantages in terms of postoperative recovery and reduced complications [3].

Despite these advancements, there are gaps in the literature, particularly concerning variability in clinical outcomes and discrepancies in the availability of surgical options. Ad-

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dressing these gaps is essential to provide clear, evidence-based guidance for selecting the most appropriate surgical technique for each patient [3].

The objectives of this review are to comprehensively examine the outcomes, management, and future directions of laparoscopic versus open surgery in the treatment of CRC. This review aims to provide a thorough understanding of the advantages and disadvantages of each approach, identify areas where further research is needed, and offer recommendations to improve clinical practice and public health policies.

Epidemiology

CRC is a significant global health concern, being one of the most common and lethal neoplasms worldwide. Understanding its prevalence and incidence in different geographic regions is essential for developing effective prevention and treatment strategies. In 2020, there were an estimated 1.9 million new cases and 930,000 deaths from CRC, making it the third most common cancer globally. The global prevalence rates of adenomas, advanced adenomas (AAD), and CRC are 23.9%, 4.6%, and 0.4%, respectively [4].

Geographic variations in CRC incidence are notable. Regions with the highest incidence include Australia/New Zealand and Europe, with rates up to 40.6 per 100,000 in men. In contrast, several African and South Asian regions show the lowest rates, with figures as low as 4.4 per 100,000 in women. In Africa, the age-standardized incidence rate (ASIR) is 5.25 per 100,000, being higher in North Africa compared to Sub-Saharan Africa. These differences reflect not only variations in genetics and environmental factors but also the availability and quality of screening and treatment programs [4].

Sex and age differences are also significant in the epidemiology of CRC. Men have higher prevalence and incidence rates than women. Additionally, older adults have higher prevalence and incidence compared to younger adults. However, an increase in CRC incidence among young adults has been observed in several countries, including the United States, Germany, and Australia. It is projected that CRC incidence will increase to 3.2 million new cases and 1.6 million deaths by 2040, with the majority of cases occurring in countries with high or very high human development index (HDI). In transitioning countries, CRC incidence is rising, particularly among young adults [5].

Mortality rates for CRC also vary considerably between regions. The highest rates are found in Eastern Europe and the lowest in South Asia. There has been a reduction in CRC mortality in North America, Oceania, and most European countries, but increases have been observed in some Asian and Latin American countries. These data underscore the importance of global efforts in cancer control and prevention, tailored to the specific needs of each region and population [5].

In summary, CRC remains a major global health issue with significant variations in its prevalence and incidence by geography, sex, and age. High-income regions such as Australia/New Zealand and Europe have the highest incidence rates, while African and South Asian regions have the lowest. Men and older adults are more affected than women and younger individuals. The increasing incidence of CRC, especially in transitioning countries and among younger populations, highlights the need for targeted prevention and early detection programs. Mortality rates are decreasing in many high-income countries but increasing in some low- and middle-income regions, emphasizing the importance of global efforts in cancer control.

Pathophysiology

CRC develops through a complex interaction of genetic, epigenetic, and environmental factors. The primary biochemical and molecular mechanisms involved in CRC pathogenesis include adiponectin, interleukin-6, and opioid signaling, as well as processes of apoptosis, autophagy, and inflammation. Genetic and epigenetic alterations, especially in the Wnt/β-catenin signaling pathway, play a crucial role in the initiation and progression of CRC. Additionally, the gut microbiome significantly contributes to CRC pathogenesis and recurrence post-surgery. Inflammation, influenced by factors such as obesity, diet, smoking, and diabetes, is increasingly recognized as a key driver of CRC. Surgical interventions impact these pathways by removing the primary tumor and potentially altering the tumor microenvironment, though the specific effects of these interventions require further investigation [6].

Specific genetic mutations also influence surgical outcomes in CRC. Studies have shown that emergency laparoscopic surgery can offer advantages in short-term outcomes and oncological results. In elderly patients, laparoscopic surgery provides perioperative benefits and long-term oncological outcomes similar to open surgery. Moreover, laparoscopic surgery has been associated with shorter hospital stays and comparable long-term outcomes, even in low-volume rural hospitals. Conversion to open surgery does not compromise oncological outcomes. Laparoscopic surgery is also linked to lower local recurrence rates and long-term oncological outcomes comparable to open surgery. These studies suggest that laparoscopic surgery can provide comparable or even superior results in CRC treatment, regardless of specific genetic mutations [6].

Regarding structural and functional changes in colorectal tissues due to cancer, both laparoscopic and open surgeries play a fundamental role in mitigation. Laparoscopic surgery is associated with lower probabilities of developing incisional hernias and adhesive bowel obstructions compared to open surgery. Patients undergoing laparoscopic surgery experience fewer complications, shorter hospital stays, lower expression of inflammatory factors, reduced stress response, better immune function, less trauma, and faster recovery. Additionally, laparoscopic surgery better preserves natural killer (NK) cell function, with a faster recovery rate of their number and activity postoperatively compared to open surgery [7].

Different surgical techniques also influence cancer progression and patient outcomes. Postoperative infections, including surgical site infections, are associated with worse oncological outcomes in CRC patients. Additional surgical resection (ASR) following endoscopic resection in patients

with T1-stage CRC is associated with better overall survival (OS). The choice of anesthetic technique can influence long-term cancer outcomes, although recent studies do not show a significant long-term benefit of regional anesthesia over other techniques. In elderly patients, surgical intervention can be beneficial if carefully selected. Enhanced recovery after surgery (ERAS) protocols optimize postoperative recovery, though the type of anesthesia used can affect certain recovery parameters [7].

Genetic and biochemical factors also have a significant impact on surgical outcomes in CRC patients. The composition of the gut microbiome and body composition profiles, such as obesity and sarcopenia, are important prognostic factors for postoperative outcomes and recurrence. Detection of circulating tumor DNA (ctDNA) post-surgery is associated with worse recurrence-free survival and lower 5-year OS. Preoperative inflammatory markers, such as the lymphocyte-C-reactive protein (CRP) ratio, are linked to worse survival outcomes and higher risk of postoperative complications. Specific genetic variants, such as the MICA A5.1 variant, are associated with better recurrence-free survival and time to surgical failure in patients undergoing resection of colorectal liver metastases (CRLMs). KRAS mutations can predict pulmonary recurrences and influence decisions regarding surgical technique and margin width in CRLM surgeries [8].

In conclusion, surgical outcomes in CRC patients are influenced by a complex interaction of genetic and biochemical factors. Understanding these factors can help personalize treatment strategies, improve prognostic accuracy, and ultimately enhance patient outcomes.

Clinical Manifestations

CRC is a prevalent malignancy that often requires surgical intervention. There are two main surgical approaches: laparoscopic surgery and open surgery. The symptoms observed in patients may vary depending on the type of surgery they undergo. Patients undergoing laparoscopic surgery typically experience fewer postoperative complications, including lower rates of incisional hernias and adhesive bowel obstructions, compared to those undergoing open surgery [9]. Additionally, patients treated with laparoscopic surgery report a better quality of life and lower severity of symptoms, such as less insomnia and concern for the future. Recovery of bowel function is faster, hospital stays are shorter, and there is less intraoperative bleeding compared to open surgery. However, bleeding, though rare, can be a serious complication in laparoscopic surgery, requiring early diagnosis and multidisciplinary approaches for management [10].

Complications and syndromes associated with CRC and its surgical interventions are diverse and can significantly impact patient outcomes and quality of life. Surgical site infections are common and can lead to worse oncological outcomes, including delayed recovery and increased morbidity. Low anterior resection syndrome (LARS) is prevalent after surgery, significantly affecting quality of life, especially in patients receiving radiation therapy, chemotherapy, or experiencing postoperative anastomotic leakage. Elevated preoperative inflammatory biomarkers are associated with a higher risk of major complications in older patients undergoing CRC surgery. Frailty and cognitive impairment in older patients are related to a greater risk of postoperative loss of independence. Additionally, comorbidities such as atrial fibrillation and chronic obstructive pulmonary disease (COPD) are independent risk factors for severe postoperative complications. Common surgical complications include infections, anastomotic leaks, and prolonged recovery times, making effective preoperative, intraoperative, and postoperative measures crucial to minimize these risks [9].

Typical findings observed in initial diagnostic tests, such as colonoscopy and imaging, are crucial for identifying and managing various gastrointestinal conditions. Colonoscopy is commonly used to diagnose significant pathologies such as CRC and inflammatory bowel disease (IBD). Typical findings include ulcerative colitis, Crohn's disease, hemorrhoids, colorectal polyps, and diverticulosis. These tests have high diagnostic yield, identifying significant pathologies in a substantial proportion of patients. Point-of-care fecal tests that combine multiple biomarkers can effectively triage symptomatic patients, reducing unnecessary colonoscopies and prioritizing high-risk patients [10].

The symptoms of CRC can change with the use of laparoscopic versus open surgeries. Laparoscopic surgery is associated with fewer postoperative complications, lower inflammatory response, better preservation of immune function, and improved quality of life. Patients undergoing laparoscopic surgery report less severity of symptoms and better quality of life compared to those undergoing open surgery. However, both surgical approaches show comparable long-term oncological outcomes, such as OS and disease-free survival (DFS), although laparoscopic surgery may be associated with a higher risk of peritoneal recurrence in some cases [11].

In conclusion, CRC presents a variety of symptoms depending on the stage of the disease and the surgical technique used. Early-stage symptoms include anemia and abdominal pain, while advanced-stage symptoms are more prevalent and include larger tumors, severe anemia, and metastasis, particularly to the liver and lungs. Early detection and appropriate surgical intervention are crucial for improving patient outcomes.

Complications

The treatment of CRC through surgery can be associated with various complications, whose incidence varies depending on whether a laparoscopic or open approach is used. Laparoscopic surgery significantly reduces the incidence of surgical site infections compared to open surgery. Additionally, the overall infection rates, including wound infections and abdominal abscesses, are lower in laparoscopic procedures. Regarding hemorrhagic complications, laparoscopic surgery is associated with less perioperative blood loss and a lower incidence of bleeding. However, there are no significant differences in the incidence of anastomotic leaks between the two surgical methods. Laparoscopic surgery is also associated with lower probabilities of developing incisional hernias and adhesive bowel

obstructions, and patients tend to have shorter hospital stays, although operative times are generally longer [12].

The differences in recovery times and hospital stays between patients undergoing laparoscopic and open surgery are notable. Laparoscopic surgery is associated with shorter hospital stays and faster recovery of bowel function, such as the time to first flatulence and defecation. Additionally, patients undergoing laparoscopic surgery experience fewer postoperative complications, such as wound infections, ileus, and pneumonia, compared to open surgery. Intraoperative blood loss is less, and trauma is reduced in laparoscopic surgery, although these procedures generally take longer to complete. Long-term oncological outcomes are comparable between both surgical approaches, including OS and DFS rates [12].

Long-term complications and quality of life outcomes in patients undergoing different surgical techniques for CRC are crucial for optimizing patient care. Laparoscopic surgery is associated with better quality of life outcomes compared to open surgery, especially in terms of physical functioning and pain reduction. Patients with a stoma report lower quality of life compared to those with preserved gastrointestinal tract continuity, with a negative impact that increases over time. Postoperative complications are linked to worse long-term oncological outcomes, including lower OS and DFS rates, and higher recurrence rates. Postoperative infections, including surgical site infections, are associated with worse oncological outcomes. Curative endoscopic resection (C-ER) for T1-stage CRC shows no risk of tumor recurrence or cancer-related deaths, while non-curative endoscopic resection (NC-ER) with ASR improves recurrence-free survival compared to surveillance-only approaches. Frailty and comorbidities are critical factors in predicting long-term outcomes, highlighting the need for personalized care strategies [13].

Recurrence rates of CRC in patients treated with laparoscopic versus open surgeries are generally comparable. Both surgical approaches show similar OS and DFS rates. However, specific recurrence patterns, such as distant metastases in lymph nodes and peritoneal recurrence, may vary between the two methods. Laparoscopic surgery is a viable alternative to open surgery, offering similar long-term oncological outcomes [13].

Mortality rates associated with laparoscopic and open surgeries in the treatment of CRC are crucial for optimizing patient outcomes. Laparoscopic surgery shows lower 30- and 90-day mortality rates compared to open surgery in population studies. For emergency colorectal procedures, laparoscopic surgery presents lower postoperative mortality compared to open surgery. Laparoscopic resection for CRLMs is associated with lower mortality rates and a higher fraction of long-term survivors compared to open surgery. Laparoscopic colectomy for T4-stage colonic cancer is associated with lower mortality rates compared to open surgery. Additionally, laparoscopic surgery is associated with fewer early and late complications, making it a viable and often preferable option for the treatment of CRC [14].

In conclusion, laparoscopic surgery for CRC offers significant advantages in terms of complications, recovery times, long-term quality of life, recurrence rates, and mortality compared to open surgery. These findings underscore the need to carefully consider the most appropriate surgical approach for each patient, taking into account the specific characteristics of the tumor and the patient's overall health status.

Criteria and Challenges

The treatment of CRC through surgery involves critical decisions based on clinical and laboratory indicators. The choice between laparoscopic and open surgery can influence various clinical and laboratory outcomes, impacting the decision-making process for optimal patient care. Laparoscopic surgery is associated with lower rates of incisional hernias and adhesive bowel obstructions compared to open surgery, as well as fewer postoperative complications such as wound infections, ileus, and pneumonia in older patients. Additionally, laparoscopic surgery results in lower levels of postoperative inflammatory markers and stress hormones compared to open surgery, better preserving cellular immunity. These benefits include shorter hospital stays, faster recovery of bowel function, and less intraoperative bleeding, although the operative time may be longer. Both approaches show comparable long-term oncological outcomes, such as OS and recurrence rates [15].

The systematic approach to diagnosing CRC includes a combination of non-invasive tests, advanced imaging techniques, and innovative technologies. The fecal immunochemical test (FIT) is highly sensitive for detecting CRC and is recommended for prioritizing patients needing further colorectal investigation. Radiomics, especially magnetic resonance imaging (MRI)-based, show promise in predicting treatment outcomes and survival in CRC patients. CtDNA is a promising biomarker for CRC screening and diagnosis, with quantitative analysis and methylation assays showing satisfactory diagnostic efficiency. Alternative non-invasive methods, such as urine, exhaled breath, and blood-based tests, are being explored to improve patient adherence and diagnostic performance. Diffusion-weighted MRI (DWI-MRI) has demonstrated high diagnostic accuracy for detecting CRC. Deep learning methods for analyzing digitized histological slides also show high accuracy in detecting CRC. Epigenetic biomarkers, such as DNA methylation, are being investigated for their potential in early CRC detection [15].

Specific findings in imaging and endoscopy are crucial for CRC diagnosis. Macroscopic evaluations, including the Paris and LST classifications, and chromoscopic evaluations such as Kudo's crypt pattern and the Japanese expert team's NBI classifications, are essential. Advanced endoscopic techniques and artificial intelligence tools have significantly improved mucosal visualization and optical diagnosis, enhancing early detection and management of CRC [16].

Preoperative evaluation is fundamental for determining the suitability of laparoscopic versus open surgery. Laparoscopic surgery is associated with significantly lower postoperative mortality and morbidity rates, including wound infections, wound dehiscence, ileus, and pulmonary and cardiac complications compared to open surgery in emergency settings. It is also associated with lower probabilities of incisional hernias and adhesive bowel obstructions. Laparoscopic surgery offers

advantages in terms of shorter hospital stays, faster recovery of bowel function, and fewer postoperative complications. However, both surgical approaches can achieve excellent oncological outcomes when performed by experienced surgeons [16].

The diagnosis of CRC and the selection of the appropriate surgical intervention present several challenges. The complexity of the disease requires a personalized approach, considering factors such as disease characteristics, microsatellite status, and prognostic and predictive mutations. Advances in medical science, including the immunoscore and liquid biopsy, have improved diagnostic and treatment precision. However, variability in treatment strategies and the need for a multidisciplinary approach complicate the process. Disparities in end-of-life care and the impact of health inequities on treatment decisions highlight the need for a patient-centered approach. Preoperative evaluation, staging, and treatment planning are crucial for determining the appropriate surgical intervention. The evolution of treatment strategies, including the use of targeted therapies and immunotherapy, has improved outcomes, but managing surgical complications remains a significant challenge [17].

Differential Diagnosis

The differential diagnosis of CRC is a complex process that requires careful evaluation to distinguish it from other gastrointestinal diseases and determine the appropriate treatment. CRC is distinguished from other gastrointestinal diseases through specific patterns of genetic mutations, such as those in the CDH1 and RHOA genes, which are highly specific for diffuse histology and advanced stages of gastric tumors. Additionally, epigenetic alterations, including changes in DNA methylation, histone modifications, chromatin structure, and non-coding RNA expression, have been identified as potential biomarkers for CRC [3].

Identifying non-surgical treatments for patients who might benefit from them, compared to those requiring surgical interventions, is crucial for optimizing outcomes. In some cases, non-surgical treatments can offer equivalent or superior results to surgical ones. For example, in the treatment of advanced hypopharyngeal cancer, non-surgical treatments are more beneficial for laryngeal preservation. In periodontal disease, non-surgical periodontal therapy significantly improves patient-reported outcomes. In distal radius fractures, surgical interventions show better short-term outcomes, but non-surgical treatments significantly improve outcomes between 3 and 12 months. Shared decision-making, especially in high-risk surgeries, requires aligning patient and clinician expectations, framing non-surgical options as active treatments [18].

Benign conditions of the colon, such as colorectal adenomas and hyperplastic polyps, present distinct characteristics from CRC that are essential for accurate diagnosis. Colitis-associated cancer (CAC) shows a higher prevalence of poorly differentiated adenocarcinoma and mucinous carcinoma compared to sporadic CRC [18]. Inflammatory and nutritional markers, such as the hemoglobin, albumin, lymphocytes, and platelets (HALP) score, are significantly lower in patients with CRC compared to those with benign colorectal neoplasms. Additionally, chronic oxidative stress and inflammation in the colonic epithelium can alter Wnt/β-catenin signaling and DNA repair pathways, leading to the development of adenomatous polyps and their potential progression to CRC [19].

The diagnosis of metastatic CRC (mCRC) requires precise diagnostic criteria to differentiate it from primary tumors. The high concordance of biomarkers such as KRAS, NRAS, BRAF, and EGFR between primary and metastatic colorectal tumors indicates that genetic testing of either can be informative for diagnosis and treatment. Advanced imaging techniques, such as dual-energy computed tomography (DECT) and positron emission tomography/computed tomography (PET/CT) with gallium 68 fibroblast activation protein inhibitor (68Ga-FAPI), offer greater diagnostic accuracy. Additionally, circulating microRNAs (miRNAs) and differentially expressed genes (DEGs) present promising avenues for future diagnostic and therapeutic strategies [19].

A comprehensive approach to the differential diagnosis of CRC must include a systematic approach based on clinical evaluation, detailed imaging studies, and histopathological analysis. It is essential to follow a comprehensive guide that addresses follow-up care, psychosocial support, and communication, ensuring that treatment options are tailored to the specific characteristics of the patient and clinician expectations. Preoperative evaluation, staging, and treatment planning are crucial for determining the appropriate surgical intervention. The evolution of treatment strategies, including the use of targeted therapies and immunotherapy, has improved outcomes, but managing surgical complications remains a significant challenge [20].

In summary, the differential diagnosis of CRC and the selection of the appropriate surgical intervention require a combination of genetic and molecular profiling, advanced imaging techniques, and clinical analysis. Understanding these differences is essential for accurate diagnosis and effective treatment planning, thereby improving patient outcomes and quality of life.

Management and Treatment

The management and treatment of CRC encompass a variety of approaches, ranging from monitoring disease progression to advanced surgical techniques, adjuvant therapies, and lifestyle modifications. Below is a detailed description of each aspect to provide a comprehensive view of CRC treatment [20].

Monitoring the progression of CRC post-surgery is crucial for improving patient outcomes and personalizing treatment plans. Various protocols and technologies have been developed to track and predict cancer recurrence and patient survival, leveraging advances in machine learning, enhanced recovery programs, and digital pathology [19]. Machine learning algorithms, such as gradient boosting machine (GBM), have demonstrated high accuracy in predicting the risk of tumor recurrence in stage IV CRC patients post-surgery. Deep learning models analyzing hematoxylin and eosin-stained sections can develop prognostic biomarkers that outperform tra-

ditional molecular and morphological markers. Additionally, ERAS programs are being studied for their long-term impact on CRC outcomes, improving 5-year survival rates and quality of life by minimizing surgical aggression and enhancing recovery [19].

Surgical techniques used in laparoscopic and open surgeries significantly impact patient outcomes. Laparoscopic surgery is associated with fewer surgical complications, shorter operative times, less blood loss, and shorter hospital stays compared to open surgery. Studies have shown that laparoscopic surgery results in less postoperative pain and a lower incidence of complications such as wound infections and adhesive bowel obstructions. Furthermore, laparoscopic surgery for CRC has been linked to shorter hospital stays without increasing total costs [20].

Disease-specific adjuvant therapies play a crucial role in improving outcomes for CRC patients post-surgery. Adjuvant chemotherapy is a standard treatment for stage III and high-risk stage II CRC, significantly improving OS and DFS. Common regimens include fluoropyrimidine-based therapies, sometimes combined with oxaliplatin, especially for high-risk patients. Cytokine-induced killer (CIK) cell therapy combined with post-surgery chemotherapy has shown to improve DFS and OS compared to chemotherapy alone, particularly in high-risk patients. Adjuvant chemotherapy after resection of CRLMs improves DFS but does not significantly extend OS. The future of adjuvant chemotherapy lies in precision medicine, using biomarkers to stratify patient risk and personalize treatments [18].

Lifestyle changes, dietary modifications, and other non-pharmacological interventions also significantly contribute to CRC management. Diets rich in fruits, vegetables, whole grains, and low in red and processed meats are associated with a reduced risk of CRC. Plant-based diets, the Mediterranean diet, and Dietary Approaches to Stop Hypertension (DASH) are beneficial in reducing CRC risk. High dietary fiber intake from fruits and vegetables can decrease CRC incidence and serve as adjuvant therapy. Western dietary patterns, high in processed meats, sugary drinks, and refined grains, increase CRC risk. Lifestyle factors such as overweight, obesity, physical inactivity, and smoking are modifiable risk factors contributing to CRC development. Intentional weight loss and maintaining a healthy body weight are crucial for reducing CRC risk. The interaction between diet, lifestyle, and the gut microbiome significantly influences CRC incidence and prognosis, and precision nutrition approaches targeting the gut microbiome can enhance cancer prevention and survival [20].

Advanced management options, such as novel surgical techniques and experimental therapies, offer new opportunities for CRC treatment. Targeted therapies, such as monoclonal antibodies against EGFR and VEGF, have significantly increased survival in metastatic disease. Cancer precision medicine, nanocarrier platforms for targeted chemotherapy, and palliative pressurized intraperitoneal aerosol chemotherapy (PIPAC) are promising interventions for stage IV CRC. Technological advancements in surgical treatment, such as laparoscopy and intracorporeal anastomosis, have improved recovery and patient outcomes [17]. Nanocarrier-based therapies, including nanomedicine and phytonanomedicine, offer potential for improved therapy. Emerging treatment options for mCRC include precision treatment strategies and immune therapies. Novel drug delivery systems, including nanocarriers, gene therapy, and radiotherapy, are also being explored. Endoscopic resection techniques, such as snare polypectomy and endoscopic mucosal resection, are available for early CRC [15].

In summary, the management and treatment of CRC involve a multifaceted approach, encompassing post-surgery disease monitoring, adjuvant therapies, lifestyle changes, and innovations in surgical techniques and experimental therapies. These comprehensive approaches are essential for improving patient outcomes and optimizing CRC treatment.

Prognosis

The prognosis of CRC in patients undergoing laparoscopic versus open surgeries is influenced by various factors. Variables impacting prognosis include the likelihood of incisional hernias and adhesive bowel obstructions, which are lower in laparoscopic surgeries. Conversion from laparoscopic to open surgery is more likely in left-sided resections, rectal resections, and local tumor invasion but does not compromise long-term oncological outcomes [21]. In obese patients, laparoscopic surgery shows better OS and cancer-free survival comparable to open surgery. For middle-aged patients, laparoscopic resection offers better 5-year OS and DFS rates. In elderly patients, long-term outcomes are similar between both techniques. A lower body mass index (BMI) and poor performance status are independent predictors of reoperation within 30 days following laparoscopic CRC surgery. These factors suggest that laparoscopic surgery is a viable and often preferable option for many CRC patients [22].

To evaluate the prognosis in CRC patients treated with different surgical techniques, various tools and methods are used. Preoperative nutritional assessment and nutritional support are fundamental. Clinicopathological factors and tumor biology are relevant for predicting survival. The multidimensional prognostic index (MPI) is a key predictor of postoperative outcomes. Specific blood markers and diagnostic prediction models are also valuable for assessing prognosis [21].

Long-term outcomes, such as survival rates and quality of life measures, have been compared between laparoscopic and open surgeries in multiple studies. In elderly patients with rectal cancer, 5-year survival rates are similar between both approaches. Laparoscopic surgery is associated with lower postoperative mortality and morbidity in emergency settings. In patients with transverse colon cancer and elderly patients, long-term outcomes are comparable between the two techniques. Overall, the rates of OS and DFS are similar between laparoscopic and open surgeries for left colon cancer and colon cancer in general [22].

Disease recurrence in CRC patients is influenced by tumor characteristics, such as advanced stage, tumor size, and lymphovascular invasion. Elevated preoperative and postoperative carcinoembryonic antigen (CEA) levels are strong predictors of recurrence. Tumor location, particularly in the rectum, is associated with a higher risk of recurrence. Surgical complications, including anastomotic leaks, increase the risk of recurrence.

Strategies to mitigate recurrence include aggressive surveillance for high-risk patients, personalized adjuvant therapies, and the use of genomic profiles to guide targeted therapies [22].

Comparing prognostic outcomes between laparoscopic and open surgeries for CRC reveals similar long-term oncological outcomes, with laparoscopic surgery offering several perioperative advantages, including shorter hospital stays and lower rates of postoperative complications. Laparoscopic surgery is particularly beneficial for elderly patients, showing similar OS and recurrence-free survival rates to open surgery. Additionally, it demonstrates safety and efficacy in patients with a higher BMI. Overall, laparoscopic surgery appears to be a viable and potentially advantageous option for CRC treatment [23].

In conclusion, the prognosis of CRC in patients undergoing laparoscopic versus open surgeries depends on a combination of tumor factors, patient characteristics, and surgical outcomes. Laparoscopic surgeries generally offer better or comparable outcomes in terms of survival, complications, and recurrence rates. Comprehensive prognostic assessment using advanced tools and predictive models is essential for improving decision-making and treatment outcomes in CRC patients.

Gaps in the Literature

The comparison between laparoscopic and open surgeries in the treatment of CRC has been extensively researched. However, there are areas where data are insufficient, particularly regarding long-term effects and early diagnostic indicators. Below are the main gaps and methodological limitations in the current literature on this topic [2].

One of the primary gaps in the research is the lack of data on the long-term effects of laparoscopic versus open surgeries. While short-term benefits of laparoscopic surgery, such as fewer complications and faster recovery, have been well documented, there is a significant need for studies evaluating long-term outcomes. Specifically, more information is needed on 5- and 10-year survival and recurrence rates, as well as the quality of life of patients after these interventions. Some studies suggest potential benefits for laparoscopic surgery in specific subgroups of patients, such as the elderly and those with CRC liver metastases, but these findings require confirmation through larger, high-quality studies [14].

Early diagnostic indicators for CRC also require further research to improve treatment outcomes. Although several promising biomarkers, such as long non-coding RNAs (lncRNAs), microsatellite instability (MSI), and mismatch repair deficiencies (dMMR), have been identified, these markers need to be validated and optimized for clinical use. The identification of non-invasive, cost-effective, and rapid diagnostic tools, such as optical nanosensors, could significantly enhance early detection and treatment outcomes, but more research is needed to develop and validate these technologies [5].

Methodological limitations in current research on laparoscopic versus open surgeries for CRC include variations in study design, patient selection, and surgical techniques. Differences in study protocols and definitions of complications can lead to inconsistent results. Moreover, most studies focus on short-term outcomes, while long-term effects, such as survival rates and quality of life, are often not adequately addressed. Future studies need to use standardized protocols, larger sample sizes, and longer follow-up periods to provide more robust evidence on the comparative effectiveness of these surgical techniques [24].

To improve understanding of the outcomes of laparoscopic versus open surgeries in CRC, well-defined, multicenter randomized controlled trials are needed. These trials should focus on emergency scenarios where laparoscopic surgery has shown lower postoperative mortality and morbidity. Population-based studies can assess the benefits of laparoscopic surgery, such as shorter hospital stays and reduced demand for opioid analgesics. The inclusion of robotics in rectal cancer surgery should also be explored to overcome technical challenges while maintaining oncological outcomes. Additionally, it is essential to evaluate the economic outcomes of laparoscopic surgeries to determine if they result in shorter hospital stays without increasing overall hospitalization costs [25].

In summary, research on laparoscopic versus open surgeries in the treatment of CRC presents several gaps and methodological limitations. More research is needed to evaluate long-term effects, validate early diagnostic indicators, and improve study methods. Addressing these gaps can enhance the available evidence and optimize treatment outcomes for CRC patients.

Future Directions

The comparison between laparoscopic and open surgeries for the treatment of CRC has been a significant focus in medical research. While multiple advantages and disadvantages of each approach have been identified, it is essential to direct future research towards areas that optimize patient outcomes [24].

Research priorities should focus on minimizing postoperative complications and understanding long-term oncological outcomes. It is crucial to explore the immunological benefits of laparoscopic surgery, which has demonstrated less suppression of cellular immunity and reduced inflammation. Addressing the technical challenges and learning curve associated with laparoscopic surgery is also necessary, ensuring that surgeons acquire the expertise needed to perform these interventions effectively. Additionally, managing postoperative complications through laparoscopic reintervention should be a priority, as it has shown favorable outcomes compared to open reinterventions [11].

Regarding biomarkers for the early diagnosis of CRC, it is fundamental to research and validate several promising candidates. Anti-p53 antibodies and proteins such as CEA and CRP have shown potential. The methylation of ctDNA, especially genes like SEPT9 and SDC2, and circulating miRNAs, such as miR-29a, are promising for early detection. LncRNAs like SNHG11 have also demonstrated high diagnostic performance. Future research should focus on validating these biomarkers in independent prediagnostic contexts and exploring their combined use in panels to improve diagnostic accuracy [25].

The development of targeted therapeutic approaches for

patients undergoing laparoscopic versus open surgeries is another crucial research area. Precision medicine and enhanced recovery pathways, especially in fast-track laparoscopic surgeries, have proven effective and safe in treating CRC. It is necessary to continue exploring the feasibility and efficacy of these techniques, particularly in the context of laparoscopic surgery [8].

Public health policies should focus on implementing ERAS pathways supported by digital health interventions, addressing socioeconomic disparities with adaptive multilevel strategies, and adopting a health equity framework for CRC screening. These measures can collectively improve patient outcomes, reduce disparities, and ensure equitable access to high-quality care [5].

Future research directions should concentrate on well-defined, multicenter randomized controlled trials that validate the use of robotic surgery compared to open and laparoscopic approaches. Further investigation is also needed to compare the long-term oncological outcomes of laparoscopic and open surgeries, particularly in elderly patients. Addressing these areas will advance the understanding and treatment of CRC, thereby optimizing patient outcomes [25].

In summary, future research on laparoscopic versus open surgeries for CRC treatment should focus on minimizing postoperative complications, validating early diagnostic biomarkers, developing targeted therapies, implementing effective public health policies, and conducting robust clinical trials. These initiatives will significantly improve treatment outcomes and the quality of life for patients with CRC.

Conclusion

In this review, a comprehensive analysis of the outcomes, management, and future directions of laparoscopic versus open surgery in the treatment of CRC has been conducted. The key findings indicate that laparoscopic surgery offers numerous advantages compared to open surgery, including fewer postoperative complications, less intraoperative blood loss, and shorter hospital stays, while both techniques show comparable long-term oncological outcomes. The studies reviewed highlight the importance of considering individual patient factors, such as age, general health status, and tumor location, when selecting the most appropriate surgical technique. In particular, elderly patients and those with significant comorbidities notably benefit from laparoscopic surgery due to its lower invasiveness and faster recovery. It is evident that further research is needed to address the existing gaps in the literature, especially regarding the long-term effects of laparoscopic and open surgeries, the validation of early diagnostic biomarkers, and the development of targeted therapies. Addressing these areas will advance the understanding and treatment of CRC, thereby optimizing patient outcomes.

Highlights

Laparoscopic surgery for CRC offers fewer postoperative complications and shorter hospital stays compared to open surgery.

Recent studies show that laparoscopy has long-term oncological outcomes comparable to open surgery.

Postoperative recovery is faster with laparoscopic surgery, improving the patient's quality of life.

There are gaps in the literature regarding the long-term effects of both surgical techniques.

More research is needed to validate early diagnostic biomarkers and optimize treatment outcomes.

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Conflict of Interest

The authors declare no conflict of interest to ensure the impartiality of the review.

Author Contributions

Jordan Llerena-Velastegui, MD: conceptualization, data curation, writing - original draft, writing - review and editing; Sebastian Velastegui-Zurita, MD: data curation, formal analysis, writing - review and editing; Ana Teran-Lopez, MD: supervision, conceptualization, writing - original draft, writing - review and editing, methodology; Francesca Velasco-Velasco, MD: supervision, conceptualization, writing - original draft, writing - review and editing, methodology.

Data Availability

All data generated or analyzed during this study are included in this published article, and further inquiries should be directed to the corresponding author.

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