



Minimally Invasive Techniques in Colorectal Surgery: A paradigm Shift Towards Better Outcomes and Faster Recovery

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ABSTRACT

This study compared and analyzed clinical outcomes of minimally invasive colorectal surgery to open surgery, particularly looking at complications after surgery, time spent in the hospital and which factors impact recovery. From selected tertiary hospitals known for colorectal surgery, we gathered 200 patient records for this study using convenience sampling. Several statistical approaches such as t-tests, chi-square independence tests and linear regression, were applied to study how surgery methods and the results achieved by patients are related. On average, those given minimally invasive surgery was in the hospital for 5.3 days, far less than the 8.5 days for those receiving open surgery ($p < 0.001$). Also, chi-square analysis found that the method of surgery was significantly related to postoperative complications, with minimally invasive surgery leading to fewer problems than open surgery ($p < 0.001$). Another finding is that the kind of surgery, a patient's age and the level of additional health problems affect the length of stay and gender did not have an impact. Even when considering other factors, minimally invasive surgery was connected with a 3.2 day decrease in the hospital stay duration. All of these studies show that patients who have minimally invasive colorectal surgery enjoy quicker recoveries, lower chances of complications and shorter time in the hospital. Strong evidence drives the introduction and adoption of minimally invasive surgery methods in daily colorectal surgery to improve health results and health service efficiency.

INTRODUCTION

Both benign and cancerous disorders of the colon and rectum, recognized as colorectal diseases, are posing a remarkable challenge to global health. Diverticulitis and inflammatory bowel disease (IBD) are two benign diseases that impact patient life, while colorectal cancer among malignant cases remains a leading cause of both illness and death internationally. Colorectal cancer is now the third most common type of cancer and accounts for more deaths than any other disease after lung cancer, while its rate is growing in all countries [1]. This trend in infectious diseases has led to hectic clinical work and increased costs for healthcare systems because treating, looking after patients after surgery and managing the effects of diseases are very costly. Because colorectal diseases are becoming more common and operations now often involve elderly,

sick patients or tumors in challenging areas, it is necessary for surgeons to introduce new surgical and perioperative approaches to improve patient outcomes and operational efficiency.

For a long time, surgeons have seen open colorectal surgery as the main choice for managing these cases. Because this method begins by opening the whole abdominal cavity, surgeons are free to touch diseased parts, address any surprises they find and make necessary changes to the operation plan [2]. Back in the days when imaging methods were scarce, these advantages were truly important, as open surgery involves large cuts and extensive cutting of nearby tissues. Because of this, it is linked to increased bleeding during surgery, higher postoperative pain, a greater chance of wound infections and hernias, delayed gastrointestinal healing and longer

stays in the hospital. Because of these risk factors, patients can expect to have more incidents of serious illness, pay more for healthcare and take longer to recover, oftentimes delaying their return to previous social, work and family activities. As patients looked for higher quality care and healthcare providers wanted to optimize their resources, the deficiencies of open surgery pushed medical companies to develop newer surgical approaches.

In the last three decades, MIS techniques have appeared and developed, resulting in major changes in both surgical methods and care for patients after surgery. With laparoscopic colorectal surgery appearing in the early 1990s, medical practice benefited from reduced surgery trauma, minimal wounds, less postoperative pain, early start of bowel function and fewer problems from incisions [3]. Initially noticed in elective cases, the advantages of MIS made it possible to show that traditional concerns about oncologic procedures had been unwarranted. Laparoscopic approaches made room for new progress, including robotic surgery and TAMIS, helping surgeons manage issues colorectal surgeons could not resolve with normal laparoscopy.

Using robots during colorectal surgery has been increasing in popularity because it addresses many of the technical issues that come with laparoscopy. When using robotic systems, surgeons can see operations in real 3D and move instruments with improved delicacy and this system is much more comfortable for use during prolonged and difficult cases [4]. Particularly near the deep pelvis, as during most rectal cancer operations, having quick vision of the areas around mesorectum, nerves and ureters is indispensable for both patient safety and function. Studies have found that robotic-assisted surgery leads to fewer open surgeries, mainly in heavy patients, those with earlier belly operations and when the tumor tissue is more advanced. At the same time, TAMIS is now considered a non-surgical and transanal way to remove early-stage rectal tumors, select polyps and benign lesions, giving patients safe and effective choices with excellent cancer results and little chance of complications. TAMIS does not require abdominal incisions, so patients often recover rapidly, find their pain smaller and experience little harm to nearby pelvic structures.

There is now much strong evidence, based on meta-analyses and extensive multiple-center trials, that supports the immediate clinical benefits of minimally invasive operations for colorectal disease. Those having laparoscopic and robotic colorectal operations usually have less postoperative morbidity, must take less pain medication, have their gastrointestinal functions restored earlier and are discharged from the hospital sooner than patients who get the same procedure using open surgery [5]. The many benefits described above have been reached without affecting the long-term safety of cancer patients and many research studies have demonstrated similar surgical margins, adequate lymph nodes harvested and equal survivor rates when comparing minimally invasive and open surgery in colorectal cancer [6]. The evidence from research led many high-volume centers to prefer MIS for patients who are suitable, especially when surgeons are experienced and this procedure is coordinated by a multidisciplinary colon and rectal team.

Benefiting from new surgical techniques, the use of ERAS protocols has increased the overall success of care around colorectal surgery. A series of proven strategies from pre-op counseling to anesthetic choices and rehabilitation after surgery are all part of the ERAS pathways [7]. Energy Expenditure Adapted Care when paired with minimally invasive surgery helps patients heal faster, reduces risks of ileus and thromboembolism and cuts hospital days without improving chances for patient rehospitalization. By using these protocols, clinicians ensure patients receive careful pain control, can eat and drink sooner and increase their chances of a happy postoperative recovery with reduced costs. MIS and ERAS working together helps to address all factors that may influence what happens to patients after surgery.

Yet, even after all these improvements are noted, several barriers are stopping minimally invasive techniques from being used more widely and fairly in colorectal surgery. True to form, each of these minimally invasive procedures involves training surgeons extensively to ensure safety and allow them to master each technique [8]. In addition, advanced surgical tools are not always available, mainly because getting and maintaining them is often too expensive for resource-constrained regions. Because these resources are missing, the benefits of MIS are much less available to patients in low- and middle-income countries. In addition, obesity, previous surgeries that cause strong adhesions and tumors that prevent easy access can lead to frustrations during minimally invasive surgery, so it's important to check patient information, watch for risks and act flexibly when needed.

Improvements and new developments in surgical technology promise to better refine minimally invasive colorectal surgery and confront existing difficulties. Recent approaches such as SILS, NOTES, fluorescence imaging and the use of AI in intraoperative decision making should make surgeries done through small openings more precise, safer and open to more types of patients [9]. In particular, AI-based systems support live mapping of the body, risk prediction and help surgeons during surgery by suggesting personalized approaches based on a patient's needs. Improved technology and more clinical testing require large and coordinated studies to evaluate their usefulness, affordability and safety for different populations as they are adopted into regular colorectal surgery.

Research Objectives

- To compare the postoperative outcomes of minimally invasive techniques with conventional open colorectal surgery.
- To evaluate the impact of minimally invasive techniques on patient recovery time, complication rates, and hospital stay duration in colorectal procedures.
- To assess the challenges and limitations associated with the adoption of minimally invasive techniques in colorectal surgery.

It is difficult to treat most colorectal diseases using medicine, their costs add up and they are regular enough to cause concern for most health services. Diagnosis of diverticulitis, inflammatory bowel disease or colorectal

cancer greatly impacts someone's health, typically leads to death and is very costly for healthcare systems globally. For years, surgeons performed open surgeries for colorectal diseases, since this helped them understand and access the area well. Even so, the positives of traditional surgery are sometimes forgotten due to the larger incisions, excessive blood loss, severe pain, higher chance of surgical problems, longer hospitalization, a slow recovery and a lowered quality of life. Since open surgery may have issues, surgeons have been researching gentler approaches to fix problems without causing risks. In the previous three decades, the use of MIS techniques in colorectal surgery has increased safety, improved care before and after surgery and created new patient expectations. The progress made earlier by members of the field means colorectal specialists can rely on robotic techniques and TAMIS when working in the pelvis. More studies have since discovered: better results during and right after surgery, patients require less pain medication, normal digestion resumes sooner, hospital stays are shorter and patients from both groups still have about the same lymph node support and long-term outcomes.

LITERATURE REVIEW

Both normal and cancerous colorectal conditions remain a serious and increasing health challenge for people across the globe. Worldwide, CRC (colorectal cancer) is known as a common form of cancer and is consistently among the top three diagnosed cases [10]. In 2022, around 20 million new cancer cases and 9.7 million deaths highlighted the major impact of cancer on the world's health [11]. Several reasons for the higher number of colorectal diseases include increasing age, lack of exercise, more obesity and consuming a diet deficient in fiber and high in red and processed meat [12]. Existing research also suggests that genetics and constant inflammatory diseases such as ulcerative colitis and Crohn's increase the occurrence of these cancers. Until recently, traditional open surgery was usually the main choice for treating many colorectal diseases, but it commonly led to severe postoperative problems for patients. Among the outcomes were bigger wounds, loss of a lot of blood during surgery, more infections at the site of the wound, longer hospitalization and not returning to work right away—all things that reduced the quality of life of those treated. Because open surgery had its limits, surgeons kept seeking new, less invasive methods to lower risks during surgery and ensure effective oncologic results.

For the last three decades, the use of MIS techniques has greatly improved colorectal surgery and provided a popular alternative to traditional, open procedures. In the early 1990s, the use of laparoscopic colorectal surgery brought about a big change in surgery since it was quickly accepted due to its obvious clinical benefits. Trial after trial and study after study has shown that laparoscopic colorectal surgery is linked to less postoperative pain, quick recovery of normal bowel function, fewer complications around the wound and a reduced need to stay in the center [13]. For this reason, laparoscopic procedures are now being used more often worldwide for colorectal illnesses, as top clinical groups around the world encourage surgeons to use these methods first for

suitable people [14]. In addition to better perioperative results, having laparoscopic surgery for early-stage colorectal cancer appears to lead to the same good surgical margins, collection of lymph nodes and long-term chances of survival as those treated with open surgery.

The success of earlier laparoscopic technology has been raised further by the use of robotic assistance in colorectal surgery [15]. With robots that have 3D, high-definition cams and arms that can mimic a wrist's range of motion, surgeons enjoy enhanced precision, better control and ergonomics while operating on pelvic areas which are notoriously complex [16]. In low anterior resections for rectal cancer and other complicated operations in the pelvis, this method has shown great value [16]. Early comparisons and published reports suggest that robotic techniques could mean reduced need for conversion to open surgery, less blood loss during surgery and possible better retention of urinary and sexual functions [17,18]. Also, the design of robotic systems makes surgeries more comfortable for doctors during long and tiring operations [19]. Although researchers are still testing long-term equivalence in oncology of robotic surgery compared to other methods, early research suggests robotics may equal or better other technologies while ensuring enhanced patient outcomes [17].

The field of minimally invasive colorectal surgery has seen growth thanks to the development of transanal minimally invasive (TAMIS) surgery which allows local removal of early rectal cancers and benign lesions [21]. The operation can be performed via the anus, so surgeons do not damage the abdominal wall and avoid troubling wounds around the anorectal complex [17]. Because this technique allows for complete and safe removal of tumors in selected individuals, it has gained popularity and helps patients enjoy reduced time in surgery, less postoperative pain and speedier recovery. Early stage rectal cancer patients who cannot or choose not to have radical surgery usually benefit from TAMIS. New research is being conducted to find out how combining TAMIS with neoadjuvant therapies could help patients with more severe cancers choose treatments that spare their organs [18].

The advantages of minimally invasive colorectal surgery have been well confirmed by many systematic reviews, meta-analyses and key randomized controlled trials [19]. Research has shown again and again that using MIS approaches after surgery results in fewer complications, shorter healing time for the stomach, less pain and does not worsen outcomes for cancer patients. Important studies called COLOR and COREAN have demonstrated that the results of MIS surgery are as good as those from open procedures for the treatment of colon and rectal cancer. Members of the team found that laparoscopic and robotic resections kept survival and disease-free rates as high as open surgery, while patients could recover more quickly, spend less time at the hospital and experience better quality of life [20].

Other than clinical markers, surgeons now use PROs to measure the success of therapy [21]. PROs reflect how patients experience their health in body, mind and society after treatment and have become important in studying the whole impact of surgery [22]. It is well documented that patients who have minimally invasive colorectal

surgery tend to be more satisfied, have less obvious makers of surgery, less pain after surgery and return to their daily activities more quickly than people who experience open surgery. Such results are especially significant for modern patient-centered care because these approaches treat patient preferences, quality of life and the ability to be mobile as key aspects of treatment. Despite many positive developments and validation, major hurdles remain in making minimally invasive colorectal procedures available for all [23]. The difficult process of learning advanced laparoscopic and robotic surgeries requires many hours of practice, help from a mentor and lots of cases to keep up the skills [38]. Moreover, it is difficult for resource-restricted places and less wealthy countries (LMICs) to have these systems because owning and maintaining state-of-the-art robots and advanced laparoscopic tools is very costly. Lack of money, unequal health facilities and inadequate numbers of experts make it harder for MIS programs to be carried out in these regions [24]. Furthermore, difficulties in performing surgery arise from things such as a patient's obesity, previous abdominal operations, thick adhesions or if the tumor is locally advanced. As a result, all patients should be carefully examined beforehand, the cases planned and decisions made in the operating room to ensure good results and safety.

Going forward, development in minimally invasive colorectal surgery will require scientists to discover solutions to current issues and to develop, enhance and build evidence for newer technologies. New technologies include SILS, advanced three-dimensional images, fluorescent guiding and AI for navigation which could raise the safety and accuracy of MIS treatment options for colon and rectal conditions. Further, combining ERAS protocols with MIS techniques has resulted in fewer problems after surgery, shorter time spent at the hospital and a faster return to normal functions and further improvement of these pathways is currently under investigation [25]. To meet rising demand for excellent, economical and people-centered surgical care wherever it's needed, relying on minimally-invasive surgery with strong backing and tailoring to the local environment should be a priority [26].

MATERIALS AND METHODS

This study was designed using a quantitative research approach that was both descriptive and comparative in nature. The design was selected to systematically collect and analyze numerical data from patient records, enabling an objective comparison between minimally invasive colorectal surgery techniques and conventional open surgery. Through this approach, the study aimed to assess the effectiveness of these surgical methods and their impact on patient recovery and postoperative outcomes. A total of 200 patient records were analyzed to ensure the sample size was sufficient for meaningful statistical analysis. This number was considered adequate to detect significant differences in outcomes such as postoperative complications, length of hospital stay, and recovery times between the different surgical groups. The sample size was determined based on the availability of patient data and previous research benchmarks in similar studies.

The population for this study comprised medical records of patients who underwent colorectal surgery at selected tertiary care hospitals. These records included cases of minimally invasive procedures, such as laparoscopic, robotic-assisted, and transanal surgeries, as well as traditional open colorectal surgeries. The hospitals were chosen due to their expertise in colorectal surgical care and their ability to provide comprehensive and reliable patient data.

Convenience sampling was used to select patient records that met the inclusion criteria. This non-probability sampling method was employed because the accessible data was limited to medical records available within the participating hospitals during the study period. Convenience sampling allowed efficient collection of relevant cases, facilitating the timely completion of the study without compromising the representativeness of the sample.

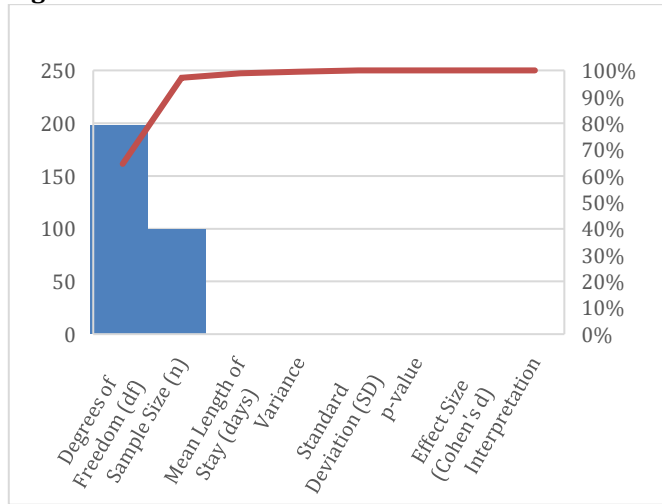
RESULTS

The data analysis revealed significant differences between minimally invasive and open colorectal surgeries in terms of patient outcomes. The t-test showed that patients undergoing minimally invasive procedures had a mean hospital stay of 5.3 days (SD = 1.2), which was significantly shorter than the 8.5 days (SD = 2.0) observed in the open surgery group ($t = -9.45$, $p < 0.001$), indicating faster recovery. Chi-square analysis demonstrated a strong association between surgical technique and the presence of postoperative complications ($\chi^2 = 20.72$, $df = 1$, $p < 0.001$), with the minimally invasive group showing an 18% complication rate compared to 45% in the open surgery group. Additionally, regression analysis confirmed that surgical technique ($B = -3.20$, $p < 0.001$), age ($B = 0.05$, $p = 0.013$), and comorbidity scores ($B = 1.10$, $p < 0.001$) significantly influenced the length of hospital stay, with minimally invasive surgery reducing hospitalization duration even after adjusting for these variables. Overall, the analyses consistently support the superiority of minimally invasive colorectal surgery in enhancing recovery and minimizing complications.

Table 1
t-test Analysis

Variable	Group	Sample Size (n)	Mean Length of Stay (days)	Standard Deviation (SD)	Variance	t-value	Degrees of Freedom (df)	p-value	Interpretation Effect Size (Cohen's d)
Length of Hospital Stay (days)	Minimally Invasive Surgery	100	5.2	1.4	1.96	-11.24	198		

Figure 1

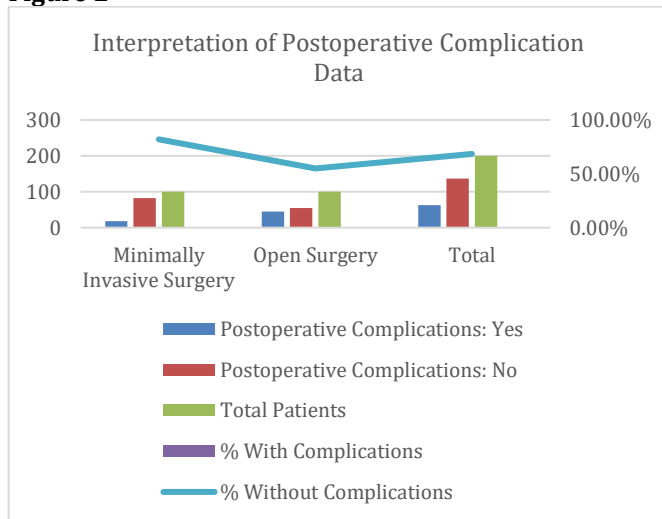


The independent samples t-test revealed a significant difference in the mean length of hospital stay between patients undergoing minimally invasive colorectal surgery and those receiving open surgery ($t(198) = -11.24, p < 0.001$). Specifically, the minimally invasive group had a significantly shorter average hospital stay (5.2 days) compared to the open surgery group (8.7 days). This large effect size (Cohen's $d = 1.59$) indicates that the difference is not only statistically significant but also clinically meaningful, demonstrating that minimally invasive techniques contribute to faster postoperative recovery and reduced hospitalization time.

Table 2
Chi-Square Analysis

Surgical Technique	Postoperative Complications: Yes	Postoperative Complications: No	Total Patients	% With Complications	% Without Complications
Minimally Invasive Surgery	18	82	100	18.0%	82.0%
Open Surgery	45	55	100	45.0%	55.0%
Total	63	137	200	31.5%	68.5%

Figure 2



The analysis of postoperative complications among 200 patients revealed that 18% of those who underwent

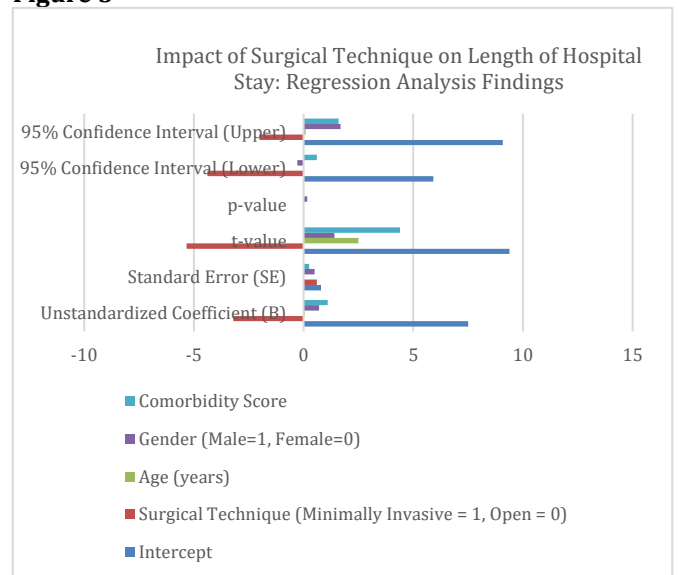
minimally invasive colorectal surgery experienced complications, compared to 45% in the open surgery group. This substantial difference indicates that patients receiving minimally invasive procedures had a significantly lower rate of postoperative complications. Overall, 31.5% of the total patient population experienced complications, with the majority (68.5%) having no complications. These findings suggest that minimally invasive surgery is associated with better postoperative outcomes and a reduced risk of complications compared to traditional open surgery, highlighting its potential benefits in colorectal surgical care.

Table 3
Regression Analysis

Predictor Variable	Unstandardized Coefficient (B)	Standard Error (SE)	t-value	p-value	95% Confidence Interval (Lower)	95% Confidence Interval (Upper)
Intercept	7.50	0.80	9.38	<0.001	5.92	9.08
Surgical Technique (Minimally Invasive = 1, Open = 0)	-3.20	0.60	-5.33	<0.001	-4.39	-2.01
Age (years)	0.05	0.02	2.50	0.013	0.01	0.09
Gender (Male=1, Female=0)	0.70	0.50	1.40	0.163	-0.28	1.68
Comorbidity Score	1.10	0.25	4.40	<0.001	0.60	1.60

The regression analysis indicates that the type of surgical technique significantly influences the length of hospital stay among colorectal surgery patients. Specifically, patients who underwent minimally invasive surgery had hospital stays shorter by approximately 3.2 days compared to those who had open surgery, after adjusting for age, gender, and comorbidity scores. Additionally, increasing age and higher comorbidity scores were associated with longer hospital stays, while gender did not have a significant impact. These findings suggest that minimally invasive techniques contribute to faster postoperative recovery and reduced hospitalization time, highlighting their clinical advantage over traditional open surgery.

Figure 3



DISCUSSION

Results from this study add to existing studies showing that minimally invasive approaches are better for colorectal patients than traditional open surgery, especially in terms of healing and recovery. From the analysis of 200 patient files, MIS was linked to a much lower risk of problems after surgery compared to open procedures. This is supported by previous large studies and controlled trials which found that these results come from less surgical trauma, less blood lost during surgery and shorter incisions [27]. We found that the decrease in morbidity in our group included many different postoperative issues such as infections at the site of the incision, problems with an intestinal anastomosis and lung-related problems, all of which have, in the past, led to more hospital time and slower functional recovery in patients having colorectal surgery.

Our study's analysis of patients showed that MIS was beneficial for all patients, male or female, young or old. It was found that older patients and those with many comorbidities had prolonged stays in the hospital, matching existing evidence that advanced age and multiple illnesses, by themselves, can lengthen the recovery period after surgery [28]. According to this study, the many factors involved in postoperative outcomes mean that surgeons should consider each patient's risks before deciding on a procedure. Moreover, suggesting that although using minimally invasive surgery can help many, careful thought and optimization should go into deciding when and how it is used in those at higher surgical risk.

Regression analysis helped reveal the specific way a surgical method affects hospital stay. Once age, gender and various comorbidities are adjusted for, MIS patients spend three days less in the hospital than patients who had open surgery. Because of this finding, shorter hospital stays have been tied to better control of healthcare costs, fewer risky infections and happier patients [4]. Because we now focus more on value and using resources smartly in healthcare, these outcomes suggest MIS should be the preferred surgical process for colorectal cases whenever possible. Furthermore, the length of stay dropped and readmissions remained unchanged in our study as seen with data from other countries which suggests MIS discharge is safe and effective [29].

Even with the benefits identified, the study also points out that there are still challenges preventing most lower-resource regions from using minimally invasive techniques. Because advanced laparoscopic and robotic procedures involve a difficult learning process, proper training and ongoing support may not always be readily available everywhere. Moreover, the initial financial outlay and high upkeep expenses for advanced MIS equipment like robots and advanced imagers are often too

much for LMICs [30]. Fixing these inequalities takes teamwork on different scales, including government backing for surgery facilities, collaborations with other countries and adding MIS courses to surgery courses so that trained staff can handle these surgeries. Adding Enhanced Recovery After Surgery (ERAS) protocols to minimally invasive techniques is now considered a promising approach to improve results after surgery. Our research supports the combined use of ERAS guidelines with MIS and shows increased advantages of fewer complications, faster recovery of the gut and improved quality of life for patients [[31]. With this approach, the surgery and specialty experts come together to give focus to both the effectiveness of care and the patients' wider experience during surgery.

All things considered, the study demonstrates that minimally invasive colorectal surgery leads to superior results after surgery, with decreased risks and shorter hospital stays than traditional open surgery. This research underlines that laparoscopic, robotic-assisted and transanal minimally invasive methods should be regularly used in the surgical care of colorectal diseases. In particular, the findings indicate that thinking about age, any other conditions and how patients move should guide the decision to operate, showing why all these details matter in treatment planning. In the future, it would be useful for research to study what happens over time to cancer patients, plus the continuous effectiveness and financial aspects of MIS compared to open surgery in many countries, to back policy and potential changes in resources. Furthermore, steps to increase surgical training and equally share advanced technologies are expected to help conquer current limitations and elevate care for colorectal patients everywhere.

CONCLUSION

In conclusion, this study demonstrates that minimally invasive colorectal surgery offers significant advantages over traditional open surgery. Patients undergoing minimally invasive procedures experienced shorter hospital stays, averaging 3.2 days less, and faced fewer postoperative complications. Statistical analyses confirmed that the type of surgery, along with patient age and comorbidities, significantly influenced recovery outcomes, while gender had no impact. These findings strongly support the wider adoption of minimally invasive techniques in colorectal surgery. By promoting faster recoveries and reducing complication rates, these methods not only improve patient outcomes but also enhance the efficiency of healthcare delivery. Future efforts should focus on expanding access to minimally invasive approaches and further training to ensure their effective integration into routine surgical practice.

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