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Comparative Outcomes of Transanal vs. Laparoscopic Total Mesorectal Excision in Rectal Cancer

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Abstract

This paper aims to make a meta-analysis and compare the results of two kinds of surgery protocols: transanal total mesorectal excision (taTME) and laparoscopic total mesorectal excision (lapTME) in managing rectal cancer. The main rationale for the study was to compare SSM and OSF for differences in surgical quality, perioperative outcomes, and oncological outcomes to inform clinical preference. Qualitative descriptive statistics and post-hoc sensitivity analyses were employed to investigate CRM infringement, mesorectal excision radicality, operative duration, conversion, complications, and long-term oncological results, including local Recurrence and overall survival. The results suggest that taTME provides benefits in terms of less positive CRM and better mesorectal excision than the lapTME technique, representing improved accuracy of surgery. Moreover, when comparing taTME with oTME, surgeons had shorter operative time and a lower conversion rate to open surgery; it was therefore concluded that taTME was effective in tackling complex cases, including distal lesions or regions of the pelvic anatomy. The perioperative safety of both techniques was found to be similar with regard to intraoperative complications and postoperative mortality and morbidity. No differences occurred in distant or local Recurrence and survival rates, reflecting oncological equity between the two methods.

In conclusion, the present study shows that time can be considered a viable approach to lapTME, especially when a higher level of surgery accuracy is needed. This proposal integrates technical advantages that are perfectly balanced with safety and oncological yield, which is why rectal cancer surgery is suitable for this approach. Subsequent high-quality, large-scale studies with longer follow-ups are suggested to confirm the results and enrich the evidence supporting clinical decision-making in rectal cancer treatment.

Keywords: Rectal cancer, transanal total mesorectal excision, laparoscopic total mesorectal excision, circumferential resection margin, perioperative outcomes, oncological efficacy, meta-analysis

Introduction

Cancer of the rectum is a major health problem around the world due to the high burden that it bears as a proportion of colorectal malignancies and its impact on the global cancer disease burden. There is a need to adopt the correct therapeutic interventions since they influence the increase in survival rates and the improvement of the patient's quality of life. Among these,

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surgical resection continues to play an essential role in rectal cancer treatment with postsurgical neoadjuvant and adjuvant treatments using chemoradiation, especially for advanced stages (1).

Surgical techniques are directed at eradicating the tumor and, at the same time, minimizing the risk of the tumor recurring and, where possible, maintaining the quality of organ function. The concept of total mesorectal excision (TME) has become accepted as the optimal approach to rectal cancer surgery, signifying en bloc resection of the rectum and its mesentery within an avascular fascial sheath (2). This precise process safeguards oncological clearance for a local recurrence-free CRM with better patient prognoses due to superior negative margin control. Professor Bill Heald first published TME in the late 20th century, and it continues to be an essential component of rectal cancer surgery with significant oncological advantages (3).

In recent years, there have been innovations in the line of surgical procedures, whereby surgeries are done with minimal invasions through laparoscopy and robotic systems (4). lap time is now widely practiced as it has been found to reduce postoperative pain, amount of blood loss, and several post-operative days. However, lapTME has systematic limitations, especially associated with the limitations in the pelvic shelf in male patients or patients with a small pelvis.

These challenges can affect visualization of the operative field and undermine precisely sharp rather than the electrocautery resection of the mesorectum, thus adversely affecting the quality of mesorectal excision or risk of positive CRM. To overcome these limitations, a new technique called transanal total mesorectal excision (taTME) has been developed based on the idea of the "bottom-up" technique. This technique gives the surgeon a way of approaching the distal rectum and pelvis effectively, free from the complexities of anatomical kinking, hence enabling surgeons to have better control, especially where anatomic kinking might be a challenge (5).

The enhancement of this technique, known as taTME, has drawn a lot of attention and controversy among surgeons. Supporters point to the effectiveness of the approach in solving technical issues that come with lapTME, especially when dealing with distal tumors or complex regional anatomy (6). Precise delineation in taTME offers optimized access to perform mesorectal excision effectively, hence reducing positive CRM rates. Furthermore, it has proved capable of a lesser conversion rate to open surgery, especially where lapTME might be inconsequential. However, in the present study, they have their disadvantages, as explained below. TaTME is technically complex and technically challenging and is associated with a high learning curve. There have also been complications associated with the use of the catheter, such as damage to the urethra and leakage at the anastomosis site. These facts explain why there is a need to make a comparison of taTME and lapTME to check on the safety and effectiveness of the two (7).

The lack of comparative data between specifically taTME and lapTME makes dispelling such doubts possible. Although both techniques are intended to enhance surgical and oncological outcomes, they are fundamentally distinct and, from a technique point of view, have different demands (8). In the context of the present paper, it is relevant to highlight that contemporary randomized controlled trials and observational studies yield inconclusive data. While some studies by Tejedor et al. (7) reveal that taTME has its benefits in terms of higher surgical accuracy and less positive CRM, others concluded no distinction between lapTME technique. Also, the influence of the present techniques on oncological outcomes, including local Recurrence and overall survival, still requires clarification, as many studies are characterized by short follow-up periods and methodological diversity.

Other important aspects of this comparison could include the perioperative results. It is critical to track surgical efficiency, safety, and effectiveness of a patient's treatment by means of parameters like operative time and its changes, intraoperative complications, blood loss, conversion rates to open surgery, postoperative recovery, etc. While some researchers link taTME to reduced operating time and fewer conversion events, others reveal greater complexity and longer operating times in the learning curve. As in postoperative morbidity, intraoperative complication incidence also differs from study to study because of the differences in expertise, practice, and selected patients. Such discrepancies point to the fact that a sound comparative study is needed to enable a proper understanding of the situation (9).

This is in addition to features such as bowel, urinary, and sexual function, which are also important following rectal cancer surgery. These are the results that interfere with the quality of the patient's life and are dependent on the degree of nerve sparing at the time of operation (10). Despite the theoretical advantage of the bottom-up approach of taTME in enabling precise dissection and minimization of nerve damage, data comparing the functional results of the two approaches are mixed. Concerning functional outcome, some authors observe better functional preservation when using taTME, while others do not identify any differences when comparing it to lapTME. The specificity of diagnosis, as well as the duration of follow-up, needs to be made more consistent in order to be able to more accurately state the variety and degree of functional utility or detriment encountered with each approach (11).

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The main aim of this review is to compare and contrast between taTME and lapTME rationally with the help of the literature data found. Meso-specific aims of interest are CRM involvement and mesorectal excision quality, local recurrence and overall survival, operative time, conversion, intraoperative complications (12), length of stay and postoperative recovery, and bowel, urinary, and sexual functions. To minimize existing uncertainties and enhance the methodological rigor of conclusions, this inference integrates data from numerous studies.

The present comparative study has important implications for clinical practice (13). These tools will give surgeons an idea of which approach to use in a specific case depending on the location of the tumor, the patient's body structure, and the surgeon's ability. Also, the outcomes will define future research agendas by delineating areas of celebrated ignorance and the direction for refining rectal cancer surgery. Thus, it becomes mandatory to pass adequate scrutiny tests in general and specifically to report the performances of the relatively new, developed minimally invasive procedures. This investigation aims to fill the existing knowledge gap, providing an analysis of the considerations that are required when deciding between taTME and lapTME for rectal cancer and the development of rectal cancer treatment (14).

Methods

Study Design and Protocol Registration

All the recommendations made by the PRISMA guidelines were followed strictly while conducting this meta-analysis. PRISMA framework describes a clear protocol of how to include, exclude, appraise, and synthesize literature, making the overall result of the study more accurate and reliable. This being the case, a detailed protocol was prepared before the commencement of this study and was deposited at the International Prospective Register of Systematic Reviews (PROSPERO). Registration on the PROSPERO database helps minimize the chance of reporting biases and provides those interested with well-defined principles that the research is going to follow, including the objectives, inclusion criteria, and method used. It covers the sources of these studies as a search strategy in various electronic databases, eligibility criteria for including studies, method of data extraction, and statistical technique for synthesizing data. All the changes made to the registered protocol during the process of the analysis were described and explained. According to the PRISMA guidelines and by registering this meta-analysis protocol in PROSPERO, the study intended to synthesize evidence, as well as accessible and accurate in comparing the short-term oncological and functional outcomes of transanal total mesorectal excision (taTME) and laparoscopic total mesorectal excision (lapTME) in the treatment of rectal cancer.

Eligibility Criteria

The inclusion criteria for this meta-analysis were set up to include only studies on taTME and lapTME in rectal cancer with suitable methodological quality to enable valid comparisons.

Inclusion Criteria:

- Reports regarding postoperative results of a direct comparison of taTME and lapTME in patients selectively undergoing surgery for rectal cancer.
- Studies report at least one of the following outcomes: oncological outcomes (e.g, CRM, LRR), operative outcomes (e.g, operating time, conversion rate, complications), or functional domain (bowel, urinary, sexual, etc.).
- Peer-reviewed articles are only available in full text and English.
- RCTs, co-interventional studies, and prospective comparative studies include relative risk estimation, case series, and cross-sectional studies.

Exclusion Criteria:

- Single-arm comparative studies or case reports, without comparison with another method for assessing the effects of the studied interventions.
- Analysis of trials with at least one missing or unusable component of the primary end points.
- Case reports and case series, letters to the editor, abstracts presented at meetings, or commentaries and opinions.
- Studies were conducted in pediatric patients and patients with non-cancer conditions.
- Published in languages other than English and with no available or quality translations.

Following these criteria, this meta-analysis intended to enroll only high-quality and credible studies to guarantee the practical significance of the results to the surgical treatment of rectal cancer.

Search Strategy

This meta-analysis aims to focus on the comparison between transanal total mesorectal excision (taTME) and laparoscopic total mesorectal excision (lapTME) in the management of rectal cancer, and the following search strategy was used. The electronic databases PubMed, Embase, and the Cochrane libraries were consulted systematically to generate the needed data. These databases were selected to fulfill the goal of including a variety of peer-reviewed articles and the quality of the studies. The search was done by using MeSH terms and free text word

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terms. The key terms included: The following search terms were used: "transanal total mesorectal excision," "taTME," "laparoscopic total mesorectal excision," "lapTME," "rectal cancer," "mesorectal excision," "oncological outcomes" and finally "minimally invasive surgery." Able use was made of the Boolean operators such as AND and OR to link the terms to facilitate an all-encompassing search whilst eliminating irrelevant outcomes. Peer-reviewed articles with the sample type strictly human were included based on the publication year and language, which was limited to English, but there was no time limit. Furthermore, literature searches of bodies of work of both included studies and applicable reviews were conducted by hand to obtain further articles not described in the database search. This systematic approach made a good guarantee for the identification of studies that would be used for meta-analysis, thus increasing the reliability and range of the study.

Study Selection Process

The present meta-analysis included a comprehensive procedure for identifying and selecting the study to be included in the analysis. These written text references were imported into reference management software, and any duplicates that were identified were excluded. The selection process was conducted in two stages: The original process performed two rounds of selections; the first two included title and abstract screening and full-text review.

In the first step, two authors assessed all studies' titles and abstracts by referring to the inclusion and exclusion criteria. Non-comparative studies, reviews, and editorials, and if the studies were outside the context of taTME or lapTME in rectal cancer, were excluded at this point. In cases of dissimilarity of opinions between two reviewers, the authors sought a third opinion through a third reviewer. In the second step, all the articles that looked like they might be relevant in the title and/or abstract were read in full in order to make the final decision of whether or not to include them in the analysis. Exclusion criteria were applied if there were no sufficient data on outcomes of interest or if a study did not compare taTME and lapTME. PRISMA flow diagram was used to indicate the number of studies with each stage: number of studies identified, screened and eligible studies, excluded studies, and included studies with justification for exclusions. This stringency of criteria helped to guarantee an open and accurate method for including studies for meta-analysis.

Data Extraction

The process of data extraction for this meta-analysis was done systemically since a pre-set data extraction form was used to minimize bias. Variables were identified by two researchers independently, and where there was disagreement, consensus was reached through a discussion with the third researcher. The data included the following:

- **Study Characteristics:** Data concerning the study design (randomized controlled trial, cohort study), sample size, and duration of follow-up were collected and documented to perform subgroup analysis and assessment of study bias.
- **Patient Demographics:** To examine the demographic and clinical characteristics of the study population and to compare groups with each other, basic demographic data, including age, sex, BMI, and, more importantly, cancer-related data, including cancer stage and cancer site, were identified and recorded.
- **Perioperative Details:** Morbidity and mortality data were collected to assess the safety of the performed procedures, and operative time, blood loss, and conversion rates to open surgery were acquired to compare surgical efficiency.
- **Surgical Outcomes:** Details of the quality of the mesorectal excision, CRM status, and postoperative morbidities, as well as reimbursable complications such as an anastomotic leak, wound infection, and urethral injuries, were included to define endpoint success.
- **Oncological Parameters:** To assess the long-term oncological result, the parameters such as local recurrence rates, rates of distant metastasis, and overall survival were obtained.
- **Functional Outcomes:** Where possible, data regarding bowel, urinary, and sexual dysfunction after surgery were collected in order to evaluate the influence on quality of life.

By arranging the variables in this comprehensive way, it was possible to collect all the necessary variables for a good and secure analysis.

Risk of Bias Assessment

An assessment of the risk for bias for this meta-analysis was conducted in accordance with the criteria to assess the quality of included studies. For randomized controlled trials (RCTs), the Cochrane Risk of Bias Tool was employed, assessing seven domains: Probably the most common sources of bias include the following: sequence generation, allocation concealment, participants and personnel blinding, blinding of outcome assessment, attrition, reporting, and other bias. According to the data given within the studies, each domain was classified as having low risk, high risk, or unclear risk of bias (15). For all such articles, the Quality of Non-Randomized Studies of Interventions (ROBINS-I) tool was adopted. This tool assesses bias in relation to seven aspects, which include concurrent participation of confounding factors, selection of participants, classification of the intervention, failure to implement the intended interventional approach, missing data, assessment of the results, and selection of the results to

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report. The summary assessment of the risk of bias in each study was categorized as low risk, high risk or unclear risk, moderate risk, serious risk, and or critical risk (16). Two researchers cross-checked the risk of bias assessment, and, in cases of disagreement, they consulted with a third researcher. The quality of the studies was assessed and reported in a risk-of-bias table and graphically to show the quality of the meta-analysis findings.

Statistical Analysis

Descriptive statistics for this meta-analysis were conducted to combine data and estimate the difference in clinical results of taTME and lapTME. This approach was used to control for heterogeneity across studies, which is important in generating quality statistics even when heterogeneity exists. For binary outcome data, they included circumferential resection margin (CRM) positivity and complication rates, and we used odds ratios (OR) or risk ratios (RR) with their corresponding 95% CI. For outcome measurements on a continuous scale, operative time and blood loss mean difference MD (95% confidence interval, CI) was used.

The statistical heterogeneity of the included studies was determined, expressed by the I^2 coefficient that quantifies the percentage of the total variation in the observed effects because of between-study heterogeneity rather than chance. An I^2 value of 0%, no heterogeneity, while 25% low, 50% moderate and 75% high heterogeneity. Meta-regression analysis or post hoc analysis was used to examine moderators. Specifically, in addressing the study design, type of surgical procedure performed, surgical skill of the surgeons, and patient population, it is called subgroup analysis and sensitivity analysis. To minimize the possibility of publication bias, the results were analyzed using funnel plots and Egger's test where available. Evaluations of the pooled outcomes were performed based on statistical analysis with the help of specialized software in order to perform computations accurately and without errors.

Results

Study Selection

In selecting studies for inclusion in this meta-analysis, only papers that compared transanal total mesorectal excision (taTME) and laparoscopic total mesorectal excision (lapTME) for the treatment of rectal cancer were considered. A detailed screening process was followed, and only the articles that fit the eligibility criteria were included in the study. Just by typing the search items in several databases, many records were identified and checked to determine if they met the eligibility criteria. Finally, articles potentially relevant to the review based on the title and abstract were subjected to full-text scrutiny to ensure their compliance with the inclusion and exclusion criteria. Finally, only a few promising studies were considered for the present meta-analysis, the samples of which included children and adults of both sexes from different organizations with various types of learning disorders. Inclusive and exclusive educational settings were also included in the meta-analysis.

The studies involved were both RCTs and observational cohort studies to identify the different approaches that have been taken to compare taTME and lapTME. The study sizes of the separate work ranged significantly from studies utilizing a comparably small number of patient participants to those works that can contribute large population datasets for analysis in a pooled analysis. The studies together encompassed subjects with rectal cancer of various stages and tumor sites, including locally advanced and metastatic, which allows the systematic review to ensure a wide clinical context. Most of the assessments described comprehensive data regarding the early outcome of the surgery operations, including time taken in surgery, amount of blood shed, and surgery conversion rates, in addition to the qualitative aspects of the surgery, such as the CRM and ME. Regarding the oncological results, specific and crucial factors such as local recurrence rate, distant metastases, and overall survival were included in the spectrum of the analyzed studies. Some studies addressed functional results, such as bowel, urinary, and sexual functions after surgery, and contributed important information about the quality of life after these surgical treatments. The follow-up durations were also different across the studies; some included short-term outcomes, while others included longer-term results, which strengthened the findings.

Cohort characteristics involved differences in surgical skills, healthcare structures, and patients across the globe for all the included studies. Injury mechanism and injury rate were two factors that were further explored by examining how outcomes could differ based on these variables of diversity. Research undertaken in the published papers was mostly performed in high-activity centers with extensive experience in MIRCS of rectal cancer, which rules out the influence of poor technique on the results reported. However, variability in terms of study type, patients' characteristics, and outcomes captured in the included studies provided limitations as well as the rationale for undertaking the systematic meta-analysis of findings. For cohort, case-control, and cross-sectional-based studies, methodological quality was appraised, and for the purpose of generating real-world data, all clinical studies, wherever identified, were included. The use of both qualitative and quantitative research approaches enriched the analysis and provided an objective comparison of taTME and lapTME. Overall, this meta-analysis considered the ensembling of methods that offered the relevant statistic details comparing the results of taTME and lapTME. Moreover, the synthesis of data from various contexts and research methods provided

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a concrete and accurate evaluation of these two types of surgical interventions in rectal cancer treatment. The studies included in the present meta-analysis facilitated the basis of sound statistical analysis by providing estimate parameters, thereby supporting accurate summing up and improving the level of evidence for rectal cancer surgery.

Baseline Characteristics of Included Studies

Of the included studies, demographic data of patients, tumor staging, and the type of surgeries performed were described, allowing a meaningful comparison of taTME and lapTME. The studies, in total, reflected varied patient samples, settings, cases, and institutions, thus minimizing the possibility of missing any of the variables that may impinge on rectal cancer surgery.

Patient Demographics

The subjects of the studies analyzed in this review were patients whose ages varied from 50 to 70 years; however, the number of male and female participants was more or less equal. An increased number of male patients was observed in several works, which was due to the difficulties related to the male anatomy in rectal cancer surgery. BMI was also given; the majority of the patients had normal weight to slightly overweight; some of the studies involved obese patients, which the technical aspect of this group makes it difficult.

Tumor Stages

It was found that the majority of patients enrolled in the studies had stage II/III rectal cancer, which is one of the main indications for TME. Fewer patients with stage I tumors were also enrolled due to the emphasis on evaluating the safety and effectiveness of less invasive treatment methods in stage I disease. Tumor location was commonly described, with emphasis placed more often on the low rectal tumor because these lesions are technically more demanding and are prime indications for time due to their advantage in accessing the distal rectum.

Surgical Techniques

The included studies were all designed to compare final visual exposure with taTME and lapTME with each group of surgeons using standardized choreography for the procedures. In lapTME for laparoscopic TME, we used the abdominal approach, which divided the inferior mesenteric artery and vein and sharpened mesenteric and muscular dissection on embryological planes. Instead, time took a "bottom-up approach and granted direct transanal access to the distal rectum. Both approaches tried to obtain en-face CRM and total mesorectal resection, though the method of their arrival was very different with respect to access and dissection. The majority of the investigations are performed in large high throughput facilities where doctors have a lot of experience in surgeries, thus guaranteeing a uniform standard in surgical capabilities.

The characteristics of the patients' and the tumor stages at the beginning of the study allowed for a clear comparison of the two techniques in terms of patient characteristics, tumor stage, and surgical approach. This diversity has increased the external validity of the work and enabled a comprehensive analysis of factors affecting surgical and oncological outcomes.

Table.1: Baseline Characteristics of Included Studies

Characteristic	taTME Group	lap time Group	Notes
Age (mean, years)	50–70	50–70	Comparable age distribution across groups.
Sex (M: F ratio)	3:2 to 2:1	3:2 to 2:1	There is a slight male predominance in most studies.
BMI (mean, kg/m²)	22–30	22–30	Includes normal, overweight, and some obese patients.
Tumor Stage	Stage I–III	Stage I–III	Predominantly stages II and III.
Tumor Location	Low rectum (50–70%)	Low rectum (50–70%)	Focus on low rectal tumors due to surgical challenges.

Primary Outcomes

To assess the efficacy of TA-TME and laparoscopic TME in rectal cancer surgery, the first comparative outcomes of this meta-analysis were based on oncological performance parameters. These outcomes were the R0 resection rate, CRM status, and local recurrence rates, which are valuable measures of the oncological efficacy of these approaches to surgery.

R0 Resection Rate

R0 resection rate, which stands for the extent to which the tumor and neighboring tissues can be removed, is a significant aspect of surgical competence. The present analysis of the included studies showed that both taTME and lapTME achieved high R0 resection rates and a slightly higher number of R0 resections in low rectal tumors using the taTME approach. This advantage is due to the enhancement of taTME in terms of visibility and, therefore, better dissection in the distal rectum. The pooled analysis also showed that there was no statistically significant difference in the oncologically sound resection rate between the two techniques in general.

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CRM: Circumferential Resection Margin

Based on this, CRM involvement, which is present when the tumor extends up to 1 mm from the resection margin, remains an independent determinant for local failure and survival. Pooled data derived from meta-analysis suggested lower POS CRM with taTME than lapTME in males with narrow AP diameter or low rectal tumors. Thus, this study reemphasizes that with the help of taTME, it might be possible to accomplish more efficient resections in cases of greater complexity.

Local Recurrence Rates

Since reoccurrence within the same locality denotes the effectiveness of the chosen surgery in the late-term, local Recurrence deserves attention as an oncological endpoint. The overall local Recurrence for both taTME and lapTME was low in the present meta-analysis, and there is no statistically significant difference between these two approaches. This implies that even though there may be one, two, or more technical advantages of performing taTME as opposed to lapTME, the oncological benefit in the long run is similar. Inconsistencies in recurrence rates from one study to another may be due to differences in follow-up time, the use of adjuvant therapy, and the proportion of patient samples that were chosen for the study.

This analysis serves to establish that both taTME and lapTME are successful in attaining the pertinent oncological results while implying particular benefits of the taTME system within particular sorts of surgeries. The effectiveness of either technique demonstrated in our study should be used to manage rectal cancer depending on patient characteristics and the surgeon's capabilities.

Secondary Outcomes

These secondary endpoint measures assessed perioperative factors, complications, and mobile/functional outcomes to complete the picture of the comparative performance of taTME and lapTME in rectal cancer surgery. These results provide important information on the safety, effectiveness, and patient experience of each approach, in addition to conventional oncological outcomes analysis.

Table. 2: Primary Oncological Outcomes

Outcome	taTME Group	lapTME Group	Notes
R0 Resection Rate	95–98%	93–97%	Both techniques show high success rates.
Positive CRM (%)	2–5%	4–8%	Lower positive CRM rates with taTME.
Local Recurrence (%)	3–7%	4–9%	Comparable long-term outcomes.

Perioperative measures of effectiveness included operative time, intraoperative blood loss, rate of conversion from laparoscopic to open surgery, and length of hospital stay. This pooled analysis also indicated that overall operative times were relatively similar between the two groups, with a marginally longer time for taTME in centers with less experience. This is consistent with the steeper learning curve for taTMEs. TaTME was demonstrated to be associated with less blood loss in all the studies due to better vision and the ability to visualize and dissect more carefully when using the transanal approach. These conversion rates to open surgery were also numerically lower for taTME, particularly in male patients, patients with narrow pelvis, or low rectal tumors where lapTME can be inevitably very challenging. Length of stay in the hospital was also very comparable between the two groups, with marginal differences due to institutional standards and operative care attending.

Safety outcomes were therefore evaluated by measures of complication rates for both methods. The rate of intraoperative complications, such as vascular or organ injury, is low and did not differ significantly between the groups. This complication was low and irrespective of the type of surgery done, taTME or lapTME, no differences were observed. But time seemed to increase the risk of urethral injuries, early phases especially, therefore, calls for highly skilled surgeons to perform this technique. Therefore, across the specialist concern, the results elucidate that Both techniques keep conceding noteworthy safety to sufferers, and their complications rate are slightly less effective than proficiencies of the surgery technique. Structure and quality of life after postsurgical bowel movement are key measures that define different patients' recovery and sustainability. The comparison between both groups showed that the bowel function was similar in both groups, and most patients regained good bowel function within six months of the operation. Superiority in QOL scores as determined by the standardized scoring system was not significantly different between the groups, and likewise, it was not different for patient-generated outcomes. Both techniques had similar renditions of nerve-sparing abilities but did not seem to spare urinary or sexual function, according to research universally. These data indicate that, although given scenarios may have technical benefits of taTME, both methods provide acceptable functional results and quality of living maintenance.

Subgroup and Sensitivity Analyses

Subgroup and sensitivity analyses were also planned to investigate clinical and demographic factors contributing to the heterogeneity of the estimates on the outcomes and to test the assumption of no difference between taTME and lapTME in this meta-analysis. These analyses give important perspectives on how concrete characteristics affect performance and guarantee the validity of combined findings.

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Table 3: Secondary Outcomes

Outcome	taTME	lapTME	Notes
Operative Time	180–250 min	170–240 min	Slightly longer for taTME initially.
Blood Loss	100–300 mL	150–400 mL	Lower blood loss with taTME.
Conversion Rates	1–5%	3–10%	Lower conversion rates with taTME.
Hospital Stay	5–8 days	5–8 days	Comparable durations.
Complication Rates	10–15%	10–15%	Similar rates; urethral injuries slightly higher with taTME.

Subgroup Analyses

Subgroup analyses focused on three primary variables: toxin concentrations and the stage of the tumor, the comorbid conditions of the patient, and the experience of the surgeon. The tumor stage was an essential confounder; stage III tumors are more complex compared to stage I and II tumors in terms of their surgical management. This study found that taTME has positional merit, where better CRM and less conversion were observed in the present study in the relatively heavy disease stage or low rectal carcinoma stage, where plebeian anatomy is problematic. Thus, concerning prognostic results, no significant difference was observed for both the kind of TME technique, both for early-stage tumors and for R0 resection rate and complications. Other characteristics, such as obesity and a history of previous pelvic surgery, were also assessed in patients. Patients who were classified under the obesity conglomerate or who have previously undergone pelvic surgeries fared better in the study since taTME permitted better access and visualization of these structures (12). Thus, these findings bear testimony to the fact that the specific mode of surgery needs to be chosen on the basis of the features that define a particular patient. The level of surgeon experience was found to be highly relevant with regard to perioperative and oncological results. TaTME complication rates and operative time decrease with greater center and surgeon case volumes, showing that there is a learning curve associated with this approach. This impact was comparatively less for lapTME because it has been in the domain earlier, and the practical training is more standard there in terms of timeframe.

Sensitivity Analyses

Thus, to verify the stability of the pooled estimates, a sensitivity analysis was conducted. These key analyses included restrictions on RCTs, the exclusion of studies with a high risk of bias, and the use of different kinds of statistical models (fixed, random, etc.). Subgroup analysis done by excluding high-risk bias studies also provided similar results, thus indicating more reliability in the results obtained above. Also, results for studies limited to RCTs were equivalent to the general meta-analysis, and these results confirmed the study's findings. The I^2 statistic examined inter-study heterogeneity. Substantial heterogeneity was more marked at the subgroup level and reduced substantially after controlling for tumor stage and surg eon's experience, which served as potential primary sources of heterogeneity in the general analysis. Potential publication bias was assessed using the funnel plot and Eggers test, finding no significant publication bias for any of the study outcomes further to support the stability of the analyses. The feature of the present study was that the subgroup analysis and sensitivity analysis were conducted to reveal the relationship between clinical, patient, and procedural factors and the outcomes of taTME and lapTME. These analyses also discussed the surgical skills of authors and patients' selection to produce satisfactory outcomes.

Table. 4: Subgroup and Sensitivity Analysis Findings

Factor	Key Findings	Implications
Tumor Stage	taTME favored in advanced or low tumors.	Tailor approach to complexity.
Comorbidities	Obesity and prior surgeries favored taTME.	taTME suits challenging cases.
Surgeon Experience	Outcomes improved with taTME expertise.	Training is critical.
Risk of Bias	Excluding biased studies upheld results.	Findings are robust.
Study Design	RCT-only analysis aligned with overall findings.	Reliable across methodologies.

These sub-analyses improve the validity of the meta- analysis and offer practice-based information for implementing rectal cancer surgery treatments. The results of the study highlight customization, the surgeon's choice, and sound methodological framework as the key to success.

Heterogeneity and Publication Bias

Randomness and publication two biases are significant characteristics when analyzing meta-analysis outcomes. This study verified both to avoid misguided interpretations of comparative results of transanal total mesorectal excision (taTME) and laparoscopic total mesorectal excision (lapTME) for rectal cancer.

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Heterogeneity

Heterogeneity was measured using the I^2 statistic, the estimate of inter-study variability beyond chance. In terms of primary oncological endpoints, e.g, R0 resection rates and CRM involvement, heterogeneity was moderate and included I^2 figures of between 30% and 50%. This is consistent with the findings of the surgical techniques used in other research studies. On the other hand, the results pertaining to postoperative characteristics like operative time and blood loss had high heterogeneity based on $I^2 > 50\%$ due to variations in patients, doctors, and center standards. Comparable findings were the least homogeneous, with $I^2 > 75\%$ of the total variation indicating significant heterogeneity in functional results, including postoperative bowel function and quality of life, which are probably due to the variability in the reporting of data and follow-up time. Know sources of variability were determined by subgroup analysis. There was some variation seen in CRM involvement and conversion rates, and it was noted that the tumor stage was a significant factor for this variation: CRM involvement and conversion rates were not all caught by advanced-stage tumors (17). Similar to prior work, surgeon experience was an important factor affecting the outcomes; high-volume centers expressed superior outcomes regarding taTME than low-volume centers. Furthermore, the presence of patient-obesity and past pelvic operations added scatter in the operative and functional parameters- because these conditions influence the technicalities of the procedure and the extent of convalescence (18).

Publication Bias

Publication bias was checked separately on publication bias using a funnel chart and Egger's test. The shapes of funnel plots for the primary endpoint, the R0 resection rate, and CRM positiveness were almost identical, and therefore, a minimal base appeared to exist. This was in concordance with Egger's test results, where most of the p-values of the outcomes were above 0.05, showing that the selective reporting of positive outcomes did not heavily rig the results. Nonetheless, whether funnel plot symmetry is present or absent, asymmetry was observed in some of the secondary outcomes, the choice of which may well be influenced by publication bias in small studies (19). Besides minimizing the publication bias, sensitivity analyses were performed to improve the reliability of the findings (20). As few as 4 RCTS with a low risk of bias could be done manually. As conducted in the main analysis, after excluding studies with a high risk of bias and restricting them to RCTs, no changes were observed in the pooled results. The sample size of subgroup analysis reduced heterogeneity, especially by tumor stage, surgeon's experience, and patient comorbidity, indicating the effect of these factors on variability in results.

Discussion

Summary of Main Findings

In the present meta-analysis, the comparative effective outcomes of transanal total mesorectal excision (taTME) and laparoscopic total mesorectal excision (lapTME) in rectal cancer surgery are reviewed. The results demonstrate a comparison and analysis between the two techniques regarding oncological, preoperative, and functional results, which provides useful information about the application of these two techniques. R0 resection rates and CRM involvement, as well as the local Recurrence, showed high performance of taTME and lapTME for treating oncological diseases (21). Complete macrosurgical resection (R0) rates were significantly high with both techniques and indicate that great emphasis had been placed on achieving negative margins. However, in the present study, this was achieved by demonstrating a slight advantage of taTME in failed cases with low rectal tumors or difficult anatomical structures, such as small pelvis or male patients. The authors attribute this advantage to taTME's "bottom-up" approach, which improves visibility and increases precision in the distal rectum. CRM positivity, one of the main determinants for local Recurrence, was marginally inferior in the taTME arm, especially in the context of more advanced cancer stages. However, the current study demonstrated that both techniques provided similar local recurrence rates in the long term. However, the technical benefits of the new taTME in specialized cases make it a suitable option in complex situations (22).

Table. 5: Heterogeneity and Publication Bias Summary

Aspect	Findings	Implications
I^2 for Primary Outcomes	Moderate (30–50%)	Outcomes are consistent across studies.
I^2 for Secondary Outcomes	High (>50%)	Perioperative and functional outcomes vary significantly.
Key Sources of Heterogeneity	Tumor stage, surgeon experience, patient comorbidities.	Subgroup analyses highlight variability.
Funnel Plot Symmetry	Symmetrical for primary outcomes.	There is a low risk of publication bias overall.
Egger's Test	Non-significant ($p > 0.05$) for most outcomes.	Findings are robust and reliable.

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The findings showed that several of the operative measures were significantly different according to the technique employed. The distribution of operative times was similar in both groups, though average times have been slightly longer in the initial trials of taTME, signifying its more protracted initial experience curve (23). With the progress of surgical skills, the time of the taTME approach is becoming similar to lapTME. Both studies demonstrated reduced blood loss associated with taTME, which was also likely due to the ability of the technique to offer precise dissection and a better view. The conversion rate to open surgery from taTME was significantly less in those studies, especially in patients with anatomical barriers such as low-located tumors or obesity. Length of stay did not significantly differ between the two groups, which supported balanced postoperative recuperation if perioperative management plans were equal (24). Complication rates were another important field to compare between the two groups. Perioperative complications of the vascular and organ damages were rare and equally distributed in both groups of taTME and lapTME. Percutaneous isolation of the stoma was not significantly different from hand-sewn colostomy regarding postoperative complications, including anastomotic leakage (25), pelvic abscesses, and wound infections. However, time revealed a slightly higher urethral injury rate, as was observed during the learning curve stage of the application of the procedure. This stresses the need for proper training and experience as these aspects unborn complications related to the learning curve. Altogether, both methods remained safe enough; the results, again, depended on the skill of a surgeon and the choice of subjects (26).

Therefore, the overall bowel functions assessed and the QoL were similar in both the taTME and lapTME groups at the long-term follow-up. Both techniques proved successful in retaining bowel functions, wherein the majority of the patients' bowel function improved within six months of the surgery. QoL indices obtained using validated scoring systems were not statistically significantly different between the two groups. Nerve-sparing abilities herein were also similar in saving urinary and sexual functions in most of the cases. Concerning functional outcome, the result indicated higher heterogeneity across the studies because of differences in assessment tools and the manner of reporting; however, the result implies that both techniques lead to satisfactory functional recovery and patient satisfaction (27). Subgroup differences were also observed for a number of outcomes, most notably the perioperative and functional variables. Various sensitivity analyses are used further, such as tumor stage, surgeon experience, and comorbidities of the patients (28). The tumor stage affects CRM invasion and conversion rates, with greater benefits for taTME in advanced or low rectal tumors. Expertise also contributed to the format of perioperative outcomes: the centers providing more taTME operations had better outcomes and fewer complications related to the learning curve. Variability arose from patient comorbidity, including obesity and prior pelvic surgery, affecting both perioperative and function outcomes; hence, there is a necessity for tailor-made surgeries (29). However, there was a slight publication bias regarding primary outcomes, where the funnel plot, especially that of First-level analysis, was symmetrical, and Egger's tests were not quite significant. This enhances the reliability of the pooled estimates to oncological measures since healthcare consumers are a unique population. However, the small degree of funnel plot asymmetry in secondary and functional outcomes points to reporting bias in small studies (30). Stratified sensitivity analysis supported the primary analysis; removing studies with a high risk of bias and then limiting the DRA analysis to RCTs reinforced the results.

The conclusions from the meta-analysis increase the evidence base generated in prior publications to validate non-invasive approaches in rectal cancer surgery (31). The results showed that compared with open TME, both taTME and lapTME achieved satisfactory oncological outcomes and safety. However, with respect to technical aspects, taTME has certain advantages, for instance, in cases with difficult pelvic anatomy or advanced tumors, whereby it should be considered. The results also raise the issue of surgeon experience and the need to identify appropriate patients and tailor surgery for them appropriately. Therefore, it is possible to state that both taTME and lapTME are highly efficient methods in rectal cancer surgery, but which can better fit particular situations in the case of its conduction. With less trauma, better exposure, and accuracy in the distal rectum, low tumor patients and patients with complex anatomy benefit from the procedure most, as it has similar oncological and functional results as lapTME. These results can encourage the practitioners to utilize taTME as a non-trivial approach to lapTME in high-volume centers with senior surgeons. There is a need for more high-quality studies reporting high-quality and functional data with follow-up long-term to clarify these questions and fine-tune the clinical pathways (32).

Interpretation in Context of Existing Literature

The conclusions of this meta-analysis help to advance the current discussion on the most appropriate technique for rectal cancer surgery, namely transanal total mesorectal excision (taTME) and laparoscopic total mesorectal excision (lapTME). These results are consistent with the literature and extend it where necessary, providing a clear comparison of the advantages and disadvantages of these approaches. The following two indices are of significant value as oncological results of rectal cancer surgery – R0 resection rates and CRM invasiveness (33). The present meta-analysis supported the use of both techniques for attaining R0 resections; however, taTME appeared to be more suitable in anatomically complex

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cases. These findings align with prior research, which has often stressed the increased visibility and accuracy of taTME in the distal rectum. For example, Heald et al.'s pioneering studies establishing TME outlined the role of CRM in the minimization of local Recurrence. In contrast, subsequent research indicates that compared with conventional 'top-down' TME, taTME facilitates a decrease in CRM positivity rates, particularly in male patients or those with narrow pelvises. However, building on this analysis, this paper serves to extend the literature by highlighting that the success of time is best demonstrated in the treatment of advanced-stage or low rectal tumors, thereby providing a finer level of distinction (34).

Others are local recurrence rates, which are one of the areas of focus in the present literature as they are considered to determine the overall oncological efficacy of surgical procedures. Consistent with systematic review and clinical guidelines, this analysis has shown that the local recurrence rate is equivalent between taTME and lapTME (35). For example, ESCP (European Society of Coloproctology) guidelines consider both approaches as a legitimate choice for rectal cancer resection and state that a tumor-free margin should be obtained. Low long-term oncological results of the two methods support the idea that both are feasible, with taTME providing benefits in certain cases. Other factors, such as operating room time, estimated blood loss, and conversion or not to open surgery, were thoroughly investigated in patients undergoing minimally invasive rectal surgery (36). The authors of this meta-analysis discovered that operative times were equally comparable between the taTME group and the lapTME group. However, ds the operative time in the taTME group was slightly longer in the early stages.

To some extent, this observation aligns with previous studies by Lee (37); however, the curve demonstrated was more inclined toward the top of the graph than our study. As experience is built up over time, operating times of taTME are reported to be at least equivalent to those of lapTME. Significantly less blood loss was reported throughout the taTME; this is an aspect similarly noted by Penna et al, who described the approach as entailing a controlled dissection because of enhanced visibility. Furthermore, this meta-analysis identified that the overall conversion rate of taTME was lower to open surgery, especially for male patients with obesity or low rectal tumors. This is an important discovery since previous systematic reviews and meta-analyses have identified the conversion to open surgery as a benchmark of technical complexity and a domain where taTME has a clear edge (38). Hence, bowel function and QoL are becoming more accepted enlargements of surgical success issues since they deal with the patient's well-being in the long run. This meta-analysis also revealed no results differing between taTME and lapTME in terms of bowel function or QoL, as studies such as Andersson et al. have also observed (39). However, disparities in functional scores distinguishing the performance of patients across the studies indicate the necessity of more standardized measures for the assessment and reporting of functional changes. This analysis also supports a recent pattern of finding that both techniques are effective in preserving nerve function, which plays an immense role in urinary and sexual function. Relatively minor variations in functional outcome imply that functional considerations should not be the overriding factor in determining the technique of choice (40); rather, oncological and anatomical concerns should be primary drivers in decision-making.

Consequently, the study by the meta-analysis also assessed the safety profiles of both taTME and lapTME with regard to intraoperative and postoperative complications, which were similar. This is in agreement with the COLOR II trial on minimally invasive rectal surgeries, which established mild complication rates. Nevertheless, the focus of this analysis reveals slightly increased rates of urethral injuries during the early period of applying taTME, as can be seen in the studies such as Denost et al, where the authors stress the significance of developing training programs to decrease such risks. Thus, the present study is in line with previous studies asserting that the high technical difficulty of taTME implies that appropriate training should be provided to facilitate safe practice (41). Heterogeneity and publication bias should be taken into account when explaining any meta-analysis. This review found moderate inter-study dispersion of primary oncological endpoints and higher variability of perioperative and functional endpoints, as seen in prior reviews. A post hoc analysis was performed to examine the demographic, clinical, and pathological characteristics of the subjects and to determine sources of variability (42); the results find congruence with previous studies suggesting that tumor stage, surgical experience, and patient comorbidity are major determinants of surgical outcome. There was a low level of publication bias for primary outcomes, which was consistent with current high-quality RCTs and cohort studies in this field. In combination, these findings correspond to the latest clinical guidelines, such as NCCN and ESCP, which recommend taTME and lapTME equally suitable for rectal cancer surgery. Nevertheless, this analysis enlarges the body of knowledge by providing a more nuanced assessment of the scenarios wherein the delivery of taTME may yield the most benefits. For example, the mentioned oncological and functional results and the comparability of techniques; however, the technical advantages of taTME in certain cases, such as low tumors and anatomic complexities at an advanced stage, make it possible to offer an optimal option instead of lapTME (43).

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Strengths and Limitations

Strengths

In the following, several strengths of this meta-analysis are to increase its reliability and applicability. First, the selected method is supported by a broad sample size across several investigations, which increases statistical validity. The theoretical framework of the research compares transanal total mesorectal excision (taTME) and laparoscopic total mesorectal excision (lapTME) using a quantitative synthesis of data from varied patient cohorts and the clinical context of the procedure. Second, the employment of sound methodological standards such as registration of study protocol in PROSPERO, adherence to PRISMA directive on reporting of meta-analysis, and the employment of standard tools to assess the risk of bias, for example, the tool by Cochrane or ROBINS-I minimizes bias. Also, the implementation of the random-effects models to address variability across several studies, as well as the subgroup and sensitivity analysis to examine sources of heterogeneity, gives extra dimension and robustness to the conclusions. Altogether, these strengths help to increase the validity of the findings and their relevance to clinical practice.

Limitations

However, the present meta-analysis has some limitations as well. Lastly, the variations observed in heterogeneity, especially related to care outcomes, reflect variations in the study samples, surgical skills, and end-of-institutional practices. Although researchers used subgroup analyses to establish some factors that led to the development of the final model, including tumor stage and surgeon experience, the presence of residual confounding factors still impacted the results. The low quality of underpinning studies is another limitation, as studies selected for analysis were of mixed quality: outranking included primarily RCTs but used observational studies to augment evidence where none was available. Parity was also found to be a weakness for some types of outcomes, where some studies failed to report functional measurements in a way that would make detailed comparisons possible across the studies. Lastly, there may be publication bias, especially regarding secondary and functional outcomes, and the possible reason might be that there was a larger number of trials with only primary outcomes. Even though publication bias was limited to a very small extent when compared to primary outcomes. Nevertheless, the research contributes to future work by identifying important aspects and emphasizing the importance of more high-quality research for answering remaining questions.

Clinical Implications

To reach general and specific conclusions about the value of laparoscopic surgery in rectal cancer treatment, the current study presents a meta-analysis. Transanal total mesorectal excision (taTME) and laparoscopic total mesorectal excision (lapTME) show similar oncological results, R0 resection (44), and low local recurrence rates. These findings support the applicability of both techniques in rectal cancer surgery by setting out conditions that may inform the preference of the taTME over the other.

Because it has yielded lower CRM positivity and a lower conversion to open surgery with time, it is particularly useful for difficult cases. Specific patient types that are most suitable for this method of intervention include patients with low rectal tumors, narrow pelvic structure, or even obesity since it provides enhanced access to the site and precision (45). These results support the continued use of time as an adjunct to lapTME and specify its applicability in intricate cases where lapTME is suboptimal. Perioperative and functional surgical data contribute further information. Taking into consideration these data on comparable oncological safety and favorable long-term functional results of bowel function and quality of life, the decision on the preferred technique for surgical resection should rely on the oncological and anatomical factors. However, as noted by previous authors, there is a significant learning curve associated with the same technique, and complete novice surgeons should not enter into surgery without prior supervised training (46). These findings are important for clinical application and guidelines to encourage the application of taTME in specialized hospitals and the application of lapTME as a stable standard. As such, these findings promote rectal cancer management based on patients' characteristics, surgeon skills, and experience, resulting in improved patient outcomes and health quality.

Future Research Directions

As evidenced by the results of the present meta-analysis, there are still many unknowns that have to be answered, and more studies of superior quality are warranted to fine-tune the approaches to rectal cancer surgery. However, there are some gaps in the current evidence that can inform future research on both taTME and lap TME. First, more blinded, high-quality RCTs are required to yield further comparison of taTME and lapTME. Information from observational studies and existing RCTs are useful; however, differences in study protocols, patient population, and method of reporting make extrapolation of studies' findings currently difficult. Highly controlled and complex M-CRCTs employing well-defined guidelines are required to compare the short- and long-term effects in different patients and environments. Such trials should also stock for the surge effect that always exists when a new technique such as taTME is introduced to the surgical practice. Second, as Rauchwerger et al. rightly pointed out, there is an urgent need to examine local recurrence rates, distant metastasis, and overall survival, all of which remain unanswered questions in the](008-017/KCI>[. The

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majority of papers report on short- to middle-term outcomes; consequently, the long-term oncological and functional effectiveness of these approaches remains ambiguous. Furthermore, patient-oriented measures, including the health-related quality of life, postoperative courses, and functional outcomes, suffer from a lack of obvious reference variables and need longer-term follow-up to obtain a comprehensive picture of surgical effectiveness. Last, future studies should explore the cost analysis and utilization of resources in practicing taTME and lapTME, especially in centers with minimal technological infrastructure and surgeon experience. Subtopics include the application of aspects of new technology and how new surgical procedures, like robotic-assisted TME, fit into the current environment.

Filling these gaps in knowledge will improve future research, refine clinical practice parameters, and improve the care of rectal cancer patients.

Conclusion

Comparison of transanal total mesorectal excision (taTME) outcomes with laparoscopic total mesorectal excision (lapTME) for rectal cancer (47). The present meta-analysis systematically and comprehensively assesses the comparative effectiveness of taTME and lapTME. Definite technical oncological efficacy was achieved with a similar R0 resection rate and low local Recurrence in both techniques. Consequently, both conditions have similar long-term functional outcomes and safety, although specific situations favored the use of taTME, such as a low rectal tumor, narrow pelvis, and obesity patients. Lower CRM positivity and the decreased rates of conversion to an open procedure also support the potential advantages of taTME in these cases (48).

Nevertheless, the critical benefits of taTME include the following: It is clear that to deliver the best results and reduce complications, learning curves associated with taTME require structured training and experience. Both techniques are still useful in the treatment of rectal cancer, and the choice of one versus the other should depend on the characteristics of the blood supply, the size and location of the tumor, and the experience of the surgeon (49). Health care institutions applying the taTME technique should commit considerable resources toward training personnel in the correct execution of the technique. In clinical practice, these findings endorse taTME as an additional approach to lapTME in institutions that possess the facilities and experience. The currently used LapTME is safe and effective; therefore, it remains a gold standard. Therefore, for future planning, decision-making will have to be patient-specific and take into account patients' anatomy, the stage of the tumor, and institutional facilities. The implementation of meta-analyses involving high-quality randomized controlled trials and LOS is especially required to fill the literature gaps. The implementation of these procedures will assist in enhancing the existing clinical protocols aiming to improve the results of the surgery on rectal cancer patients (50).

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