Comparative Study between High and Low Inferior Mesenteric Artery Ligation in Laparoscopic Total Mesorectal Excision in Rectal Cancer Patients

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Introduction: Surgery is the primary treatment for rectal cancer, with laparoscopy improving visualization during total mesorectal excision (TME). There are two techniques for ligating the inferior mesenteric artery (IMA): high ligation at its aortic origin and low ligation after branching the left colic artery.

Aim of work: The present study aims to evaluate the difference between high and low ligation of the (IMA) regarding healing; vascularity and recurrence after laparoscopic (TME) in cases of rectal cancer

Patients and methods: This prospective / retrospective study was conducted on 43 patients with rectal cancer at two tertiary hospitals from January 2014 to December 2017. The patients were divided into two groups: high ligation of the inferior mesenteric artery group (HL) (19 cases), and a group that underwent low ligation (LL) of the artery (21 cases); another 3 patients underwent a new approach described as functional high ligation (FHL). Retrospective cases were followed up for 4 years postoperatively.

Results: Our study revealed no significant difference between the two groups regarding complications. Leakage occurred in 3 cases with high ligation and 2 cases with low ligation of IMA. Sloughing of the stoma was encountered in 2 cases done with high ligation and 1 case done with low ligation of IMA. Follow-up revealed 2 cases of recurrence; one case in each group

Conclusion: No difference was found between high and low ligation of the inferior mesenteric artery in laparoscopic total mesorectal excision (TME) in cases of cancer rectum regarding complications.

Key words: Rectal carcinoma, total mesorectal excision, inferior mesenteric artery ligation, laparoscopy.

Introduction

Colorectal carcinoma is the most common type of cancer in the digestive system. As economies have grown and factories have been built, the number of people getting rectal cancer has been going up dramatically. It starts to rise after age 35 and quickly after age 50, reaching its highest point in the seventh decade. However, younger ages are now also being affected. Rectal cancer is the third most common type of cancer in both men and women in the United States right now.[1]

The most common way to treat rectal cancer is through surgery. Introduction of Total mesorectal excision (TME) concept to surgical interventions has made a big difference in the outcomes for people with rectal cancer, especially when it comes to local recurrence rates of the tumor.[2] After TME, the rates of local recurrence dropped from 30% - 40% to 5%.[3]

Exposure of the pelvic operative field in open TME surgery could be a problem, because of narrow pelvis and impaired visibility as the dissection proceeds caudal and pertaining to difficulties in pelvic dissection leading to functional urogenital problems as bladder dysfunction occurs in 7-68%, especially in male patients.[4]

The introduction of laparoscopy to surgeries for rectal cancer has helped to get better visualization, use more delicate tools, and handle tissues more carefully. This could then lead to adequate dissection up to the pelvic floor with better protection of the hypogastric plexus and nerves, which could then lead to a good functional and oncological outcomes.[5]

There are different types of surgeries for each area of the rectum that is involved by tumor. In cases of middle and high third rectal cancer, there is low anterior resection and anterior resection respectively, which are based on the level of peritoneal foldings in the pelvis. In cases of lower third rectal cancer, there is intersphinctric resection (Sphincter preservation) and abdomino-perineal resection (APR).[6]

During TME, there are two common ways to ligate the inferior mesenteric artery: the first is to ligate the artery where it starts from the aorta (High Ligation); the second is to ligate the artery after it splits off from the left colic artery and keeps it intact (Low Ligation).[7] Whereas functional high ligation (FHL) is a newly adopted technique where ligation is performed after branching the left colic artery and dissection of apical lymph nodes till the level of origin of the IMA from the aorta.[8]

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Aim of work: The aim of our study was to evaluate the difference between high and low ligation of the inferior mesenteric artery in terms of healing and blood flow at the site of anastomosis or at the stoma site in laparoscopic total mesorectal excision (TME) for rectal cancer cases.

Patients and methods

This retrospective/ prospective study was conducted on 43 patients presenting with rectal and anal cancer at the outpatient clinics of two tertiary hospitals. The study included data of the participants who were candidates for surgeries entailing inferior mesenteric artery ligation and were collected retrospectively from January 2014 to December 2017 to assess recurrence rates of cancer and other outcomes of the surgeries performed. From January 2017 to December 2017 another group of patients were operated upon as well to assess the outcomes of each ligation type prospectively. The study excluded cases with previous surgeries on the abdominal aorta, those presenting with acute bowel obstruction or adjacent pelvic organs invasion or having atherosclerotic IMA and its branches.

Ethical consideration: The organization Ethical Research Committee reviewed the study protocol and gave its approval. The patients who took part in the study were clearly told how it would work and what its goal was. Before they were allowed to join the study, the participants gave written permission after being told about the pros and cons of the process. The patients could quit at any time; participation was entirely voluntary. In line with the Declaration of Helsinki, all steps of gathering, entering, and analyzing data were done in a very private and secret way.

Preoperative preparations

History taking, general and abdominal examinations, including per-rectal (PR) and per-vaginal (PV) were performed for all patients. Pre-operative tumor markers (CEA, CA 19-9 & AFP), ECG and Echocardiography, colonoscopy with biopsy, abdomen & pelvic ultrasound (U/S), chest, abdomen & pelvis computed tomography (CT) with contrast to exclude metastases and pelvic magnetic resonance imaging (MRI) were done to look for evidence of local infiltration, assess the size of tumor and regional lymph node involvement.

Mechanical bowel preparation was done one day before the operation and anticoagulant prophylactic dose was given 12 hours before the procedure.

Intraoperative preparation

Systemic antibiotics and metronidazole are given at the time of induction of general anesthesia. An oro-gastric tube and a Foley's catheter were inserted together with elastic stockings.

Operative technique

Laparoscopic abdominoperineal resection steps will be described here as it was the most commonly performed procedure in our study.

The patient was positioned in modified lithotomy. Pneumoperitoneum was established via Veress needle at the umbilicus (14 mm Hg CO_2). A 10-mm supraumbilical port with camera was inserted, followed by a 12-mm right lower quadrant port, a 5-mm right upper quadrant port, and a 5-mm left lower quadrant port, all lateral to the epigastric vessels. The patient was rotated with the left side up and right side down and put in Trendelenburg position, where the small bowel was displaced to the right by this position.

The greater omentum was reflected over the transverse colon, and the stomach was decompressed. The small bowel was moved to the patient's right side, allowing visualization of the medial aspect of the rectosigmoid mesentery pedicle.

The rectosigmoid mesentery was tented. This area was then stretched up toward the left lower quadrant port, stretching the inferior mesenteric vessels away from the retroperitoneum. and peritoneum opened at the sacral promontory to expose the inferior mesenteric vessels **(Fig. 1A).** The vessel was divided using a high ligation (Above the left colic artery) or using a low ligation (After preservation of left colic artery). Laparoscopic clips are used to divide the vessel. Other energy sources were also used. The inferior mesenteric vein was identified and divided proximally at the lower border of the pancreas **(Figs. 1B,1C).**

The lateral peritoneal attachments of the sigmoid were divided along the white line of Toldt, mobilizing the left colon medially to facilitate a tension-free left iliac fossa colostomy. The mesocolon was separated from retroperitoneum medial-to-lateral, with marginal artery division as needed. The colon was divided with a linear stapler.

In females, the uterus was retracted out of the field. The rectosigmoid was elevated, and the mesorectal plane was dissected posteriorly in the avascular presacral space, preserving hypogastric nerves. Peritoneum was divided bilaterally to the level of seminal vesicles or rectovaginal septum, allowing circumferential mobilization to the pelvic floor. Anterior dissection proceeded in front of Denonvillier's fascia (Or unilaterally) to protect neurovascular bundles.

The lowest rectal dissection was completed perineally. After elliptical perianal incision and

closure of the anal canal, ischiorectal fossae were entered laterally to the sphincter. Levator ani were divided near the coccyx to enter the pelvis **(Figs. 2A,2B).** Dissection proceeded anteriorly, protecting vagina or prostate/urethra. The specimen was delivered, pelvic cavity irrigated, suction drain placed, and perineal wound closed in layers **(Figs. 3A,3B).**

A trephine colostomy was fashioned at the left iliac

Fig 1: A: A groove between the medial side of the inferior mesenteric pedicle and the retroperitoneum. B: Ligation of the inferior mesenteric artery. C: Ligation of the inferior mesenteric vein.

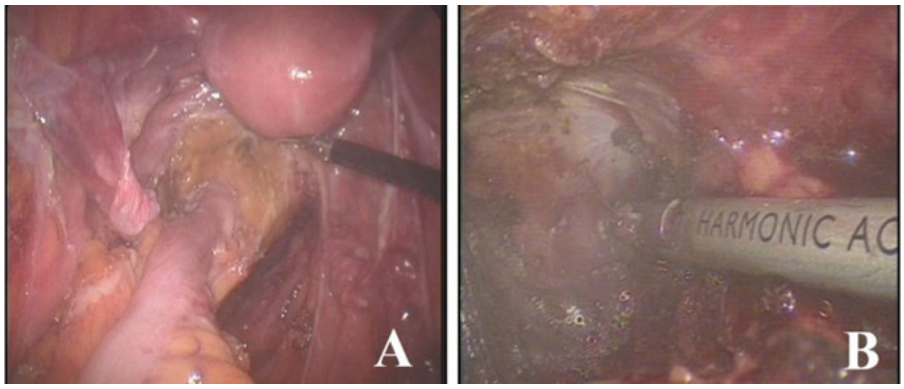

Fig 2: Mobilization of the rectum. B: Dissection down to the levator muscle.

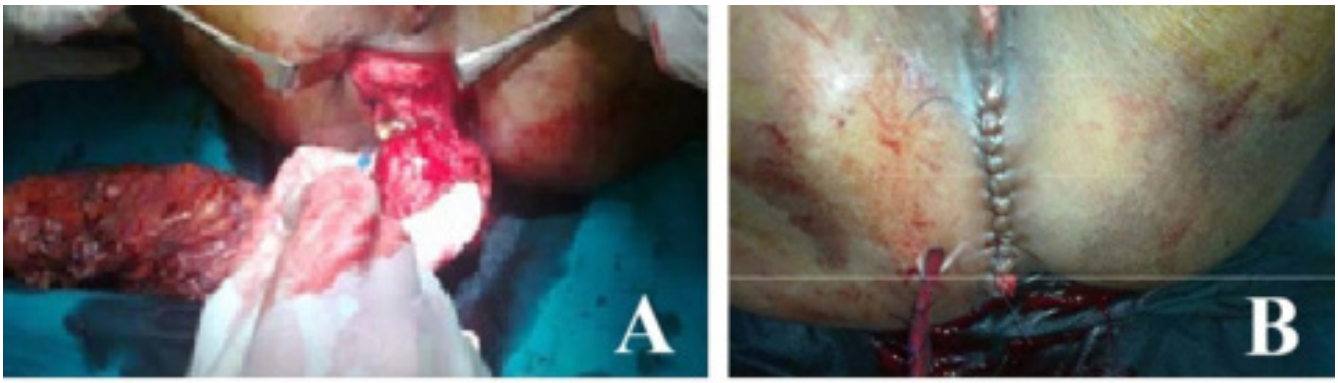

Fig 3: A: Delivery of the specimen & separation of anterior attachment. B: Closure of the perineal wound.

fossa port site. The anterior rectus sheath was cruciately incised, rectus split, and peritoneum opened. The stapled end of colon was delivered, staple line excised, and colostomy matured with 3/0 vicryl.

Statistical methods: Data entry was carried out using SPSS (Statistical Package for Social Science) version 23.0 (IBM®, SPSS, USA). Variables were examined for normality. Categorical variables were expressed in numbers and percentages; Chi-square and Fisher's exact tests were applied as appropriate. Continuous variables were expressed using mean and standard deviation or median for normally distributed data and interquartile range for not normally distributed data; the T-test, Mann Whitney, and other tests of significance were used for comparison as appropriate. P value <0.05 was considered significant.

Results

This study was conducted on 43 cases diagnosed as rectal or anal carcinoma. The patients' ages ranged from 21 to 84, with a mean age of 48.93±14.05 years. Statistical analysis showed that the peak incidence of rectal cancer was found in the sixth decade. Female predominance (25 females and 18 male patients) was noted, with a male-to-female ratio of 1:1.39 **(Table 1).**

The majority (28; 65.11%) of the cases presented with bleeding per rectum among other symptoms, while 2 (4.7%) cases were asymptomatic. Regarding comorbidity, 29 (67.4%) cases had no coexisting diseases, while others suffered from diabetes mellitus (DM), hypertension (HTN), cardio-pulmonary diseases, or hepatitis C virus (HCV) **(Table 1).**

As regards surgical history, 25 (58.14%) cases had no history of operations, while those who confirmed previous operations underwent cesarean section (CS), appendectomy, hemorrhoidectomy, fissurectomy, cholecystectomy, modified radical mastectomy (MRM), GIST resection, or lipoma excision **(Table 1).**

For the tumor grading, 34 (79.1%) cases were grade II, while 9 (20.9%) cases were grade III. Regarding lymph node status, 26 (60.5%) cases presented with lymph node metastasis **(Table 1).**

Most cases were classified as adenocarcinoma (31;72.1%). Neoadjuvant chemotherapy was needed in 13 cases (30.23%), radiotherapy in 10 cases, combined chemotherapy and radiotherapy in 4 cases, and CCCR in 8 cases (18.6%); 8 cases (18.6%) received no neoadjuvant treatment **(Table 1).**

As for the type of operation, twelve patients (27.9%) underwent abdominoperineal resection, 5 (11.63%) underwent low anterior resection (LAR), 6 (13.95%) underwent intersphincteric resection with ileostomy, 14 (32.56%) underwent LAR with stoma, 4 (9.3%) underwent pelvic exenteration, and 2 (4.7%) underwent anterior resection (AR) **(Table 2).**

Regarding the type of ligation, nineteen patients (44.19%) underwent low ligation, 21 patients (48.84%) underwent high ligation, and 3 patients (6.98%) underwent FHL ligation **(Table 2).**

The number of LNs dissected ranged from 0 to 30, with a mean of 14.28 ± 6.6. Seventeen patients (39.5%) had no lymph node metastasis, whereas 26 patients (60.5%) had metastatic nodes. Notably, HCV-positive patients presented with a statistically significantly higher number of positive lymph nodes (P-value = 0.041).

Also, the mean number of LNs dissected was highest in the HL group, which had an average of 21 nodes, while the low ligation group had the lowest average, with only 10 nodes. A statistically significant association was identified between the type of ligation and the number of lymph nodes dissected, with a P-value <0.0001, indicating that HL ligation resulted in the highest mean number of lymph nodes dissected, while low ligation resulted in the lowest. However, the type of surgical operation did not show a significant relationship with the number of lymph nodes dissected, as indicated by a P-value of 0.121.

About 3 quarters of the study population (32; 74.4%) had no postoperative complications. Among the remaining patients, leakage occurred in 5 (11.63%), stomal sloughing in 3 (6.98%), stenosis in 2 (4.7%), and slipped anastomosis in 1 (2.3%).

As for anastomotic leakage which occurred in five patients (11.6%) (three after high ligation, two after low ligation of the IMA), they were all following AR or LAR without a protective stoma. Symptoms appeared on postoperative day five, and imaging confirmed the leakage. All patients underwent re-exploration, re-anastomosis, and creation of a covering colostomy.

Stoma sloughing and necrosis after APR occurred in three cases (6.98%) (Two after high ligation, one after low ligation), developing within seven days and requiring revision. Anastomotic stricture was detected in two cases (One after high ligation, one after low ligation) during pre-closure evaluation about six months postoperatively; stoma closure was contraindicated. Coloanal anastomotic slippage occurred in one HL case following intersphincteric resection with ileostomy.

Analyzing the factors that could be related to higher complications, we found no significant association between ligation type and postoperative complications (P-value= 0.068).

Also, the type of operation was significantly associated with postoperative complications (P-value= 0.001), where out of the 11 cases who suffered post-opertaive complications, 4 (36.4%) underwent LAR with colostomy. It is worth noting that pelvic exenteration was free of postoperative vasculature related complications as leakage; sloughing or stenosis (100% complication-free), whereas both LAR with colostomy and AR were associated with a 100% complication rate **(Table 3).**

However, neoadjuvant therapy was significantly associated with a lower rate of postoperative

complications (P-value= 0.005), with most patients (35; 81.4%) being complication-free.

No significant associations were found between postoperative complications and surgical history (P-value= 0.872), comorbidities (P-value= 0.304), age (P-value= 0.07), gender (P-value= 0.816), or tumor grade (P-value= 0.574). Similarly, tumor grade showed no significant relationship with postoperative complications (P-value>0.05).

During retrospective analysis of a four-year follow-up, recurrence was noted in two patients. One case (Low ligation) developed a malignant perineal fistula 10 months after posterior pelvic exenteration. The second case (High ligation) developed a malignant colovaginal fistula two months after ileostomy closure for LAR; both required radical salvage surgery with permanent colostomy.

Table 1: Demographic and clinical history and tumor characteristics of the studies patients

Category	Variable	Number of Cases (n)	Percentage (%)
Demographics	Age range (years)	21–84	—
	Mean ± SD	48.93 ± 14.05	—
	Peak incidence	Sixth decade	—
	Male	18	41.9
	Female	25	58.1
	Male: Female ratio	01:01.4	—
Clinical Presentation	Bleeding per rectum	28	65.11
	Abdominal pain	3	6.98
	Constipation	6	13.95
	Pain during defecation	2	4.7
	Anal mass	2	4.7
	Asymptomatic	2	4.7
Comorbidities	None	29	67.4
	Diabetes mellitus (DM)	4	9.3
	Hypertension (HTN)	4	9.3
	Cardiac disease	1	2.3
	Hepatitis C virus (HCV)	2	4.7
	Asthma	1	2.3
Pathology	Tumor Grade II	34	79.1
	Tumor Grade III	9	20.9
	Lymph nodes: No metastasis	17	39.5
	Lymph nodes: Metastatic	26	60.5
Histological Type	Adenocarcinoma	31	72.1
	Mucoid carcinoma	8	18.6
	Signet ring carcinoma	2	4.7
	Squamous cell carcinoma	1	2.3
	Melanoma	1	2.3
Neoadjuvant Therapy	None	8	18.6
	Short-term radiotherapy	7	16.27
	Long-term radiotherapy	3	6.98
	Chemotherapy only	13	30.23
	Chemotherapy + short-term radiotherapy	1	2.3
	Chemotherapy + long-term radiotherapy	3	6.98
	Concurrent chemoradiotherapy (CCCR)	8	18.6

Table 2: Surgical procedures, ligation types, and lymph node status among study participants

	Category & Subcategory	n (%)
Type of Operation	Abdominoperineal resection	12 (27.9%)
	Low anterior resection (LAR)	5 (11.63%)
	Intersphincteric resection with ileostomy	6 (13.95%)
	LAR with colostomy	4 (9.3%)
	LAR with ileostomy	10 (23.26%)
	Pelvic exenteration	4 (9.3%)
	Anterior resection (AR)	2 (4.7%)
Type of Ligation	Low ligation	19 (44.19%)
	High ligation	21 (48.84%)
	FHL ligation	3 (6.98%)
Lymph Node Status	No metastasis	17 (39.5%)
	Metastatic nodes	26 (60.5%)

Table 3: Presence of vascular supply related complications according to type of operation among study participants

Operation type	Complications n (%)	
	Not present	Present
APR	11(34.4%)	1(9.1%)
LAR	3(9.4%)	2(18.2%)
Inter-sphincteric resection and ileostomy	5(15.6%)	1(9.1%)
LAR and colostomy	0(0%)	4(36.4%)
LAR and ileostomy	9(28.1%)	1(9.1%)
Pelvic exenteration	4(12.5%)	0(0%)
AR	0(0%)	2(18.2%)
Total	32(100%)	11(100%)

Discussion

There is some disagreement about the best place to tie off the inferior mesenteric artery (IMA) during surgery for rectal cancer. High closure makes it easier to remove metastatic nodes all at once and allows tension-free anastomosis in low anterior resections without raising the risk of leaks. This may improve quality of life after surgery by protecting the hypogastric nerve.[9]

However, in laparoscopic anterior rectal resection, the ligation level impacts genito-urinary and bowel functions, with low ties potentially improving outcomes due to enhanced blood supply from the left colic artery.[10] High ties can increase colonic length by 10 cm, raising further debate.[11]

More high ties have been used since introduction of laparoscopic surgeries for treatment of rectal cancer, this type of ties may affect vascularity and make it harder for the stump to get better blood flow.[12] In the end, there is still disagreement about whether high or low ties of inferior mesenteric artery is superior, with studies showing different benefits.[13]

The current study was conducted on 43 cases diagnosed with rectum and anal canal carcinoma to evaluate the difference between high and low ligation of the IMA regarding complications or recurrence in laparoscopic total mesorectal excision.

Out of the forty-three cases, 21 cases underwent high ligation and 19 cases underwent low ligation and 3 cases had functional high ligation of IMA

Different types of ligation did not cause any statistically significant changes in the number of problems seen in this study.

In agreement, other researchers found no difference in the incidence of complications between high and low ligation in rectal cancer, other than anastomotic leakage between the two groups.[14]

Anastomotic leakage occurred in five patients, more frequently after high ligation of the IMA and exclusively in cases without a protective stoma. This supports previous evidence that omission of

diversion in anterior resections may increase leakage risk.[15] Presentation on postoperative day five with fever, vomiting, and abdominal pain was typical, and imaging confirmed leakage in all cases. The subsequent need for re-exploration and diversion highlights the morbidity of leakage and reinforces the potential benefit of selective protective stoma formation in high-risk patients.

Colostomy stoma sloughing and necrosis occurred in three APR cases, predominantly after high ligation of the IMA, consistent with reports suggesting compromised blood supply as a contributing factor. These complications emerged within the first postoperative week and required stoma revision, underscoring the importance of meticulous vascular assessment during stoma creation.

Anastomotic strictures were identified in two cases, one after high ligation and one after low ligation, during routine evaluation prior to stoma closure. The timing, approximately six months postoperatively following adjuvant therapy, aligns with the delayed fibrotic changes described in previous studies. In both cases, stoma closure was contraindicated due to the high risk of failure and obstruction, highlighting the need for early detection and intervention.

In patients undergoing FHL, coloanal anastomotic slippage was observed in one case following intersphincteric resection with covering ileostomy. This rare complication, detected within days of surgery, emphasizes the necessity for careful anastomotic technique and close early postoperative surveillance.

Part of the study analysis was done retrospectively to uncover the recurrence incidence among this type of patient. Long-term follow-up revealed two cases of local recurrence, highlighting the persistent risk even years after definitive surgery. The first patient, following posterior pelvic exenteration and low ligation of the IMA, developed a malignant perineal fistula within 10 months, with MRI confirming invasion of the posterior bladder wall. The second, after LAR with high ligation and covering ileostomy, developed a malignant colovaginal fistula two months after ileostomy closure, with recurrence localized at the stapler line. These findings are consistent with previous reports indicating that local recurrence often presents with complex fistulous disease, significantly complicating management. The need for extensive salvage procedures, including APR and posterior vaginal wall excision, underscores the aggressive nature of such recurrences and the importance of vigilant surveillance in high-risk patients.[16]

From all previous results, our study showed no significant difference, benefits, or advantages between the two groups of ligation regarding the rate of complications related to the vasculature of the proximal colon, such as leakage, stenosis, or sloughing of necrosis.

In accordance, a meta-analysis indicates that both techniques are comparable in most aspects and suggests that the choice of technique should be based on individual patient factors and surgeon preference.[17]

Another meta-analysis found that there is no difference between high and low ligation of the IMA in terms of oncological outcomes or postoperative morbidity and mortality.[18]

This aligns with Bonnet et al. and Koji Yasuda et al. who reported no statistically significant differences in the number of complications between two groups of IMA ligation. Adding to that the length of hospital stay also did not differ significantly in both groups of IMA ligation.[11,14]

On the contrary, a previous research concluded that although the prognosis of patients with node metastases at and around the origin of the IMA is poor, the survival rate of patients with rectal cancer may be improved by performing high ligation of the IMA combined with neoadjuvant and adjuvant therapy.[9]

A study by Roberto Cirocchi and his colleagues reported that high tie has the advantage of a lower anastomosis traction and the disadvantage of the worst vascularization of the stumps.[12]

On the other hand, a meta-analysis in 2021 recommends ligating the IMA below the level of the left colic artery with high dissection for sigmoid colon and rectal cancers.[19]

Another study stated that during laparoscopic low anterior resection, a combination of low ligation at the IMA and vascular root lymph node dissection may help protect the blood supply of the anastomosis, reduce postoperative complications, and enhance recovery, without compromising radical excision.[8]

Meijin et al. in 2017 reported that low ligation with apical nodes dissection may decrease the risk of anastomotic leakage.[13]

Limitations

The study has the limitation of a small sample size. Although part of the study was prospective, some data were collected retrospectively to facilitate an extended follow-up period, which may introduce recall or documentation bias.

Conclusion

Our study revealed no significant difference between high and low ligation of the inferior mesenteric

artery regarding complications related to poor blood supply as leakage or stricture at site of anastomosis or necrosis and sloughing of stoma of colostomy, nor oncological outcome and recurrence rate in laparoscopic total mesorectal excision (TME) in cases of cancer rectum.

Recommendations

The authors recommend conducting larger, multicenter prospective studies with standardized surgical techniques and follow-up schedules to validate these findings and refine patient selection criteria for high vs. low ligation.

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