E-ISSN: 2536-4901

Volume 36

Issue 3

September 2026

Turkish Journal of COLORECTAL DISEASE

Official Journal of the Turkish Society of Colon and Rectal Surgery

www.turkishjcrd.com

Turkish Journal of
COLORECTAL DISEASE

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Printing at: Son Sürat Daktilo
Gayrettepe Mahallesi Yıldızposta Caddesi Evren Sitesi A Blok No: 3D:1-, 34394 Beşiktaş/İstanbul **Phone:** 021288 45 75 / 76 **Mail:** print@sonsuratdaktilo.com
Printing Date: September 2026 **ISSN:** 2536-4898 **E-ISSN:** 2536-4901

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The journal is published online.

Owner: Emre Balık on behalf of the Turkish Society of Colon and Rectal Surgery

Responsible Manager: Fatma Ayça Gültekin

Turkish Journal of
COLORECTAL DISEASE

CONTENTS

DOI: 10.4274/tjcd.galenos.2026.2026-3-1
Turk J Colorectal Dis 2026;36(3):73-79

RESEARCH ARTICLE

LigaSure Hemorrhoidectomy versus Non-Doppler Artery Ligation with Mucopexy for Grade IV Hemorrhoids: Short-Term Outcomes of a Retrospective Cohort Study

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ABSTRACT

Aim: The present study was designed to evaluate early surgical outcomes, recurrence rates, and exploratory patient-reported outcome measures between LigaSure excisional hemorrhoidectomy and non-Doppler-guided hemorrhoidal artery ligation with mucopexy in patients with Grade IV hemorrhoidal disease.

Method: A retrospective cohort study was performed involving 92 consecutively included patients treated for Grade IV hemorrhoidal disease in a single high-volume center between January 2021 and July 2024. Participants were allocated to either LigaSure hemorrhoidectomy (n=46) or non-Doppler-guided hemorrhoidal artery ligation with mucopexy (n=46). Postoperative pain, complications, recurrence, and patient-reported outcomes were assessed, with follow-up at 6 months.

Results: Early postoperative pain and complication rates did not differ significantly across groups. However, recurrence at 6 months was significantly higher in the non-Doppler ligation with mucopexy group than in the LigaSure group (30.4% vs. 10.9%, p=0.018). Exploratory patient-reported outcomes at 6 months favored LigaSure hemorrhoidectomy in terms of daily activity, comfort, social functioning, and psychological well-being.

Conclusion: In patients with Grade IV hemorrhoidal disease, non-Doppler-guided hemorrhoidal artery ligation with mucopexy was associated with higher short-term recurrence rates without demonstrating clear advantages in early postoperative or patient-reported outcomes compared with LigaSure hemorrhoidectomy. Exploratory patient-reported outcome findings should be interpreted cautiously due to the absence of validated assessment tools and preoperative baseline measurements. Careful patient selection is warranted, and extended follow-up is needed to confirm the present observations.

Keywords: Hemorrhoidal disease, hemorrhoidectomy, hemorrhoidal artery ligation, mucopexy, recurrence, patient-reported outcome scores, short-term follow-up

Introduction

Hemorrhoidal disease is a frequently encountered benign anorectal condition that can significantly affect quality of life due to manifestations such as rectal bleeding, mucosal prolapse, perianal discomfort, and pruritus ani.[1] Although early-stage disease is usually managed conservatively, advanced cases—particularly Grade IV—often require surgical intervention.[2]

Excisional hemorrhoidectomy is widely accepted as a definitive treatment for advanced (Grade III-IV) disease due to its durability and low recurrence rates.[3] The introduction of energy-based vessel-sealing devices, such as LigaSure™, has aimed to reduce intraoperative blood loss and postoperative pain while maintaining the long-term effectiveness of conventional excisional techniques.[4] However, excisional surgery is still associated with postoperative discomfort and wound-related morbidity.

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Received: 05.03.2026 **Accepted:** 15.06.2026 **Epub:** 16.09.2026 **Publication Date:** 28.09.2026

Cite this article as: Gündoğdu A, Sert H, Kızıltoprak N, Kılıç MG, Başdoğan MK, Özkaya G, Aydın İ. LigaSure hemorrhoidectomy versus non-Doppler artery ligation with mucopexy for grade IV hemorrhoids: short-term outcomes of a retrospective cohort study. Turk J Colorectal Dis. 2026;36(3):73-79

In contrast, tissue-sparing techniques such as hemorrhoidal artery ligation combined with mucopexy have gained popularity due to their potential to reduce postoperative pain and accelerate recovery.[5] By avoiding excision of anoderm and minimizing tissue trauma, these approaches are thought to preserve anal anatomy and function. Although Doppler-guided hemorrhoidal artery ligation has been widely studied, non-Doppler-guided ligation with mucopexy represents a simpler and more accessible alternative.[6] Nevertheless, concerns remain regarding its durability, particularly in patients with advanced (Grade IV) hemorrhoidal disease.

Data comparing excisional energy-based hemorrhoidectomy with non-Doppler artery ligation and mucopexy specifically in Grade IV hemorrhoids are limited. Furthermore, the balance between recurrence risk and postoperative patient-reported outcomes in this patient population remains unclear.

The purpose of this study is to evaluate early postoperative outcomes, recurrence rates, and patient-reported outcome measures of LigaSure excisional hemorrhoidectomy and non-Doppler-assisted hemorrhoidal artery ligation with mucopexy among individuals with Grade IV hemorrhoidal disease. We hypothesized that non-Doppler-assisted hemorrhoidal artery ligation with mucopexy would yield comparable early postsurgical outcomes but may be associated with higher recurrence rates than LigaSure excisional hemorrhoidectomy.

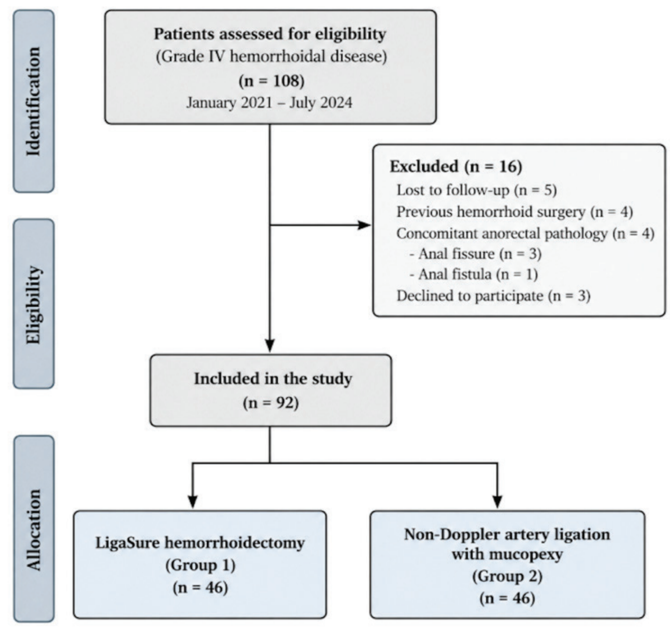

Figure 1. Flow diagram of patient selection and allocation according to surgical technique

Materials and Methods

Study Design and Patients

This retrospective cohort study included patients who underwent surgical treatment for Grade IV hemorrhoidal disease between January 2021 and July 2024 at a single tertiary referral center. Eligibility criteria included age ≥18 years, symptomatic Grade IV hemorrhoidal disease (irreducible prolapse according to the Goligher classification), and elective surgical treatment. Exclusion criteria included prior hemorrhoidal surgery, concurrent anorectal pathology (anal fissure, fistula, perianal abscess, or rectal prolapse), inflammatory bowel disease, pregnancy, anticoagulant therapy, or incomplete follow-up data at 6 months. Overall, 108 patients were assessed for eligibility throughout the enrollment period; 16 were not included [5 were lost to follow-up, 4 had a history of prior hemorrhoidal surgery, 4 had concurrent anorectal pathology (3 anal fissure, 1 anal fistula), and 3 declined to participate], leaving 92 patients in the study cohort (Figure 1). The study population was separated into two groups according to the surgical technique performed: LigaSure excisional hemorrhoidectomy (Group 1, n=46) and non-Doppler-assisted hemorrhoidal artery ligation combined with mucopexy (Group 2, n=46). The operations were carried out by two senior colorectal surgeons, each with >5 years of experience in proctological surgery. Surgeon A predominantly performed LigaSure hemorrhoidectomy, and Surgeon B predominantly performed non-Doppler artery ligation with mucopexy. The allocation of patients to a particular surgical technique was primarily determined by which surgeon the patient was referred to in the outpatient clinic, rather than a deliberate selection based on disease severity or clinical characteristics. Both surgeons had completed their learning curves for their respective techniques prior to the study period. The equal group size of 46 patients was coincidental and resulted from the consecutive inclusion of patients meeting the eligibility criteria. All procedures were performed under spinal anesthesia. Ethical clearance was granted by the University of Health Sciences Türkiye, Sancaktepe Şehit Prof. Dr. İlhan Varank Training and Research Hospital Scientific Research Ethics Committee (approval no.: 297, dated: 27.08.2025). The study was conducted in accordance with the principles of the Declaration of Helsinki.

Surgical Techniques

In Group 1, excisional hemorrhoidectomy was performed using a bipolar vessel-sealing instrument (LigaSure™ Small Jaw Open Sealer/Divider; Medtronic, Minneapolis, MN, USA). Hemorrhoidal pedicles were sealed and divided at their vascular origin while preserving mucocutaneous bridges. Hemostasis was achieved with the same device, and the wounds were left open.

In Group 2, non-Doppler-assisted hemorrhoidal artery ligation with mucopexy was undertaken. Absorbable sutures

(2-0 polyglactin 910, Vicryl™; Ethicon, Somerville, NJ, USA) were inserted approximately 2-3 cm above the dentate line. Six ligation sutures were applied at six standard clock-face positions (1, 3, 5, 7, 9, and 11 o'clock) using a figure-of-eight technique. Mucopexy was then performed at the same levels to correct mucosal prolapse. No excision of hemorrhoidal tissue was undertaken in this group.

Postoperative Care

A standardized postoperative care protocol was applied to both groups. Postoperative analgesia was standardized for all patients. Paracetamol (1 g, intravenous or oral) was administered every 8 hours in combination with a nonsteroidal anti-inflammatory drug, either dexketoprofen (50 mg, intravenous) or diclofenac (75 mg, intramuscular), given at regular intervals. Tramadol (100 mg, intravenous) was used as rescue analgesia in cases of insufficient pain control, defined as a visual analog scale (VAS) score >5. The same analgesic protocol was applied to both study groups. Laxatives (lactulose or fiber supplementation) were prescribed to all patients to prevent constipation and straining. Patients were instructed to perform sitz baths two to three times daily and to maintain local wound hygiene. Dietary advice included a high-fiber diet with adequate fluid intake. Patients were discharged on postoperative day 1 once they tolerated oral intake, had voided, and pain was adequately controlled. Follow-up visits were scheduled at postoperative week 1 and at months 1, 3, and 6.

Data Collection and Follow-up

Demographic and clinical information was retrieved from the institutional electronic health records. Recorded baseline parameters encompassed age, sex, body mass index (BMI), comorbid conditions, and previous hemorrhoidal treatments. Previous treatment was categorized as (a) none (no prior treatment), (b) conservative only (dietary and lifestyle modifications, including fiber-rich diet, adequate hydration, and avoidance of excessive straining), or (c) conservative combined with medical treatment (the above measures plus topical or oral pharmacological agents, such as flavonoids, topical analgesics, or corticosteroid preparations). Intraoperative complications were documented.

Postoperative outcomes encompassed VAS pain ratings, postoperative bleeding, tenesmus, surgical site infection, fecal incontinence, flatus incontinence, anal stenosis, and recurrence. The VAS pain rating was assessed using a standard 0-10 scale at two time points: postoperative day 1 (approximately 24 hours after surgery, assessed at rest before discharge) and at the postoperative week 1 follow-up visit.

The analgesic protocol was standardized across both groups (see postoperative care). Postoperative bleeding was classified as (a) minor/self-limiting (requiring no intervention), (b) requiring outpatient treatment (e.g., local hemostatic measures), (c) requiring readmission, or (d) requiring reoperation. Recurrence was defined as the reappearance of prolapsing hemorrhoidal tissue (Grade II or higher according to the Goligher classification) and/or the recurrence of hemorrhoid-related symptoms (bleeding, prolapse) at clinical examination during follow-up. Anal stenosis was defined as difficulty in digital rectal examination or patient-reported symptoms of obstructed defecation. Return to normal activity was defined as resumption of daily activities without restriction as reported by the patient.

All patients were followed up at postoperative week 1 and at months 1, 3, and 6. Follow-up evaluations were conducted in the outpatient clinic by the operating surgeon or a trained surgical team member who was not involved in the procedure. Clinical assessment included postoperative pain (VAS), complications, and recurrence. Recurrence was assessed by clinical examination including inspection and digital rectal examination. Functional outcomes, including flatus incontinence, fecal incontinence, and anal stenosis, were re-evaluated at 6 months postoperatively. Postoperative patient-reported outcome scores were evaluated at 6 months using an author-designed, non-validated 5-domain 0-10 scale assessing general health status, ability to perform daily activities, life comfort, social relationships, and psychological well-being. No preoperative baseline scores were available. This scale has not been psychometrically validated, and the results should therefore be interpreted as exploratory.

Statistical Analysis

Statistical computations were performed with IBM SPSS Statistics, version 29.0 (IBM Corp., Armonk, NY, USA). The distribution of continuous variables was assessed with the Kolmogorov-Smirnov test. Based on the distribution pattern, continuous variables were presented as mean±standard deviation or median (interquartile range) and analyzed with Student's t-test or the Mann-Whitney U test, respectively. Categorical data were expressed as frequencies and percentages and evaluated by the chi-square test or Fisher's exact test where applicable. Statistical significance was defined as a two-tailed p-value of <0.05. Although multivariable logistic regression analysis was initially planned for the primary outcome of recurrence, the small number of observed recurrences (n=19) did not allow for reliable model construction in accordance with the recommended minimum of 10 events per predictor variable.

Results

Baseline Characteristics

Ninety-two patients with Grade IV hemorrhoidal disease were included, with 46 patients in each group. The mean age was 43.19±11.97 years in the LigaSure group and 46.48±11.14

years in the non-Doppler ligation with mucopexy group. The mean BMI was 27.38±4.35 kg/m^2 in Group 1 and 26.57±3.73 kg/m^2 in Group 2. There were no significant differences across groups in terms of age, BMI, sex ratio, comorbid conditions, or previous treatment history (Table 1). No intraoperative complications were observed in either group.

Early Postoperative Outcomes

Initial postoperative findings are detailed in Table 2. Postoperative pain scores were comparable between the two groups. The mean VAS pain score on postoperative day 1 was 5.38±2.21 in the LigaSure group and 5.00±2.97 in the non-Doppler ligation with mucopexy group (p=0.483). At postoperative week 1, the mean VAS pain score decreased to 1.94±1.62 and 1.76±1.66, respectively (p=0.608).

No statistically meaningful differences were detected across groups regarding postoperative bleeding (19.6% vs. 17.4%, p=0.788), tenesmus (10.9% vs. 6.5%, p=0.487), flatus incontinence (10.9% vs. 8.7%, p=0.739), fecal incontinence (4.3% vs. 0%, p=0.496), or anal stenosis (2.2% vs. 0%, p=1.000). No surgical site infections were recorded in either group.

The mean time to return to normal activity was 3.91±2.60 days in the LigaSure group and 3.26±1.61 days in the non-Doppler group, without reaching statistical significance (p=0.149).

Table 1. Baseline characteristics of the study population

Variable	Group 1 (LigaSure) n=46	Group 2 (non-Doppler + Mucopexy) n=46	p-value
Age (years), mean±SD	**43.19±11.97**	46.48±11.14	0.176
BMI (kg/m^2), mean±SD	27.38±4.35	26.57±3.73	0.339
Male sex, n (%)	29 (63.0%)	31 (67.4%)	0.662
Female sex, n (%)	17 (37.0%)	15 (32.6%)	0.662
Diabetes mellitus, n (%)	3 (6.5%)	6 (13.0%)	0.293
Hypertension, n (%)	6 (13.0%)	8 (17.4%)	0.562
Cardiovascular disease, n (%)	3 (6.5%)	4 (8.7%)	0.694
COPD, n (%)	0 (0%)	3 (6.5%)	0.242
Malignancy, n (%)	1 (2.2%)	0 (0%)	1.000
Previous treatment, n (%)			0.096
None	15 (32.6%)	22 (47.8%)	
Conservative only	29 (63.0%)	19 (41.3%)	
Conservative + medical	2 (4.3%)	5 (10.9%)	
Intraoperative complications, n (%)	0 (0%)	0 (0%)	1.000

Values are presented as mean±standard deviation (SD) or number (percentage)

BMI: Body mass index, COPD: Chronic obstructive pulmonary disease

Table 2. Early postoperative outcomes

Parameter	Group 1 (LigaSure) n=46	Group 2 (non-Doppler + Mucopexy) n=46	p-value
VAS pain score (postoperative day 1), mean±SD	5.38±2.21	5.00±2.97	0.483
VAS pain score (postoperative week 1), mean±SD	1.94±1.62	1.76±1.66	0.608
Postoperative bleeding, n (%)	9 (19.6%)	8 (17.4%)	0.788
Tenesmus, n (%)	5 (10.9%)	3 (6.5%)	0.487
Surgical site infection, n (%)	0 (0%)	0 (0%)	1.000
Flatus incontinence, n (%)	5 (10.9%)	4 (8.7%)	0.739
Fecal incontinence, n (%)	2 (4.3%)	0 (0%)	0.496
Anal stenosis, n (%)	1 (2.2%)	0 (0%)	1.000
Time to return to normal activity (days), mean±SD	3.91±2.60	3.26±1.61	0.149

Values are presented as mean±standard deviation (SD) or number (percentage)

VAS: Visual analogue scale

Six-Month Postoperative Outcomes

At 6 months postoperatively, recurrence was significantly more frequent in the non-Doppler ligation with mucopexy group than in the LigaSure group (30.4% vs. 10.9%, p=0.018) (Table 3). All early postoperative functional complications, including flatus incontinence, fecal incontinence, and anal stenosis, had resolved completely in both groups by the 6-month follow-up visit.

Regarding exploratory patient-reported outcome scores assessed with a non-validated author-designed scale, most domains appeared to favor the LigaSure group at 6-month follow-up. The mean general health score was 9.57±1.23 in the LigaSure group and 8.91±2.01 in the non-Doppler group, approaching statistical significance (p=0.059). Notable differences emerged in the ability to perform daily activities (9.57±1.23 vs. 8.80±2.15, p=0.037), life comfort (9.49±1.38 vs. 8.48±2.27, p=0.011), social relationships (9.49±1.38 vs. 8.57±2.23, p=0.019), and psychological well-being (9.60±1.17 vs. 8.59±2.46, p=0.013), all favoring the LigaSure group.

Discussion

This study compared LigaSure-based excisional hemorrhoidectomy with non-Doppler-guided hemorrhoidal artery ligation combined with mucopexy in patients with Grade IV hemorrhoidal disease. The key findings were as follows: early postoperative outcomes, including pain and complication rates, were similar between the two techniques; recurrence at 6 months was higher in the ligation with mucopexy group; and patient-reported outcomes tended to favor the excisional approach. However, these findings warrant cautious interpretation given the use of a non-validated instrument and the absence of preoperative baseline data.

Excisional hemorrhoidectomy remains the reference standard for advanced hemorrhoidal disease, primarily due to its durability and low recurrence rates.[7] In the present study, the recurrence rate after LigaSure hemorrhoidectomy was 10.9%, which aligns with previously published data demonstrating low recurrence rates after excisional hemorrhoidectomy in advanced hemorrhoidal disease.[8] These findings reinforce the established role of excisional surgery, particularly in Grade IV hemorrhoids, where irreversible prolapse and a frequently prominent external component may limit the long-term effectiveness of non-excisional techniques.

In contrast, tissue-sparing approaches such as hemorrhoidal artery ligation with mucopexy have gained popularity due to the perceived advantages of reduced postoperative pain and faster recovery.[9,10] By preserving anoderm and minimizing tissue trauma, these techniques aim to reduce wound-related morbidity and functional impairment. However, most published data on artery ligation techniques involve Doppler-guided procedures and predominantly include Grade II-III disease. Evidence specifically addressing non-Doppler-guided ligation with mucopexy in Grade IV hemorrhoids remains limited.[11]

In our study, early postoperative pain scores and complication rates were similar across the two study arms. Notably, no significant differences were observed in VAS scores on postoperative day 1 or at week 1, nor in rates of bleeding, tenesmus, incontinence, anal stenosis, or interval to resumption of routine activity. The absence of a pain advantage in the artery ligation group deserves particular attention, as reduced postoperative pain is considered one of the principal benefits of tissue-sparing techniques in current guidelines. However, most studies demonstrating a pain advantage of artery ligation have compared it with conventional (cold-knife or scissors) excisional hemorrhoidectomy. Therefore, the lack of a notable pain disparity in our study may reflect the already favorable pain profile of the LigaSure technique rather than a failure of the artery ligation approach. LigaSure hemorrhoidectomy has previously been associated with lower postoperative pain

Table 3. Six-month postoperative outcomes

Parameter	Group 1 (LigaSure) n=46	Group 2 (non-Doppler + Mucopexy) n=46	p-value
Recurrence, n (%)	5 (10.9%)	14 (30.4%)	0.018
Flatus incontinence, n (%)	0 (0%)	0 (0%)	1.000
Fecal incontinence, n (%)	0 (0%)	0 (0%)	1.000
Anal stenosis, n (%)	0 (0%)	0 (0%)	1.000
General health status, mean±SD	9.57±1.23	8.91±2.01	0.059
Ability to perform daily activities, mean±SD	9.57±1.23	8.80±2.15	0.037
Life comfort, mean±SD	9.49±1.38	8.48±2.27	0.011
Social relationships, mean±SD	9.49±1.38	8.57±2.23	0.019
Psychological well-being, mean±SD	9.60±1.17	8.59±2.46	0.013

Quality-of-life parameters were assessed using a 5-domain 0-10 patient-reported scale. Higher scores indicate better perceived quality of life. Values are presented as mean±standard deviation (SD) or number (percentage) compared with conventional excisional hemorrhoidectomy due to reduced lateral thermal injury and improved vessel sealing.[4] Therefore, the expected pain advantage of tissue-sparing approaches may have been attenuated in the present comparison. Nevertheless, we cannot fully exclude the possibility that technical factors or surgeon experience may have contributed to this finding. The single case of early postoperative anal stenosis observed in the LigaSure group was mild and transient in nature, likely related to postoperative edema and sphincter spasm rather than fixed fibrotic narrowing, and was resolved with conservative management during follow-up. These results suggest that, in experienced hands, excisional hemorrhoidectomy using a modern energy device may not necessarily be associated with increased early morbidity compared with tissue-sparing techniques, even in advanced disease.

The most clinically relevant finding of this study was the significantly higher recurrence rate observed in the non-Doppler ligation with mucopexy group (30.4% vs. 10.9%). This approximately threefold increase in recurrence highlights the potential limitations of a non-excisional approach in the setting of Grade IV hemorrhoidal disease. Advanced hemorrhoidal disease is characterized by persistent prolapse and structural changes that may not be fully corrected by arterial ligation and mucosal suspension alone. In this context, excision of redundant tissue may provide more definitive anatomical correction and durable symptom control.[12]

Several factors related to the non-Doppler technique itself may have contributed to the higher recurrence rate. Without Doppler guidance, the identification and ligation of hemorrhoidal arterial branches relies entirely on standard anatomical positions. However, the number and distribution of hemorrhoidal arteries show considerable anatomical variability, and non-guided ligation may result in incomplete arterial interruption or missed branches.[13] Schuurman et al.[6] demonstrated comparable results between Doppler-guided and non-Doppler ligation in Grade II-III hemorrhoids; however, in Grade IV disease, the greater tissue redundancy and vascular complexity may make Doppler guidance more relevant.[6] Additionally, the mucopexy component alone may be insufficient to address the degree of prolapse and external component frequently seen in Grade IV disease, where permanent structural changes in the hemorrhoidal cushions have occurred.

It is important to note that the European Society of Coloproctology and the Italian Society of Colorectal Surgeons recommend hemorrhoidal artery ligation primarily for Grade II-III hemorrhoids and suggest excisional methods for Grade IV disease, with a high level of evidence.[14,15] Applying artery ligation in Grade IV disease therefore goes beyond the recommended indications, and the higher recurrence rate observed in our study is consistent with the concerns expressed in these guidelines. Nevertheless, several studies have reported favorable outcomes with artery ligation and mucopexy in selected Grade IV patients, suggesting that the technique may still have a role when careful patient selection criteria are applied.[16]

Exploratory patient-reported outcome scores at 6 months appeared to favor the excisional approach in most domains, including daily activities, life comfort, social relationships, and psychological well-being. However, these findings must be interpreted with considerable caution. The scale used was a non-validated, author-designed instrument, and no preoperative baseline scores were collected. Therefore, it is not possible to determine whether the observed differences reflect the direct effect of the surgical technique or are instead a consequence of the higher recurrence rate in the non-Doppler group leading to lower patient satisfaction. Future studies using validated instruments, such as the Sodergren Hemorrhoid Symptom Score[17] or EQ-5D, with preoperative baseline assessments, are needed to clarify the impact of surgical technique on patient-reported outcomes in advanced hemorrhoidal disease.

The present study has several strengths. All patients had Grade IV hemorrhoids, providing a homogeneous and clinically relevant study population. Both groups were comparable in baseline characteristics, and standardized follow-up was performed at 6 months. Furthermore, the comparison specifically addressed non-Doppler-guided ligation, a simpler and more accessible alternative to Doppler-guided techniques, which increases the practical applicability of the findings.

Study Limitations

However, certain limitations deserve mention. Foremost, the retrospective, non-randomized nature of the study introduces a risk of selection bias, as unmeasured clinical factors such as prolapse severity, external component, and symptom burden may have influenced treatment selection. In addition, the Goligher classification does not fully capture disease heterogeneity. Second, procedures were predominantly performed by two surgeons, each favoring a specific technique, introducing a potential surgeon-related confounder. Third, outcome assessors were not blinded. Fourth, follow-up extended only to 6 months, preventing conclusions about long-term outcomes. Fifth, patient-reported outcomes were assessed using a non-validated scale without preoperative baseline data, limiting interpretability. Finally, the modest sample size constrains statistical power and restricts adjustment for confounders. Therefore, these results should be regarded as preliminary and hypothesis-forming.

Despite these limitations, our results suggest that in Grade IV hemorrhoidal disease, non-Doppler-guided hemorrhoidal artery ligation carries a considerably higher short-term recurrence rate than LigaSure excisional hemorrhoidectomy, without a clear advantage in early postoperative recovery or patient-reported outcomes. Careful patient selection is therefore essential when considering tissue-sparing approaches in advanced disease, particularly in the presence of major prolapse.

Conclusion

Well-designed prospective randomized trials with extended follow-up, validated outcome measures, and larger cohorts are required to delineate the optimal surgical strategy more precisely. Comparative studies in Grade IV disease may further clarify the role of artery ligation techniques.

Ethics

Ethics Committee Approval: Ethical clearance was granted by the University of Health Sciences Türkiye, Sancaktepe Şehit Prof. Dr. İlhan Varank Training and Research Hospital Scientific Research Ethics Committee (approval no.: 297, dated: 27.08.2025).

Informed Consent: For this type of study, formal consent is not required.

Footnotes

Authorship Contributions

Surgical and Medical Practices: H.S., İ.A., Concept: A.G., N.H.K., İ.A., Design: A.G., N.H.K., Data Collection or Processing: A.G., M.G.K., M.K.B., G.Ö., Analysis or Interpretation: A.G., H.S., N.H.K., M.G.K., Writing: A.G., N.H.K.

Conflict of Interest: No conflict of interest was declared by the authors.

Financial Disclosure: The authors have no conflicts of interest including relevant financial interests, activities, relationships, and affiliations.

Declaration Regarding the Use of AI and AI-Assisted Technologies: Artificial intelligence-assisted tools were used for language editing purposes during the preparation of this manuscript. The authors take full responsibility for the accuracy and integrity of all content.

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DOI: 10.4274/tjcd.galenos.2026.2026-1-7
Turk J Colorectal Dis 2026;36(3):80-88

RESEARCH ARTICLE

Comparison of Unroofing and Curettage versus Midline Excision with Primary Closure for the Treatment of Sacrococcygeal Pilonidal Disease: A Retrospective Comparative Cohort Study

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ABSTRACT

Aim: To compare unroofing and curettage with excision followed by midline primary closure in terms of perioperative recovery, postoperative morbidity, and recurrence in patients undergoing elective surgery for chronic sacrococcygeal pilonidal disease.

Method: This single-center retrospective comparative cohort study included 289 consecutive patients treated between March 2019 and December 2021: unroofing and curettage (n=147) and midline primary closure (n=142). The predefined outcomes were operative time, length of hospital stay, time to return to work or school, postoperative complications, and recurrence. Because treatment allocation was not randomized, all between-group comparisons were interpreted as unadjusted associations.

Results: The groups were broadly comparable with respect to age, sex distribution, body mass index, American Society of Anesthesiologists class, and follow-up duration. However, clinically relevant baseline imbalance was present in disease status, with recurrent disease being more frequent in the midline primary closure group. Compared with midline primary closure, unroofing and curettage was associated with shorter operative time [14.0±3.9 vs. 32.46±8.5 min; mean difference (MD), -18.46 min; 95% confidence interval (CI), -19.99 to -16.93; p<0.001], shorter hospital stay (8.0±3.4 vs. 25.0±7.6 h; MD, -17.00 h; 95% CI, -18.37 to -15.63; p<0.001), and earlier return to work or school (3.5±2.8 vs. 11.09±3.6 days; MD, -7.59 days; 95% CI, -8.34 to -6.84; p<0.001). Postoperative complications occurred less frequently after unroofing and curettage [2/147 (1.36%) vs. 33/142 (23.24%); relative risk (RR), 0.06; 95% CI, 0.01-0.24; p<0.001]. Recurrence was numerically lower in the unroofing and curettage group [5/147 (3.40%)] than in the midline primary closure group [10/142 (7.04%)]; however, this difference was not statistically significant (RR, 0.48; 95% CI, 0.17-1.38).

Conclusion: In this retrospective cohort, unroofing/curettage was associated with more favorable perioperative recovery and lower postoperative morbidity than excision followed by midline primary closure. Although the observed recurrence rate was lower after unroofing and curettage, the between-group difference was not statistically significant. Given the non-randomized design and baseline imbalance, which suggest potential selection bias and confounding by disease complexity, these findings should be interpreted as associative rather than causal.

Keywords: Sacrococcygeal pilonidal disease, unroofing and curettage, midline primary closure

Introduction

Sacrococcygeal pilonidal disease is a common acquired inflammatory disorder of the natal cleft that predominantly affects adolescents and young adults and is associated with substantial morbidity, impaired quality of life, and loss of work or school time.[1-3] Current evidence supports an acquired pathogenesis in which loose hairs penetrate vulnerable skin within a deep natal cleft under the influence of friction, moisture, and repetitive microtrauma, leading to a foreign-body reaction, sinus formation, and recurrent inflammation.[2-4]

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Received: 21.01.2026 **Accepted:** 26.06.2026 **Epub:** 18.09.2026 **Publication Date:** 28.09.2026

Cite this article as: Başkent A, Çetinkaya G, Çalık V, Başkent MF. Comparison of unroofing and curettage versus midline excision with primary closure for the treatment of sacrococcygeal pilonidal disease: a retrospective comparative cohort study. Turk J Colorectal Dis. 2026;36(3):80-88

Although numerous surgical options have been described, the optimal treatment strategy remains controversial because procedures differ in postoperative morbidity, wound healing, recovery time, and recurrence.[1-3] Contemporary guidelines increasingly discourage routine midline primary closure because of less favorable wound and recurrence outcomes than off-midline or tissue-sparing approaches.[1,5-7] Nevertheless, excision followed by primary closure is still used in selected patients in routine practice, making direct real-world comparisons clinically relevant.

Unroofing and curettage is a tissue-sparing open technique that can often be performed under local anesthesia in an outpatient setting and has been associated with short operative time, rapid recovery, and low complication rates.[8-11] In contrast, midline primary closure may be more vulnerable to wound complications because the suture line remains within the deep intergluteal cleft.[1,2,5-7,12-14] Comparative studies have shown heterogeneous results across open, tissue-sparing, flap-based, and closure-based techniques, and outcomes may additionally be influenced by baseline disease complexity and patient-related factors.[15-20] Relevant comparative studies have further demonstrated variability in recurrence and postoperative outcomes across different surgical approaches.[8,9,11,16-21]

However, direct comparisons between unroofing/curettage and conventional midline primary closure remain limited, and the available literature is heterogeneous in case selection, disease classification, and outcome definitions.[2,4,10-14] Therefore, the present study aimed to compare unroofing and curettage with excision followed by midline primary closure in terms of perioperative outcomes, postoperative complications, and recurrence in patients undergoing elective surgery for chronic sacrococcygeal pilonidal disease. We hypothesized that unroofing and curettage would be associated with more favorable perioperative recovery and lower postoperative morbidity than midline primary closure.

Materials and Methods

Study Design and Setting

This single-center retrospective comparative cohort study was conducted at the Clinic of General Surgery, University of Health Sciences Türkiye, Kartal Dr. Lütfi Kırdar City Hospital, İstanbul, Türkiye. Consecutive patients who underwent elective surgery for chronic sacrococcygeal pilonidal disease between March 2019 and December 2021 were screened for eligibility. The study was designed, conducted, and reported in accordance with the Strengthening the Reporting of Observational Studies in Epidemiology statement.[22]

Ethics

Ethics committee approval was obtained prior to data collection from the University of Health Sciences Türkiye, Kartal Dr. Lütfi Kırdar City Hospital Clinical Research Ethics Committee (approval no.: 2022/51-4/222/1; dated: 30.03.2022). The study was conducted in accordance with the Declaration of Helsinki.[23] Because of the retrospective design and the use of anonymized clinical records, written informed consent was waived in accordance with institutional policy.

Participants

All patients undergoing elective surgical treatment for chronic sacrococcygeal pilonidal disease during the study period were assessed for eligibility. Inclusion criteria were age ≥16 years, clinical diagnosis of chronic sacrococcygeal pilonidal disease, treatment with either unroofing and curettage or excision followed by midline primary closure, and availability of follow-up information. Exclusion criteria were acute pilonidal abscess treated only by drainage, hidradenitis suppurativa or ectopic pilonidal disease, previous complex flap reconstruction, and procedures other than the two study techniques under investigation, including excision with secondary healing, marsupialization, phenol-based treatment, endoscopic procedures, and laser-based techniques.

The final analytic cohort comprised 289 patients: 147 in the unroofing and curettage group and 142 in the midline primary closure group. A reconstructed flow diagram based on the final analytic cohort and predefined eligibility criteria is presented in Figure 1.

Data Sources and Variables

Patient data were obtained from hospital records, operative notes, outpatient follow-up files, and structured telephone follow-up when necessary. Recorded variables included age, sex, body mass index, American Society of Anesthesiologists (ASA) class, anesthesia type, sinus status, operative time, hospital stay, time to return to work or school, postoperative complications, recurrence, and follow-up duration.

Disease Classification

Disease status was categorized pragmatically from preoperative clinical assessment and operative documentation as follows: primary disease, defined as single or multiple midline pits without prior surgery or lateral extension; complicated disease, defined as sinus disease with lateral fistulization related to previous infection or abscess formation; and recurrent disease, defined as disease arising in a previously operated field. This framework was adopted for chart-based categorization. It is acknowledged that it does not represent a universally standardized international classification system.[4]

Surgical Technique

Unroofing and Curettage

In the unroofing and curettage group, the procedure was performed with the patient in the prone position, predominantly under local anesthesia; a small minority underwent spinal anesthesia because of patient preference. Local anesthesia consisted of 2% lidocaine with epinephrine (1:200,000). A curved probe was introduced through the primary pit into the sinus tract, and the overlying tissue was incised to completely deroof the tract. Lateral extensions, when present, were similarly identified and opened. Hair, keratinous debris, and necrotic material were removed, and the cavity walls were gently curetted while preserving viable granulation tissue at the wound base. Electrocautery was not routinely used. Hemostasis was achieved via direct manual compression. The wound was packed with ointment-impregnated gauze and left open for healing by secondary intention. Patients were observed for approximately 6 h and discharged on the same day if no active bleeding was detected. An illustrative postoperative wound appearance and a completely healed wound are shown in Figure 2.

Midline Excision with Primary Closure

In the midline primary closure group, all procedures were performed under spinal anesthesia with the patient in the prone jackknife position. Sinus tracts were delineated using methylene blue instilled through visible pit openings. A midline elliptical incision encompassing the pits and stained tracts was made, and all diseased tissue was excised en bloc down to the presacral fascia. Hemostasis was achieved using electrocautery and ligation as required. No off-midline mobilization, flap-based reconstruction, or tension-reducing flap technique was used. The wound was closed in layers, with absorbable sutures used for deep subcutaneous approximation and non-absorbable interrupted sutures for skin closure. Drain placement was selective rather than routine and was reserved for patients considered intraoperatively at increased risk of postoperative fluid collection or bleeding. In this cohort, a drain was placed in three patients. Patients were generally discharged after wound inspection at approximately 24 h. Preoperative and postoperative views of this technique are shown in Figure 3.

Treatment Allocation

Treatment allocation was not randomized. The choice of surgical technique was made by the operating surgeon according to clinical judgment, technical feasibility, disease extent, and patient-related factors, including anesthetic preference. This non-randomized allocation represents a

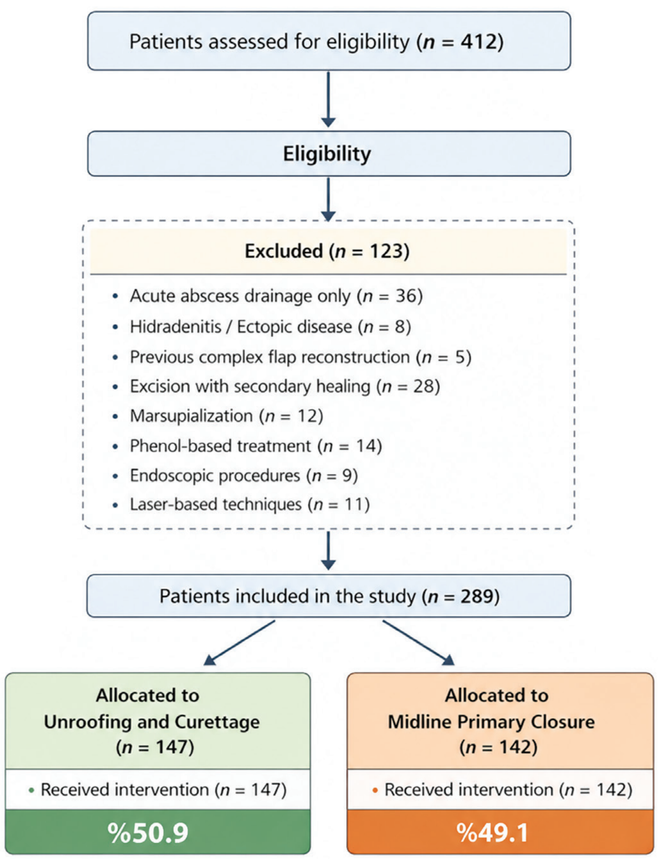

Figure 1. Flow diagram of patient selection and inclusion. Flow chart showing the number of patients assessed for eligibility, excluded according to predefined criteria, and included in the final analytic cohort, stratified into the unroofing and curettage group and the midline primary closure group

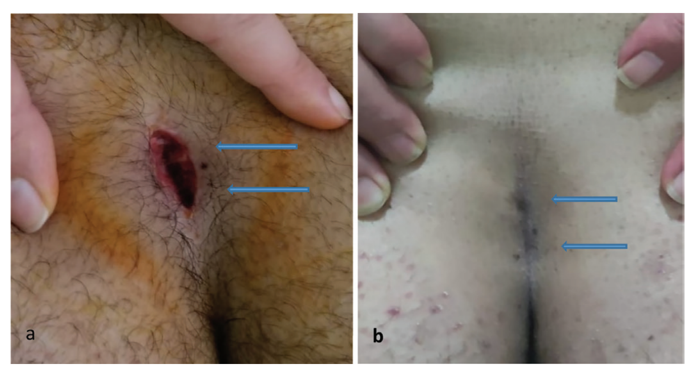

Figure 2. Unroofing and curettage in sacrococcygeal pilonidal disease. (a) Immediate postoperative appearance of the wound after unroofing and curettage (arrows). (b) Completely healed wound after unroofing and curettage (arrows)

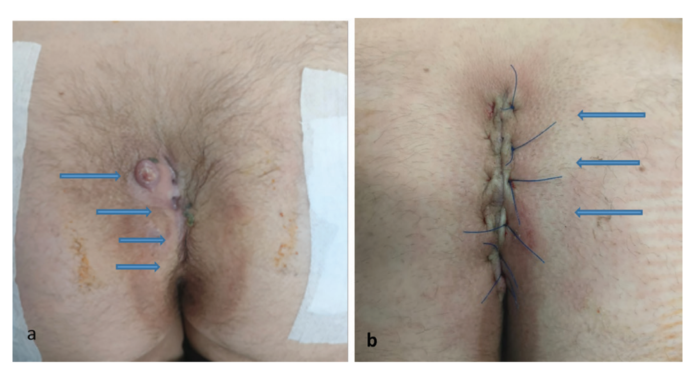

Figure 3. Midline excision with primary closure in complicated sacrococcygeal pilonidal disease. (a) Preoperative view demonstrating sinus openings in a complicated case (arrows). (b) Postoperative appearance after complete excision and midline primary closure (arrows)

potential source of selection bias and confounding and was considered in the interpretation of all comparative findings. Because complete regression-ready patient-level data were not available during manuscript reconstruction, multivariable-adjusted analyses could not be performed.

Postoperative Care and Follow-up

Patients in the unroofing and curettage group underwent daily dressing changes using non-adherent gauze with topical antiseptic ointment. Following instruction, dressings could be performed by relatives or at local healthcare facilities. Patients in the midline primary closure group received standard wound care, and skin sutures were removed 10-14 days after surgery. Prophylactic antibiotics were not used routinely unless there was clinical evidence of infection. All patients were advised regarding local hygiene and hair depilation as adjunctive preventive measures.[24]

Follow-up visits were scheduled at postoperative weeks 1, 3, and 6 and then at approximately 6-month intervals until complete wound healing. If in-person attendance was not feasible, structured telephone follow-up was used. Mean follow-up duration was 32.25±7.5 months in the unroofing and curettage group and 31.07±6.5 months in the midline primary closure group, as summarized in Table 1.

Outcome Definitions

The predefined outcomes were operative time, length of hospital stay, time to return to work or school, postoperative complications, and recurrence. Operative time was defined as the interval from skin incision to completion of wound dressing or skin closure. Length of hospital stay was measured in hours from the end of surgery to discharge. Time to return to work or school was defined as the number of days from surgery to full resumption of usual occupational or educational activities based on patient report.

For this retrospective analysis, postoperative complications were classified as wound infection, abscess, wound dehiscence, hematoma, and postoperative bleeding. Recurrence was defined as the development of a new sinus opening, discharge, abscess, or clinically diagnosed recurrent disease in the previously treated area after documented initial healing. Recurrence ascertainment was based primarily on outpatient clinical examination and, when necessary, structured telephone follow-up. It is acknowledged that partial reliance on telephone follow-up may have introduced recall bias or outcome misclassification.

Time to complete wound healing, formal pain scores, cosmetic assessment, and validated patient-reported outcomes were not consistently available in the original dataset and were therefore not analyzed.

Statistical Analysis

Statistical analyses were performed using IBM SPSS Statistics for Windows, version 20.0 (IBM Corp., Armonk, NY, USA). Continuous variables were summarized as mean ± standard deviation when approximately normally distributed and compared using the independent-samples Student's t-test. The Mann-Whitney U test was used for non-normally distributed continuous variables. Categorical variables were summarized as

Table 1. Baseline demographic, clinical, and disease characteristics of patients undergoing unroofing and curettage or midline primary closure for chronic sacrococcygeal pilonidal disease

Variable	Unroofing and curettage (n=147)	Midline primary closure (n=142)	p-value
Age, years	25.4±7.9	26.7±8.1	0.17
Male sex, n (%)	118 (80.3)	114 (80.3)	1.00
Body mass index, kg/m²	27.9±5.7	26.7±5.3	0.065
ASA class, n (%)			0.34
Class I	105 (71.4)	94 (66.2)	
Class II	42 (28.6)	48 (33.8)	
Anesthesia type, n (%)			<0.001
Local	132 (89.8)	0 (0.0)	
Spinal	15 (10.2)	142 (100.0)	
Sinus status, n (%)			0.019
Primary	125 (85.1)	107 (75.4)	
Complicated	17 (11.6)	18 (12.7)	
Recurrent	5 (3.4)	17 (12.0)	
Follow-up duration, months	32.25±7.5	31.07±6.5	0.15

Values are presented as mean±standard deviation or number (percentage), as appropriate. P-values refer to between-group comparisons

ASA: American Society of Anesthesiologists number (percentage) and compared using the chi-square test or Fisher's exact test, as appropriate. For key continuous outcomes, mean differences (MDs) with 95% confidence intervals (CIs) were calculated. For key dichotomous outcomes, relative risks (RRs) with 95%CIs were calculated. Absolute risk reduction and number needed to treat were calculated for postoperative complications. A two-sided p-value <0.05 was considered statistically significant. Because treatment allocation was not randomized and adjusted regression modeling was not feasible with the reconstructed dataset, all comparative results were interpreted as unadjusted associations.

Results

Baseline Characteristics

A total of 289 patients were included in the final analysis, comprising 147 patients in the unroofing and curettage group and 142 patients in the midline primary closure group. Baseline demographic and clinical characteristics are summarized in Table 1.

The two groups were broadly comparable with respect to age, sex distribution, body mass index, ASA class, and duration of follow-up. Mean age was 25.4±7.9 years in the unroofing and curettage group and 26.7±8.1 years in the midline primary closure group. Male sex predominated in both groups. Body mass index and ASA class distribution were also similar between groups.

However, clinically relevant baseline imbalance was present in disease status. Recurrent disease was proportionally more frequent in the midline primary closure group than in the unroofing and curettage group [17/142 (12.0%) vs. 5/147 (3.4%)]. In addition, unroofing/curettage was performed predominantly under local anesthesia, whereas all procedures in the midline primary closure group were performed under spinal anesthesia. These differences suggest potential confounding by disease complexity and treatment selection.

Perioperative Outcomes

Perioperative outcomes are presented in Table 2. Unroofing/curettage was associated with a significantly shorter operative time than midline primary closure (14.0±3.9 vs. 32.46±8.5 min; MD, -18.46 min; 95%CI, -19.99 to -16.93; p<0.001). Length of hospital stay was also significantly shorter in the unroofing and curettage group (8.0±3.4 vs. 25.0±7.6 h; MD, -17.00 h; 95%CI, -18.37 to -15.63; p<0.001). Likewise, time to return to work or school was markedly shorter following unroofing and curettage than after midline primary closure (3.5±2.8 vs. 11.09±3.6 days; MD, -7.59 days; 95% CI, -8.34 to -6.84; p<0.001).

Postoperative Complications

Postoperative complications occurred in 2 of 147 patients (1.36%) in the unroofing and curettage group and in 33 of 142 patients (23.24%) in the midline primary closure group (RR, 0.06; 95%CI, 0.01-0.24; p<0.001), as detailed in Table 2. The absolute risk reduction was 21.88%, corresponding to a number needed to treat of approximately 5 to prevent one additional postoperative complication, assuming the observed association reflects a true effect.

In the unroofing and curettage group, both complications were postoperative bleeding events that were successfully managed

Table 2. Perioperative outcomes, postoperative morbidity, and recurrence according to surgical technique

Outcome	Unroofing and curettage (n=147)	Midline primary closure (n=142)	Effect estimate (95% CI)	p-value
Perioperative outcomes				
Operative time, min	14.0±3.9	32.46±8.5	MD, -18.46 (-19.99 to -16.93)	<0.001
Length of hospital stay, h	8.0±3.4	25.0±7.6	MD, -17.00 (-18.37 to -15.63)	<0.001
Time to return to work or school, days	3.5±2.8	11.09±3.6	MD, -7.59 (-8.34 to -6.84)	<0.001
Postoperative morbidity				
Any postoperative complication, n (%)	2 (1.36)	33 (23.24)	RR, 0.06 (0.01 to 0.24)	<0.001
Wound infection, n	0	23	-	-
Postoperative abscess, n	0	5	-	-
Wound dehiscence, n	0	4	-	-
Hematoma, n	0	1	-	-
Postoperative bleeding, n	2	0	-	-
Recurrence				
Disease recurrence, n (%)	5 (3.40)	10 (7.04)	RR, 0.48 (0.17 to 1.38)	0.19

Values are presented as mean ± standard deviation or number (percentage), as appropriate. P-values represent unadjusted between-group comparisons

MD: Mean difference, RR: Relative risk, CI: Confidence interval with bedside local intervention, and no patient required reoperation. No wound infection, abscess, wound dehiscence, or hematoma was observed in this group. In contrast, wound infection was the most common complication in the midline primary closure group (n=23), followed by abscess formation (n=5), wound dehiscence (n=4), and hematoma (n=1). No perioperative mortality occurred in either group.

Recurrence

During follow-up, recurrence was observed in 5 of 147 patients (3.40%) in the unroofing and curettage group and in 10 of 142 patients (7.04%) in the midline primary closure group (RR, 0.48; 95% CI, 0.17-1.38), as shown in Table 2. Although recurrence was numerically less frequent after unroofing and curettage, the between-group difference was not statistically significant.

To contextualize these recurrence findings, the recurrence rates observed in the present cohort should be interpreted alongside the heterogeneous comparative literature summarized in Table 3, which demonstrates that recurrence estimates vary across tissue-sparing, open, flap-based, and closure-based techniques, as well as with follow-up duration and comparator strategy.[8,9,11,16-21]

Discussion

In this retrospective comparative cohort study, unroofing/curettage was associated with shorter operative time, shorter hospital stay, earlier return to work or school, and substantially lower observed postoperative morbidity than excision followed by midline primary closure. These findings are clinically relevant because sacrococcygeal pilonidal disease predominantly affects adolescents and young adults, in whom treatment-related disability, time away from work or school, and postoperative wound burden are important determinants of overall treatment value.[1-3]

The favorable short-term recovery profile observed after unroofing and curettage is consistent with previous reports indicating that this tissue-sparing technique can be performed efficiently in an outpatient setting, often under local anesthesia, with a rapid return to daily activities.[8-11] In the meta-analysis by Garg et al.[10], deroofing with curettage was associated with low recurrence and complication rates, short operative duration, and early resumption of normal activity. Similarly, observational cohort studies have reported acceptable short-term outcomes for unroofing and curettage in both simple and more complex forms of disease.[9,11,20,21,25] Earlier comparative studies have also demonstrated that open or limited techniques may provide favorable morbidity profiles relative to closure-based strategies, although differences in wound-healing time and recurrence have varied across studies.[16,17] By contrast, studies evaluating flap-based or modified closure techniques have generally shown better results than conventional midline closure, underscoring that the critical issue is not closure itself but whether it is placed in the midline and exposed to unfavorable local conditions.[18,19] These patterns are reflected in Table 3.

The marked difference in postoperative morbidity observed in the present cohort deserves particular attention. Complications were concentrated in the midline primary closure group, with wound infection representing the most frequent adverse event. This pattern is biologically plausible, as the intergluteal cleft constitutes a moist, high-friction, hair-bearing environment

Table 3. Selected studies relevant to unroofing/curettage and closure-based procedures in sacrococcygeal pilonidal disease

Study	Year	Surgical technique(s)	Number of patients	Follow-up, months, mean ± SD or median (range)	Recurrence, n (%)
Gencosmanoglu and Inceoglu[8]	2005	Modified lay-open (modified UC)/primary closure	73/69	47 (24-69)	1 (1.4)/12 (17.4)
Karakayali et al.[17]	2009	Unroofing and marsupialization/Limberg flap	70/70	12-15	0/1 (1.4)
Kepenekci et al.[9]	2010	Unroofing and curettage	297	54±28	6 (2.02)
Muzi et al.[18]	2010	Limberg flap/primary closure	130/130	47.83±6.6/45.74±7.6	0/5 (3.8)
Lorant et al.[16]	2011	Modified lay-open (modified UC)/primary closure	41/39	12	1 (2.44)/4 (10.25)
Arslan et al.[19]	2016	Primary closure/Modified primary closure	44/54	Not reported	4 (9.1)/0
Garg and Yagnik[20]	2021	Unroofing and curettage	111	38 (6-111)	4 (3.6)
Sahin et al.[21]	2022	Unroofing and curettage/modified Limberg flap	135/143	64.53±14.9/62.15±13.04	2 (1.5)/6 (4.2)
Olcucuoglu and Sahin[11]	2022	Unroofing and curettage	203	52 (36-67)	10 (4.9)
Current study	-	Unroofing and curettage/midline primary closure	147/142	32.25±7.5/31.07±6.5	5 (3.4)/10 (7.04)

Follow-up is reported as mean ± SD or median (range), according to the original article. "Not reported" indicates that the corresponding summary measure was not clearly available in the accessible source

UC: Unroofing and curettage, SD: Standard deviation that may compromise wound healing when the suture line is positioned in the midline. This interpretation is consistent with the broader literature indicating that midline closure is associated with less favorable wound outcomes than off-midline closure or tissue-sparing open techniques.[1,2,5-7,12-14] McCallum et al.[12] demonstrated that, when closure is selected, off-midline closure is superior to midline closure with respect to wound complications and recurrence. More recent evidence, including the meta-analysis by Stauffer et al.[13] and the network meta-analysis by Bi et al.[14], has further reinforced the unfavorable profile of primary midline closure relative to off-midline approaches. Sinusectomy with primary closure has also been investigated as an alternative to wider excision and primary closure, again underscoring that technical nuances matter when closure-based outcomes are interpreted.[26]

The recurrence findings in our study warrant more cautious interpretation than the perioperative and morbidity outcomes. Although the observed recurrence rate was lower in the unroofing and curettage group, the difference did not reach statistical significance, and the CI was wide. Moreover, the comparison remains vulnerable to confounding. The midline primary closure group included a higher proportion of patients with recurrent disease at baseline, and all procedures in that group were performed under spinal anesthesia, whereas most unroofing and curettage procedures were performed under local anesthesia. These differences likely reflect surgeon-driven treatment allocation according to disease extent, technical feasibility, and patient-related factors. Accordingly, the recurrence result should be interpreted as an unadjusted observational finding rather than definitive evidence of causal superiority.

The comparative literature also indicates that recurrence should be interpreted in light of heterogeneity across techniques grouped under the broad labels of "open" and "closure-based" procedures. For example, Lorant et al.[16] compared laying open with primary closure, whereas Karakayali et al.[17] evaluated unroofing and marsupialization against Limberg flap repair. Muzi et al.[18] reported favorable outcomes with Limberg flap compared with modified primary closure, and Arslan et al.[19] described improved results with a modified closure method. Likewise, long-term follow-up after laying open and curettage under local anesthesia has shown durable outcomes in selected patients.[20] The present study should therefore not be interpreted as a comparison between unroofing and curettage and all closure-based strategies; rather, it specifically compares unroofing and curettage with conventional midline primary closure, a distinction that is important and is illustrated in Table 3.

The present findings should also be interpreted in the context of contemporary clinical guidance. International guidelines no longer favor routine midline primary closure as a first-line strategy for sacrococcygeal pilonidal disease.[1,5-7] Instead, off-midline closure techniques and tissue-sparing approaches are increasingly preferred when surgery is indicated, and minimally invasive strategies and adjunctive measures such as sinusectomy, endoscopic treatment, and laser-assisted hair control continue to evolve.[1,2,14,24,26] Within this context, our results do not challenge prevailing treatment trends; rather, they provide institutional real-world data suggesting that unroofing and curettage may be associated with lower postoperative wound burden and faster recovery than a conventional midline closure strategy.

Study Limitations

This study has several strengths. First, it included a relatively large single-center cohort, evaluated clinically relevant outcomes, and provided mean follow-up exceeding 31 months in both groups. Second, the two index procedures were clearly identifiable, and the comparator was explicitly defined as midline primary closure, which is essential for clinical interpretability. In addition, all unroofing and curettage procedures were performed by the same senior surgeon, which likely improved technical consistency within that group.

Several limitations should also be acknowledged. First, the retrospective, non-randomized design is susceptible to selection bias. Second, the imbalance in recurrent disease and anesthesia type suggests confounding by case complexity. Third, multivariable-adjusted or propensity-based analyses could not be performed because complete regression-ready patient-level data were not available during manuscript reconstruction. Fourth, complications were not prospectively graded using a standardized severity classification, such as the Clavien-Dindo system. Fifth, pain scores, cosmetic outcomes, patient satisfaction, and time to complete wound healing were not available in a standardized format. Sixth, recurrence ascertainment partly relied on structured telephone follow-up, which may have introduced recall bias or misclassification. Finally, disease status was categorized using a pragmatic chart-based framework rather than a universally standardized international classification system.[4]

Future studies should incorporate prospective designs, standardized disease classification, predefined treatment-allocation criteria, validated patient-reported outcomes, and adjusted analytical strategies. Multivariable regression, propensity-based approaches, and time-to-event analyses for recurrence would materially strengthen comparative interpretation. Until such data are available, unroofing and curettage should be regarded as a pragmatic tissue-sparing option with favorable short-term recovery and low postoperative morbidity in appropriately selected patients, rather than a universally superior approach.

Conclusion

In this retrospective comparative cohort study, unroofing and curettage was associated with shorter operative time, shorter hospital stay, earlier return to work or school, and lower observed postoperative complication rates than excision followed by midline primary closure. Although the observed recurrence rate was lower after unroofing and curettage, the between-group difference was not statistically significant. Because treatment allocation was non-randomized and baseline imbalance suggests potential selection bias and confounding by case complexity, these findings should be interpreted as associative and hypothesis-generating rather than definitive causal evidence. Within these limitations, unroofing/curettage appears to be a clinically useful tissue-sparing option for selected patients with chronic sacrococcygeal pilonidal disease.

Ethics

Ethics Committee Approval: Ethics committee approval was obtained prior to data collection from the University of Health Sciences Türkiye, Kartal Dr. Lütfi Kırdar City Hospital Clinical Research Ethics Committee (approval no.: 2022/51-4/222/1; dated: 30.03.2022).

Informed Consent: Because of the retrospective design and the use of anonymized clinical records, written informed consent was waived in accordance with institutional policy.

Footnotes

Authorship Contributions

Surgical and Medical Practices: A.B., G.Ç., Concept: A.B., G.Ç., Design: A.B., G.Ç., Data Collection or Processing: M.F.B., Analysis or Interpretation: V.Ç., Literature Search: A.B., V.Ç., Writing: A.B.

Conflict of Interest: No conflict of interest was declared by the authors.

Financial Disclosure: The authors have no conflicts of interest including relevant financial interests, activities, relationships, and affiliations.

Declaration Regarding the Use of AI and AI-Assisted Technologies: The authors declare that no artificial intelligence (AI) or AI-assisted technologies were used in the preparation of this manuscript.

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DOI: 10.4274/tjcd.galenos.2026.2025-10-9
Turk J Colorectal Dis 2026;36(3):89-97

RESEARCH ARTICLE

Stoma Creation Tendency and Short-Term Surgical Outcomes in Low Anterior Resection for Rectal Cancer: Analysis from the TSCRS Colorectal Cancer Database (TSCRS-CCD)

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ABSTRACT

Aim: Anastomotic leakage (AL) is a major complication following low anterior resection (LAR), leading to significant morbidity. Although diverting stomas have been shown to reduce both the incidence and severity of AL, data on stoma creation practices and their impact on short-term surgical outcomes in the Turkish population remain limited. This study evaluates trends in ostomy creation and their impact on postoperative outcomes among patients with rectal cancer undergoing LAR.

Method: We retrospectively analyzed prospectively collected data from the Turkish Society of Colon and Rectal Surgery's Colorectal Cancer Database (2018-2024) for patients who underwent curative-intent LAR for rectal cancer located ≤12 cm from the anal verge. Patients with synchronous tumors, inflammatory bowel disease, hereditary colorectal cancer, or those undergoing emergency surgery were excluded. Patients were stratified into stoma and no-stoma groups. The primary outcome was AL, and secondary outcomes included 30-day readmission, reoperation, and mortality rates.

Results: Of 313 patients (37.1% women; median age: 62), 260 (83%) underwent stoma creation. Patients without a stoma had lower tumor stages (T1-T2: 43.4% vs. 18.1%; p<0.001) and a lower incidence of lymph node metastasis (50.9% vs. 67.3%; p=0.023). Additionally, tumors and anastomoses were located higher in patients without an ostomy (9 vs. 7 cm, p<0.001; 4 vs. 3 cm, p<0.001, respectively). Patients with an ostomy were more likely to undergo neoadjuvant treatment (56.5% vs. 88.5%, p<0.001). Partial mesorectal excision was more common in the no-stoma group (35.8% vs. 8.8%, p<0.001). AL occurred at a significantly higher rate in the no-stoma group (11.3% vs. 4.2%; p=0.038), leading to a higher reoperation rate (15.1% vs 4.2%; p=0.003), although other complications did not differ significantly.

Conclusion: This study demonstrates that diverting stoma formation in patients undergoing LAR for rectal cancer was associated with reduced AL and the need for reoperation. These findings highlight the importance of individualized consideration of diverting stoma creation in patients undergoing LAR for rectal cancer.

Keywords: Rectal cancer, low anterior resection, stoma, ostomy, anastomotic leakage

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Received: 28.11.2025 **Accepted:** 10.07.2026 **Epub:** 18.09.2026 **Publication Date:** 28.09.2026

Cite this article as: Baki BE, Erözkan K, Bozbıyık O. Stoma creation tendency and short-term surgical outcomes in low anterior resection for rectal cancer: analysis from the TSCRS Colorectal Cancer Database (TSCRS-CCD). Turk J Colorectal Dis. 2026;36(3):89-97

Presented in: This study has been presented as an oral presentation for the 20th Turkish Society of Colon and Rectal Surgery (TSCRS) Congress, 16-20 May 2025, Antalya-Türkiye.

Introduction

Rectal cancer management frequently involves a multimodal approach; however, surgery—specifically, total mesorectal excision (TME)—remains the cornerstone of curative treatment. In patients without invasion of the anal sphincter complex, low anterior resection (LAR) with colorectal or coloanal anastomosis is the preferred surgical strategy. Despite advances in surgical techniques and perioperative care, postoperative complications remain common, and anastomotic leakage (AL) represents one of the most severe and clinically significant adverse outcomes.[1,2] AL is associated with increased morbidity, prolonged hospitalization, need for reintervention, impaired functional recovery, and mortality.[3,4] Reported rates of AL range from 5% to 21%, particularly in low pelvic anastomoses.[5]

To mitigate the risk of clinically significant AL, many surgeons construct a temporary diverting stoma—most commonly a loop ileostomy—to divert the fecal stream and protect the anastomosis and potential AL-related complications.[6] Numerous studies have demonstrated that diverting stomas reduce the incidence and severity of AL, the need for reoperation, and hospital readmission.[7] However, controversy persists regarding which patients benefit most from diversion and whether routine stoma creation is justified in all low rectal resections.

Despite global evidence supporting selective use of diverting stomas, current decision-making patterns among colorectal surgeons in Türkiye remain unclear. National data on the frequency of stoma formation, associated outcomes, and surgeon preferences are lacking. This knowledge gap limits the development of standardized guidelines and may contribute to variability in clinical practice and patient outcomes.

Therefore, this study assesses the rate of diverting stoma formation during LAR for rectal cancer in Türkiye and evaluates its association with AL and postoperative outcomes. We hypothesized that diverting stomas are underutilized among Turkish colorectal surgeons and that a lower diversion rate is associated with a higher incidence of AL.

Materials and Methods

Patient Selection

This retrospective cohort study utilized prospectively collected data from the Turkish Society of Colon and Rectal Surgery's Colorectal Cancer Database (TSCRS-CCD) covering 2018-2024. The Ege University Ethics Committee of Medical Research approved the study protocol (approval no.: 25-3T/58, dated: 06.03.2025). Patients who underwent curative-intent LAR for rectal adenocarcinoma located ≤12 cm from the anal verge in the middle and lower rectum were included. Patients with upper rectum or colon tumors, rectal tumors with synchronous tumors, inflammatory bowel disease, hereditary colorectal cancer syndromes, or those undergoing emergency surgery and metastatic colorectal cancers were excluded. Patients were stratified into two groups based on whether a diverting stoma was created intraoperatively (stoma group vs. no-stoma group). Demographic characteristics, tumor- and treatment-related variables, surgical details, and short-term postoperative outcomes were compared between the two groups. The primary outcome was AL, and secondary outcomes included 30-day readmission, reoperation, and mortality rates. Furthermore, factors affecting AL were evaluated to identify independent risk factors.

Turkish Society of Colon and Rectal Surgery's Colorectal Cancer Database

To qualify as a contributing center capable of uploading data to TSCRS-CCD, institutions must perform at least 50 colorectal cases annually and have at least one board-certified colorectal surgeon. Centers that repeatedly failed to enter complete patient data, specifically those that submitted incomplete data for more than 10% of patients in multiple quarterly periods, were excluded from the database. The database comprises detailed information on patient demographics [including age, sex, body mass index (BMI), comorbidities, American Society of Anesthesiologists (ASA) score, and smoking status]; clinical and familial cancer history; preoperative findings such as presenting symptoms, tumor localization, serum tumor markers [carcinoembryonic antigen (CEA), carbohydrate antigen 19-9 (CA 19-9)], and clinical staging Tumor, Node, Metastasis (TNM); and neoadjuvant therapy details, including type, duration, and time interval to surgery. Operative variables include the urgency of the procedure (elective or emergency), surgical technique (open, laparoscopic, robotic), type and extent of resection, anastomotic configuration and method, intraoperative findings, blood loss and transfusion requirement, operative duration, and creation of a diverting stoma. Postoperative outcomes assessed within 30 days include both surgical and non-surgical complications (e.g., surgical site infections, intra-abdominal abscesses, AL, ileus, urinary retention, pulmonary embolism), need for reoperation, length of hospital stay, mortality, and hospital readmission. AL was recorded as a binary variable (present/absent) as per the database structure; no standardized grading system, such as the International Study Group of Rectal Cancer classification, was available to further subclassify leakage severity. Pathological variables encompass histologic tumor type and grade, number of retrieved and metastatic lymph nodes, pathological TNM stage, lymphovascular and perineural invasion, tumor budding, surgical margin status, tumor perforation, and response to neoadjuvant therapy. All data were recorded in a secure, web-based system by authorized personnel, using standardized definitions outlined in the CCD dictionary.

Variables Examined

Demographic data, including age, sex, BMI, comorbidities, ASA score, and smoking history, were recorded. Clinical parameters included presenting symptoms, tumor location, serum tumor markers (CEA, CA 19-9), family history, and clinical TNM staging based on imaging studies [magnetic resonance imaging (MRI), positron emission tomography-computed tomography]. Details regarding neoadjuvant treatment (type, duration, chemotherapy before and/or after radiation, and interval to surgery) were also documented. Operative data encompassed urgency of surgery (elective/emergency), surgical approach (open, laparoscopic, robotic), type of resection, tumor resection margins, creation and type of stoma, operative time, estimated blood loss, intraoperative transfusions, and intraoperative complications. Anastomotic details, including configuration, technique (hand-sewn or stapled), level from the anal verge, and construction site (intra- or extracorporeal), were noted. Postoperative outcomes within 30 days included surgical complications (AL, surgical site infection, bleeding, intra-abdominal abscess, ileus, evisceration, urinary and pancreatic fistulas), non-surgical complications (e.g., venous thromboembolism, myocardial infarction, pneumonia), need for reoperation, length of hospital stay, readmissions, and mortality. AL following LAR is defined as a loss of anastomotic integrity that results in the release of intestinal contents, gas, or contrast material into the pelvic or peritoneal cavity, detected clinically or radiologically. Pathological findings included tumor type, differentiation grade, total and metastatic lymph node counts, pathological TNM stage, lymphovascular and perineural invasion, tumor budding, tumor perforation, distal and radial resection margins, mesorectal excision quality, inflammatory bowel disease, multiorgan involvement, and response to neoadjuvant therapy.

Statistical Analysis

The Shapiro-Wilk test was utilized to assess the normality of continuous variables. Continuous variables were summarized as medians with interquartile ranges (IQRs), and comparisons were made using the Mann-Whitney U test because most continuous variables were non-normally distributed. For the normal distribution of other continuous parameters, Student's t-test was used. Categorical variables were represented as frequencies and percentages, with group comparisons conducted using either the chi-square test or Fisher's exact test, as appropriate. A two-tailed p-value of <0.05 was considered statistically significant. A multivariable logistic regression model was constructed to identify independent predictors of AL. Although variables with a p-value <0.20 in the univariate analysis were initially considered, "MRI utilization" and "previous abdominal surgery" were excluded from the final model to prevent quasi-complete separation and mathematical instability due to zero-cell counts in the cross-tabulations. Consequently, the final multivariable model included only three clinically relevant variables: age, sex, and presence of a diverting stoma. Statistical analyses were conducted using Jamovi software [version 2.6; The Jamovi Project (2005), Sydney, Australia].

Results

A total of 313 patients who underwent LAR for rectal cancer were included in this study. The median age of the cohort was 62 years (IQR, 16), and 37.1% were women. A diverting stoma was created in 260 patients (83%), whereas 53 patients (17%) underwent surgery without a stoma. The baseline demographic characteristics were comparable between groups regarding age, sex, BMI, ASA score, smoking status, and previous abdominal surgery (Table 1). Constipation as a presenting symptom was more frequent among patients with a stoma (33.1% vs. 17%, p=0.020). Patients with a stoma also had more advanced clinical T stage and MRI T stages (p<0.001) and were more likely to present with positive nodal status (p=0.023) and stage III disease at diagnosis (p=0.016). Consistent with these findings, neoadjuvant treatment was more frequently observed in the stoma group than in the non-stoma group (88.5% vs. 56.5%, p<0.001).

Operative variables were similar between the two groups in terms of approach (open, laparoscopic, or robotic), anastomotic technique, and intraoperative blood loss (Table 1). However, TME was performed more frequently in the stoma group (91.2% vs. 64.2%, p<0.001). The median operative time was 200 minutes (IQR, 92.5), and the median length of hospital stay was 7 days (IQR, 3). The overall conversion rate was 9.7%.

Postoperative short-term outcomes are summarized in Table 2. The overall rate of AL was 5.4% (17/313); AL occurred significantly more often in patients without a diverting stoma than in those with a stoma (11.3% vs. 4.2%, p=0.038). Similarly, the 30-day reoperation rate was higher in the non-stoma group (15.1% vs. 4.2%, p=0.003). Other postoperative complications, including surgical site infection (11.8%), postoperative ileus (8.9%), and urinary complications (4.8%), did not differ significantly between the two groups. The 30-day readmission rate was 8.6%, and the 30-day mortality rate was 0.3%, both of which were comparable between groups.

The comparison of patients with and without AL is presented in Table 3. No significant differences were observed in demographic factors, ASA classification, tumor stage, or neoadjuvant treatment rates between the two groups. However, AL was more common in patients without a diverting stoma (35.3% vs. 15.9%, p=0.038). Logistic regression analysis revealed that the omission of a diverting stoma was the variable most closely associated with an increased risk of AL [odds ratio (OR): 0.34; 95% confidence interval (CI): 0.11-0.99; p=0.05].

Table 1. Demographics, tumor characteristics, and surgical details (no stoma vs. stoma)

	All (n=313)	No stoma (n=53)	Stoma (n=260)	p-value
Age, year (IQR)	62 (16)	60 (14)	62.5 (16)	0.61
Female sex, n (%)	116 (37.1%)	20 (37.7%)	96 (36.9%)	0.91
BMI, kg/m² (IQR)	25.5 (4.2)	26 (3.8)	25.4 (4.3)	0.86
Symptoms, n (%)				
Bleeding	205 (65.5%)	32 (60.4%)	173 (66.5%)	0.39
Constipation	95 (30.4%)	9 (17%)	86 (33.1%)	**0.020**
Abdominal pain	93 (29.7%)	16 (30.2%)	77 (29.6%)	0.93
Anemia	18 (5.8%)	1 (1.9%)	17 (6.5%)	0.32
Screening	22 (7%)	7 (13.2%)	15 (5.8%)	0.05
Incidental	10 (3.2%)	4 (7.5%)	6 (2.3%)	0.07
ASA score, n (%)				
I	82 (26.2%)	15 (28.3%)	67 (25.8%)	0.46
II	190 (60.7%)	34 (64.2%)	156 (60%)	
III	41 (13.1%)	4 (7.5%)	37 (14.2%)	
Previous abdominal surgery, n (%)	60 (19.2%)	7 (13.2%)	53 (20.4%)	0.22
Non-smoker, n (%)	202 (64.5%)	37 (69.8%)	165 (63.5%)	0.65
CRC family history, n (%)	43 (13.8%)	10 (19.2%)	33 (12.7%)	0.21
Preoperative CEA level, (IQR)	3 (3)	2 (4)	3 (3)	0.50
Preoperative CA19-9 level, (IQR)	9 (16)	10 (15)	9 (16)	0.63
cT stage				
T1	16 (5.1%)	7 (13.2%)	9 (3.5%)	**<0.001**
T2	54 (17.3%)	16 (30.2%)	38 (14.6%)	
T3	209 (66.8%)	27 (50.9%)	182 (70%)	
T4	34 (10.9%)	3 (5.7%)	31 (11.9%)	
Positive nodal status, n (%)	202 (64.5%)	27 (50.9%)	175 (67.3%)	**0.023**
Stage at the time of diagnosis, n (%)				
I	37 (14.4%)	11 (29.7%)	26 (11.8%)	**0.016**
II	56 (21.8%)	7 (18.9%)	49 (22.3%)	
III	164 (63.8%)	19 (51.4%)	145 (65.9%)	
MRI utilization, n (%)	265 (84.7%)	46 (86.8%)	219 (84.2%)	0.63
MRI T stage, n (%)				
T1	9 (3.4%)	5 (10.9%)	4 (1.8%)	**<0.001**
T2	43 (16.2%)	16 (34.8%)	27 (12.3%)	
T3	179 (67.5%)	22 (47.8%)	157 (71.7%)	
T4	34 (12.8%)	3 (6.5%)	31 (14.2%)	
MRI-positive nodal status, n (%)	187 (70.6%)	25 (54.3%)	162 (74%)	**0.008**
Tumor distance to anal verge, cm (IQR)	7 (4)	9 (3)	7 (3)	**<0.001**
Neoadjuvant treatment, n (%)	261 (83.1%)	30 (56.5%)	231 (88.5%)	**<0.001**
Time to surgery, weeks (IQR)	10 (4)	8 (6)	10 (4)	0.12
Surgical approach, n (%)				
Open	129 (41.2%)	19 (35.8%)	110 (42.3%)	0.75
Hand assisted	1 (0.3%)	0 (0%)	1 (0.4%)	
Laparoscopic	169 (54%)	32 (60.4%)	137 (52.7%)	
Robotic assisted	14 (4.5%)	2 (3.8%)	12 (4.6%)	
Conversion, n (%)	18 (9.7%)	3 (8.8%)	15 (10%)	1.00
Total mesorectal excision, n (%)	271 (86.6%)	34 (64.2%)	237 (91.2%)	**<0.001**

Table 1. Continued

	All (n=313)	No stoma (n=53)	Stoma (n=260)	p-value
Stapler anastomosis, n (%)	278 (88.8%)	45 (84.9%)	233 (89.6%)	0.32
Intracorporeal anastomosis, n (%)	114 (36.4%)	21 (67.7%)	93 (67.4%)	0.97
Anastomosis distance to anal verge, cm (IQR)	3 (2)	4 (3)	3 (2)	**<0.001**
Intraoperative complication, n (%)	11 (3.5%)	1 (1.9%)	10 (3.8%)	0.69
Operative time, min (IQR)	200 (92.5)	200 (90)	200 (98)	0.61
EBL, mL (IQR)	100 (95)	85 (100)	100 (90)	0.35
Intraoperative blood transfusion	9 (2.9%)	0 (0%)	9 (3.5%)	0.36

Note: Stage at diagnosis data were available for 257 of 313 patients (82.1%). Data were missing for 56 patients (17.9%), including 16 patients in the non-stoma group and 40 patients in the stoma group. Percentages for stage at diagnosis were calculated based on patients with available staging data.

p-values shown in bold indicate statistically significant differences, defined as p<0.05.

IQR: Interquartile range, BMI: Body mass index, ASA: American Society of Anesthesiologists, CRC: Colorectal cancer, CEA: Carcinoembryonic antigen, CA19-9: Carbohydrate antigen 19-9, MRI: Magnetic resonance imaging, EBL: Estimated blood loss, TNM: Tumor, Node, Metastasis

Table 2. Postoperative short-term surgical outcomes (no stoma vs. stoma)

	All (n=313)	No stoma (n=53)	Stoma (n=260)	p-value
Surgical site infection, n (%)	37 (11.8%)	8 (15.1%)	20 (11.2%)	0.48
Deep surgical site infection, n (%)	7 (2.2%)	0 (0%)	7 (2.7%)	0.60
Evisceration, n (%)	3 (1%)	0 (0%)	3 (1.2%)	1.00
Postoperative ileus, n (%)	28 (8.9%)	4 (7.5%)	24 (9.2%)	1.00
Anastomotic leakage, n (%)	17 (5.4%)	6 (11.3%)	11 (4.2%)	**0.038**
Urinary leakage, n (%)	3 (1%)	0 (0%)	3 (1.2%)	1.00
Urinary retention, n (%)	10 (3.2%)	2 (3.8%)	8 (3.1%)	0.67
Urinary incontinence, n (%)	2 (0.6%)	0 (0%)	2 (0.8%)	1.00
Postoperative bleeding, n (%)	3 (1%)	2 (3.8%)	1 (0.4%)	0.07
Mechanical bowel obstruction, n (%)	5 (1.6%)	2 (3.8%)	3 (1.2%)	0.20
Non-surgical complications, n (%)	11 (3.5%)	4 (7.5%)	7 (2.7%)	0.09
LOS, day (IQR)	7 (3)	7 (3)	7 (3)	0.41
Reoperation (30-day), n (%)	19 (6.1%)	8 (15.1%)	11 (4.2%)	**0.003**
Readmission (30-day), n (%)	27 (8.6%)	4 (7.5%)	23 (8.8%)	1.00
Mortality (30-day), n (%)	1 (0.3%)	1 (1.9%)	0 (0%)	0.16

p-values shown in bold indicate statistically significant differences, defined as p<0.05.

LOS: Length of stay, IQR: Interquartile range

Age and sex demonstrated trends toward increased risk but did not reach statistical significance (p=0.078 and p=0.100, respectively) (Table 4).

Discussion

This study demonstrated that the absence of a diverting stoma in patients undergoing LAR for rectal cancer was associated with a significantly higher rate of AL and reoperation. The rate of diverting stoma creation during LAR procedures among Turkish surgeons was higher than that reported in the international literature.[8] This may primarily be attributed to the tendency of Turkish surgeons to perform a prophylactic stoma during surgery to prevent potential postoperative complications.

The rate of diverting stoma formation in our study was markedly high at 83%, whereas large series from Asia have generally reported lower rates ranging between 32.3% and 42.1%.[9] In contrast, data from Europe indicate intermediate diversion rates; for example, a meta-analysis of nine randomized controlled trials reported a diversion rate of 51.7%.[6] The lower diversion rates reported in Asian cohorts may partly reflect the earlier timeframes in which many of these studies were conducted compared with more recent European series. Over the past decade, there has been a noticeable global

Table 3. Demographics, tumor characteristics, and surgical details (anastomotic leak vs. no leak)

	All (n=313)	Anastomotic leak (n=17)	No leak (n=296)	p-value
Age, years (IQR)	62 (16)	57 (21)	62.5 (15.3)	0.13
Female sex, n (%)	116 (37.1%)	3 (17.6%)	113 (38.2%)	0.08
BMI, kg/m² (IQR)	25.5 (4.2)	25.3 (4.2)	25.6 (4)	0.38
Symptoms, n (%)				
Bleeding	205 (65.5%)	10 (58.8%)	195 (65.9%)	0.55
Constipation	95 (30.4%)	3 (17.6%)	92 (31.1%)	0.29
Abdominal pain	93 (29.7%)	5 (29.4%)	88 (29.7%)	0.97
Anemia	18 (5.8%)	1 (5.9%)	17 (5.7%)	1.00
Screening	22 (7%)	0 (0%)	22 (7.4%)	0.61
Incidental	10 (3.2%)	1 (5.9%)	9 (3%)	0.43
ASA score, n (%)				
I	82 (26.2%)	7 (41.2%)	75 (25.3%)	0.31
II	190 (60.7%)	8 (47.1%)	182 (61.5%)	
III	41 (13.1%)	2 (11.8%)	39 (13.2%)	
Abdominal surgical history, n (%)	60 (19.2%)	0 (0%)	60 (20.3%)	0.05
Non-smoker, n (%)	202 (64.5%)	13 (76.5%)	189 (63.9%)	0.56
CRC family history, n (%)	43 (13.8%)	1 (5.9%)	42 (14.2%)	0.48
Preoperative CEA level (IQR)	3 (3)	2 (3)	3 (3)	0.34
Preoperative CA19-9 level (IQR)	9 (16)	7 (11.8)	9 (16.5)	0.41
cT stage				
T1	16 (5.1%)	0 (0%)	16 (5.4%)	0.27
T2	54 (17.3%)	5 (29.4%)	49 (16.6%)	
T3	209 (66.8%)	12 (70.6%)	197 (66.6%)	
T4	34 (10.9%)	0 (0%)	34 (11.5%)	
Positive nodal status, n (%)	202 (64.5%)	12 (70.6%)	190 (64.2%)	0.59
Stage at the time of diagnosis, n (%)				
I	37 (14.4%)	2 (15.4%)	35 (14.3%)	0.92
II	56 (21.8%)	2 (15.4%)	54 (22.1%)	
III	164 (63.8%)	9 (69.2%)	155 (63.5%)	
MRI utilization, n (%)	265 (84.7%)	17 (100%)	248 (83.8%)	0.08
MRI T stage, n (%)				
T1	9 (3.4%)	0 (0%)	9 (3.6%)	0.71
T2	43 (16.2%)	4 (23.5%)	39 (15.7%)	
T3	179 (67.5%)	12 (70.6%)	167 (67.3%)	
T4	34 (12.8%)	1 (5.9%)	33 (13.3%)	
MRI-positive nodal status, n (%)	187 (70.6%)	13 (76.5%)	174 (70.2%)	0.58
Tumor distance to anal verge, cm (IQR)	7 (4)	7 (3)	7 (4)	0.93
Neoadjuvant treatment, n (%)	261 (83.1%)	15 (88.2%)	246 (83.1%)	0.74
Time to surgery, weeks (IQR)	10 (4)	8 (3.5)	10 (4)	0.30
Surgical approach, n (%)				
Open	129 (41.2%)	9 (52.9%)	120 (40.5%)	0.41
Hand assisted	1 (0.3%)	0 (0%)	1 (0.3%)	
Laparoscopic	169 (54%)	7 (41.2%)	162 (54.7%)	
Robotic assisted	14 (4.5%)	1 (5.9%)	13 (4.4%)	

Table 3. Continued

	All (n=313)	Anastomotic leak (n=17)	No leak (n=296)	p-value
Conversion, n (%)	18 (9.7%)	0 (0%)	18 (10.2%)	1.00
Total mesorectal excision, n (%)	271 (86.6%)	15 (88.2%)	256 (88.5%)	1.00
Stapler anastomosis, n (%)	278 (88.8%)	15 (88.2%)	263 (88.9%)	1.00
Intracorporeal anastomosis, n (%)	114 (36.4%)	8 (47.1%)	106 (35.8%)	0.50
Anastomosis distance to anal verge, cm (IQR)	3 (2)	3 (1)	3 (2)	0.54
Intraoperative complication, n (%)	11 (3.5%)	1 (5.9%)	10 (3.4%)	0.46
Operative time, min (IQR)	200 (92.5)	200 (70)	200 (95)	0.90
EBL, mL (IQR)	100 (95)	75 (150)	100 (91)	0.67
Intraoperative blood transfusion	9 (2.9%)	0 (0%)	9 (3%)	1.00
No diverting stoma, n (%)	53 (16.9%)	6 (35.3%)	47 (15.9%)	**0.038**

p-values shown in bold indicate statistically significant differences, defined as $p<0.05$.

IQR: Interquartile range, BMI: Body mass index, ASA: American Society of Anesthesiologists, CRC: Colorectal cancer, CEA: Carcinoembryonic antigen, CA19-9: Carbohydrate antigen 19-9, MRI: Magnetic resonance imaging, EBL: Estimated blood loss

Table 4. Anastomotic leakage predictors

	Ref	Odds ratio (95% CI)	p-value
Age at diagnosis	-	1.03 (0.99-1.08)	0.078
Sex	Female	0.34 (0.09-1.23)	0.100
Stoma	Performed	0.34 (0.11-0.99)	0.050

CI: Confidence interval

trend toward increased utilization of diversion stomas, driven by growing awareness of AL-related morbidity and its impact on postoperative outcomes. By comparison, the notably higher rate observed in our cohort may also reflect the proactive attitude of Turkish surgeons toward preventing the clinical consequences of AL, in line with contemporary literature emphasizing its significant impact on postoperative morbidity and mortality; this highlights how national practice patterns regarding diversion stoma creation during LAR may influence postoperative outcomes. To our knowledge, this is the first and largest database-based study conducted in Türkiye to investigate these patterns and their clinical consequences.

In the 132-patient series reported by Lefebure et al.[10], the rate of defunctioning stoma was 31.8%, and although the incidence of AL was similar between patients with and without a stoma (7.1% vs. 11%), both mortality and the development of a permanent stoma were observed exclusively in the non-diverted group. In an analysis of 1,791 patients using the National Surgical Quality Improvement Program database, protective stoma formation was found to provide no additional benefit in low pelvic anastomoses and was even associated with an increased risk of renal complications; however, in coloanal anastomoses, the absence of a stoma was significantly associated with higher rates of sepsis, septic shock, and reoperation.[11] In our cohort, diverting stoma creation was associated with lower observed rates of AL and reoperation; however, these findings should be interpreted in the context of substantial baseline differences between groups.

In a large multicenter meta-analysis, the rate of clinical AL was 18.3% in patients without diversion compared with 6.3% in those with diversion, and reoperation rates were 16.3% and 5.6%, respectively; however, no significant difference in mortality was observed.[12] Taken together, our national data indicate that diversion not only limits the clinical consequences of AL but may also reduce its overall incidence, thereby contributing important complementary evidence to the international literature. Postoperative complications other than AL—such as surgical site infection or urinary problems—did not differ significantly with stoma creation, consistent with findings reported in the existing literature.[11]

In our cohort, diverting stoma creation was associated with a lower observed rate of AL, consistent with the findings of Park et al.[13], who reported a significantly lower risk of leakage in patients undergoing diversion (hazard ratio=0.65; $p<0.05$). However, given the limited number of leakage events and the potential for residual confounding, this association should be interpreted with caution.[13] In a large meta-analysis (n=9,675), neoadjuvant therapy was not identified as an independent risk factor for AL (OR=1.16; 95% CI: 0.99-1.36; p=0.07), indicating that treatment modality alone does not significantly compromise anastomotic integrity.[14] Our findings are consistent with these results, indicating that neoadjuvant therapy did not independently increase the risk of leakage in our cohort.

In our cohort, diverting stoma creation was associated with the administration of neoadjuvant therapy and a lower anastomotic level. Neoadjuvant treatment was more frequent in the stoma group than in the non-stoma group (88.5% vs. 56.5%, p<0.001), while the median anastomotic distance from the anal verge was lower in the stoma group (3 vs. 4 cm, p<0.001). Similarly, in a large multicenter study, the most frequently cited criteria influencing surgeons' decision-making were neoadjuvant chemoradiotherapy (88%) and the anastomotic level (96%).[15] This alignment indicates that, both nationally and internationally, these two parameters remain the key considerations for protective stoma formation. Notably, although patients without a diverting stoma had earlier-stage tumors and relatively higher anastomotic levels, they exhibited higher rates of AL and reoperation. This finding suggests that the decision to omit diversion should not be based solely on these apparently favorable characteristics. However, the contribution of unmeasured technical and surgeon-related factors cannot be excluded.

Study Limitations

The main strength of our study is the use of a large national colorectal database, which enabled analysis of a substantially broader cohort than previously reported Turkish series and provided robust comparisons between diverted and non-diverted groups. Multivariate analysis further demonstrated that the absence of a stoma was associated with an increased risk of AL, underscoring the clinical relevance of our findings. However, the retrospective design may have introduced selection bias, as the decision to create a stoma depended on surgeon preference. Another important limitation is the potential for confounding by indication. Since the decision to create a diverting stoma was surgeon dependent and guided by intraoperative risk assessment, patients perceived as at greater risk of AL were more likely to undergo stoma formation. Therefore, despite the observed association between diversion and lower leakage rates, this finding should be interpreted with caution, as substantial baseline differences between the groups and potential confounding by indication may have contributed to it. It should also be recognized that diverting stomas are not without morbidity. Although they may mitigate the clinical consequences of AL, stoma formation can be associated with stoma-related complications such as dehydration, electrolyte imbalance, skin irritation, prolapse, parastomal hernia, and the need for an additional reversal procedure. Long-term outcomes such as permanent stoma rates and functional results were not assessed, which limits the scope of our conclusions. AL was recorded in the database only as a dichotomous variable (yes/no), without grading according to a standardized classification system. Therefore, although we were able to evaluate the association between diverting stoma formation and leakage, we could not assess whether diversion affected the clinical severity of leakage, which may be a more relevant outcome in this context. Finally, the low absolute number of AL events (n=17) represents a statistical limitation. Including multiple predictor variables in the logistic regression model with this number of events resulted in a low events-per-variable ratio, which may increase the risk of overfitting and limit the predictive power of the multivariable analysis. Nevertheless, this study provides national, database-based evidence from Türkiye showing an association between diverting stoma formation during LAR and lower observed rates of AL and reoperation. These findings bridge an important gap in the literature by reflecting real-world surgical practice and decision-making trends in a large, multicenter cohort. It provides valuable data to support the development of standardized surgical strategies and guideline recommendations in the management of rectal cancer.

Conclusion

In this observational cohort, diverting stoma formation during LAR for rectal cancer was associated with lower rates of AL and reoperation. However, given the retrospective design and potential selection bias, these findings should be interpreted as associated with lower observed rates of AL. Despite having earlier-stage tumors and relatively higher tumor and anastomosis levels, patients without a stoma exhibited a higher incidence of AL with increased reoperation rates. These findings highlight the importance of individualized consideration of diverting stoma creation in patients undergoing LAR for rectal cancer.

Ethics

Ethics Committee Approval: The Ege University Ethics Committee of Medical Research approved the study protocol (dated: 06.03.2025, approval no.: 25-3T/58).

Informed Consent: This retrospective cohort study utilized prospectively collected data

Acknowledgements

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Footnotes

Authorship Contributions

Concept: K.E., O.B. Design: K.E., O.B. Data Collection or Processing: B.E.B., K.E., Analysis or Interpretation: K.E., Literature Search: B.E.B., K.E., Writing: B.E.B., K.E., O.B.

Conflict of Interest: No conflict of interest was declared by the authors.

Financial Disclosure: The authors have no conflicts of interest including relevant financial interests, activities, relationships, and affiliations.

Declaration of Artificial Intelligence Use: The authors declare that language editing to improve grammar, clarity, and readability was performed using Paperpal Prime Plan and Gemini 3.1 Pro.

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DOI: 10.4274/tjcd.galenos.2026.2026-1-8
Turk J Colorectal Dis 2026;36(3):98-105

RESEARCH ARTICLE

Minimum Apparent Diffusion Coefficient as a Robust Magnetic Resonance Imaging Biomarker for Predicting Mesorectal Fascia Involvement in Rectal Cancer

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ABSTRACT

Aim: To investigate the diagnostic value of minimum, mean, and maximum apparent diffusion coefficient (ADC) measurements from the rectal tumor component closest to the mesorectal fascia (MRF) for predicting MRF involvement and to evaluate the influence of tumor mucin content and patient age.

Method: This retrospective study included 129 patients with pathologically confirmed rectal cancer who underwent preoperative rectal magnetic resonance imaging (MRI) between 2018 and 2025. ADC measurements were obtained from the tumor region closest to the MRF on diffusion-weighted images, and minimum, mean, and maximum ADC values were recorded. Statistical analyses included group comparisons, receiver operating characteristic curve analysis, and multivariable logistic regression.

Results: Patients with MRF involvement demonstrated significantly lower minimum, mean, and maximum ADC values than those without involvement (all $p<0.001$). In multivariate analysis, minimum ADC emerged as the only independent predictor of MRF involvement. Receiver operating characteristic curve analysis showed that minimum ADC had the highest diagnostic performance (area under the curve: 0.836). The optimal cut-off value for minimum ADC was $\leq 0.95\times10^{-3}$ mm²/s, yielding a sensitivity of 86.3%, specificity of 69.2%, positive predictive value of 64.7%, and negative predictive value of 88.5%. Subgroup analyses confirmed the robustness of minimum ADC across age and sex. Tumor mucin content influenced ADC performance, with reduced discriminative ability in low-mucin tumors.

Conclusion: Targeted ADC measurements obtained from the tumor-MRF interface, particularly minimum ADC, provide valuable information for predicting MRF involvement. Incorporating minimum ADC into routine rectal MRI assessment may improve preoperative risk stratification and treatment planning.

Keywords: Rectal cancer, apparent diffusion coefficient, mesorectal fascia, magnetic resonance imaging

Introduction

Rectal cancer remains a major health burden, and accurate preoperative staging is essential for treatment planning. Magnetic resonance imaging (MRI) is the standard modality for local staging, particularly in assessing the relationship between the tumor and the mesorectal fascia (MRF)—a key determinant of circumferential resection margin status and prognosis.[1] Tumor extension within ≤1 mm of the MRF is associated with an increased risk of local recurrence.[2]

Although high-resolution T2-weighted MRI provides detailed anatomical assessment, it has limitations in characterizing tumor biology. This has led to increasing interest in diffusion-weighted imaging (DWI) and its quantitative parameter, the apparent diffusion coefficient (ADC).[3]

Tumor heterogeneity represents a major challenge in imaging assessment. The tumor component closest to the MRF is of particular clinical relevance, as it represents the region most directly related to potential margin involvement.

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Received: 06.02.2026 **Accepted:** 14.07.2026 **Epub:** 14.09.2026 **Publication Date:** 28.09.2026

Cite this article as: Parlatan C, Turunç ŞG, Dilek O. Minimum apparent diffusion coefficient as a robust magnetic resonance imaging biomarker for predicting mesorectal fascia involvement in rectal cancer. Turk J Colorectal Dis. 2026;36(3):98-105

However, the diagnostic value of ADC measurements specifically obtained from this region remains insufficiently investigated.[4]

Mucinous rectal adenocarcinoma, characterized by abundant extracellular mucin pools, demonstrates distinct diffusion properties compared with non-mucinous subtypes, resulting in characteristically higher ADC values due to reduced restriction of water molecule movement.[5,6] However, whether this histological subtype difference systematically influences ADC-based assessment of MRF involvement—particularly when measurements are confined to the tumor region closest to the fascia—remains to be clarified.

This study aims to evaluate the diagnostic performance of minimum, mean, and maximum ADC values obtained from the tumor component closest to the MRF in predicting MRF involvement. These three metrics are assessed separately to capture distinct aspects of tumor diffusion behavior, as each may reflect different underlying tissue characteristics, including cellularity and mucin content. Additionally, the influence of histological subtype (mucinous vs. non-mucinous) and patient age on ADC measurements is investigated as a secondary objective.

Materials and Methods

The institutional review board approved this retrospective study and waived the requirement for informed consent. The study was approved by the University of Health Sciences Türkiye, Adana City Training and Research Hospital Clinical Research Ethics Committee (approval no.: 742, dated: 25.09.2025) and conducted in accordance with the principles of the Declaration of Helsinki.

Patient Selection

This retrospective single-center study included patients with histopathologically confirmed rectal adenocarcinoma who underwent pretreatment high-resolution pelvic MRI, including DWI and corresponding ADC maps, between January 2018 and March 2025. MRF involvement and lymph node status were determined based on histopathological evaluation of total mesorectal excision specimens and served as the reference standard. To minimize the potential impact of interval tumor progression on the reference standard, only patients whose pretreatment MRI was performed within 14 days before surgery were included. No neoadjuvant treatment was administered between imaging and surgery in any included patient. A total of 271 patients were initially identified. After application of the inclusion and exclusion criteria, 142 patients were excluded, resulting in a final cohort of 129 patients for analysis.

Eligible patients were required to have sufficient image quality to allow reliable assessment of the tumor-MRF relationship and quantitative ADC measurements and to have undergone imaging prior to any oncologic treatment.

Patients were excluded if they received neoadjuvant chemoradiotherapy or any other oncologic treatment before MRI, had a history of pelvic surgery or radiotherapy that could distort normal pelvic anatomy, had examinations with significant motion artifacts or technical limitations precluding accurate ADC analysis, had tumors with extensive nonsolid components preventing reliable region-of-interest placement, or had incomplete clinical or imaging data (Figure 1).

Rectal Magnetic Resonance Imaging Protocol

MRI was performed on a 3-T scanner (Philips Ingenia, Eindhoven, Netherlands) using a phased-array superficial body coil. T2-weighted sequences (axial, coronal, and sagittal) were acquired with a matrix of 220×205, a field of view (FOV) of 220 mm, a slice thickness of 3 mm, and a repetition time/echo time (TR/TE) of 3,299/110 ms. Pre- and postcontrast T1-weighted sequences used a matrix of 312×224, an FOV of 250 mm, a slice thickness of 4 mm, and a TR/TE of 514/8 ms. Dynamic T1-weighted imaging was performed with a matrix of 220×223, an FOV of 240 mm, and a TR/TE of 6.0/1.88 ms. DWI was acquired using b-values of 0 and 1,000 s/mm^2. Oblique axial, sagittal, and coronal high-resolution T2-weighted images were obtained parallel or orthogonal to the tumor's long axis. Contrast enhancement was performed with 0.1 mmol/kg gadobutrol (Gadovist, Bayer Schering Pharma, Berlin, Germany) administered intravenously at 2 mL/s, followed by a 15-mL saline flush.

Image Analysis and Measurement

Tumor mucin content was determined based on histopathological evaluation and classified into three categories based on the proportion of extracellular mucin, in accordance with established histopathological definitions. Tumors with <5% mucin were classified as having low mucin content (Type 1), those with 5-50% mucin as having intermediate mucin content (Type 2), and those with >50% mucin as having high mucin content (Type 3, corresponding to mucinous adenocarcinoma).[7,8]

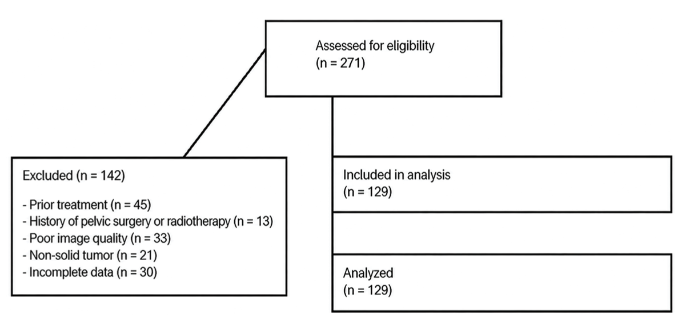

Figure 1. Flow diagram of patient selection

Diffusion-weighted imaging-derived ADC measurements were performed on ADC maps using high-resolution axial T2-weighted images as anatomical reference. For each tumor, the region of interest (ROI) was placed on the solid tumor component closest to the MRF, defined as the shortest distance between the outer tumor margin and the MRF (Figure 2).

Regions of interest were manually drawn on at least three consecutive axial slices covering the tumor region. Care was taken to avoid areas of necrosis, hemorrhage, cystic change, luminal contents, and susceptibility artifacts. In tumors with mucinous components, ROIs were strictly positioned on the solid tumor portions to minimize the confounding effect of extracellular mucin on ADC measurements (Figure 3).

Region of interest sizes ranged between 20 and 50 mm^2, depending on tumor size and morphology. For each ROI, minimum, mean, and maximum ADC values were automatically extracted, and the average of measurements obtained from consecutive slices was used for statistical analysis. ADC values were expressed in units of $\times 10^{-3}$ mm^2/s.

On MRI, a tumor-MRF distance of ≤1 mm was considered indicative of radiological MRF involvement, in accordance with established criteria for circumferential resection margin involvement.[9] The distance between the tumor and the MRF was measured on high-resolution axial T2-weighted images as the shortest linear distance from the outermost tumor margin to the MRF. Measurements were performed perpendicular to the tumor surface at the level where the tumor was closest to the MRF, and the minimal distance was recorded in millimeters for analysis.

Two radiologists with 4 and 11 years of experience in pelvic MRI independently performed all ADC measurements, both blinded to the histopathological results. In cases of discrepancy, a consensus reading was performed.

Statistical Analysis

Descriptive statistics were expressed as mean, standard deviation, median, minimum, maximum, frequency, and percentage values. The distribution of variables was assessed using the Kolmogorov-Smirnov and Shapiro-Wilk tests. Both mean±standard deviation and median values were reported to comprehensively describe the distribution of variables, given that some parameters did not follow a normal distribution. For normally distributed independent quantitative variables, the Independent Samples t-test was used, whereas the Mann-Whitney U test was applied for non-normally distributed independent quantitative variables. Categorical variables were analyzed using the chi-square test. Discriminative performance and optimal cut-off values were evaluated using receiver operating characteristic (ROC) curve analysis. The effects of variables were assessed using univariate and multivariable logistic regression analyses. Due to multicollinearity among ADC parameters, only the most predictive variable (minimum ADC) was included in the multivariable model. Optimal cut-off values were determined using the Youden index. Positive predictive value (PPV) and negative predictive value (NPV)

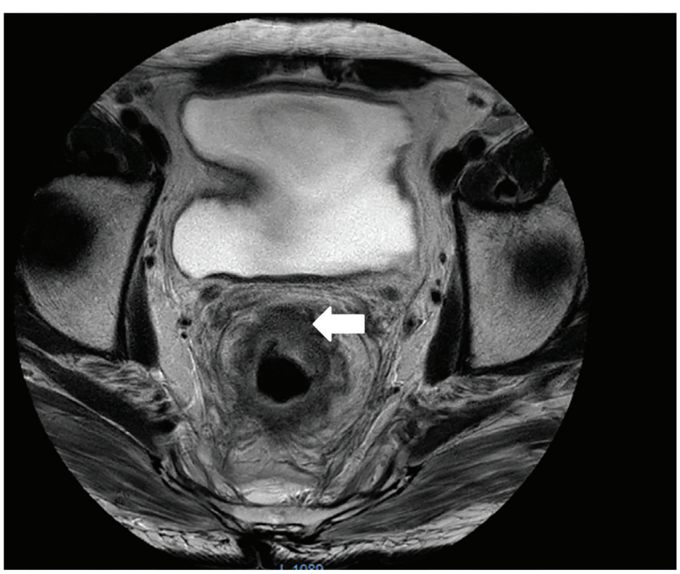

Figure 2. Axial high-resolution T2-weighted MRI of a 56-year-old female patient showing a rectal tumor (arrow). The tumor-mesorectal fascia relationship is demonstrated and used as a reference for ROI placement on the solid tumor component for ADC measurements, avoiding non-solid areas

MRI: Magnetic resonance imaging, ROI: Region of interest, ADC: Apparent diffusion coefficient

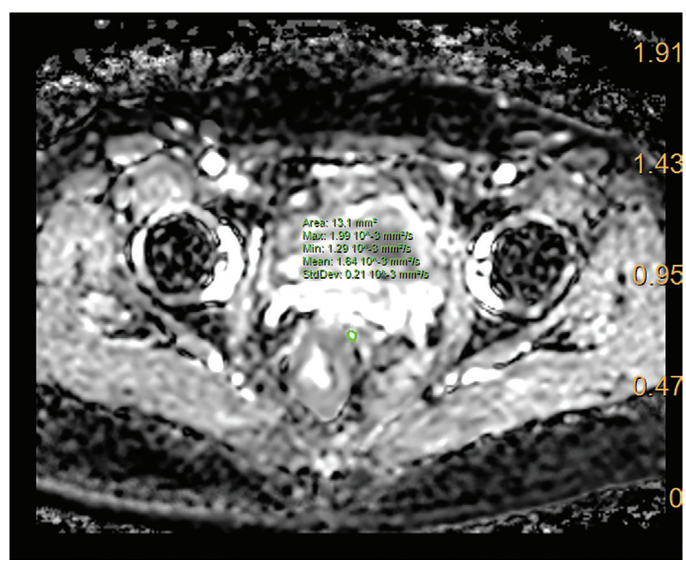

Figure 3. Axial apparent diffusion coefficient (ADC) map of the same patient shown in Figure 2, demonstrating ROI placement on the solid tumor component. Quantitative ADC measurements (minimum, mean, and maximum) were obtained from this region

ROI: Region of interest

were calculated based on the observed prevalence of MRF involvement in the study cohort. All statistical analyses were performed using SPSS Statistics (version 28.0).

Potential sources of bias, including selection bias and measurement variability, were minimized through predefined inclusion criteria and blinded image analysis. No significant missing data were present for the variables included in the analysis.

Results

A total of 129 patients with rectal cancer were included in the study. The patients' ages ranged from 32 to 84 years, with a median age of 64 years and a mean age of 63.5±11.6 years. Of the study population, 51.2% (n=66) were younger than 65 years, whereas 48.8% (n=63) were aged 65 years or older. The cohort consisted of 79 men (61.2%) and 50 women (38.8%).

The minimum ADC values measured from the tumor component closest to the MRF ranged from 0.10 to 2.10×10^{-3} mm^2/s, with a median of 0.90×10^{-3} mm^2/s and a mean of $0.98\pm0.42\times10^{-3}$ mm^2/s. Mean ADC values ranged from 0.30 to 3.00×10^{-3} mm^2/s, with a median of 1.30×10^{-3} mm^2/s and a mean of $1.32\pm0.50\times10^{-3}$ mm^2/s. Maximum ADC values ranged from 0.40 to 3.30×10^{-3} mm^2/s, with a median of 1.70×10^{-3} mm^2/s and a mean of $1.70\pm0.60\times10^{-3}$ mm^2/s (Table 1).

Regarding tumor characteristics, mucin content was graded as Type 1 in 76 patients (58.9%), Type 2 in 46 patients (35.7%), and Type 3 in 7 patients (5.4%). The distance between the tumor and the MRF ranged from 1.0 to 26.5 mm, with a median distance of 8.0 mm and a mean distance of 8.49±5.77 mm. MRF involvement was present in 51 patients (39.5%) and absent in 78 patients (60.5%) (Table 1).

Comparative analysis between patients with and without MRF involvement demonstrated no statistically significant differences in age distribution or sex ($p>0.05$ for all). Similarly, no significant differences were observed between the two groups with respect to tumor mucin content or the distance between the tumor and the MRF ($p>0.05$) (Table 2).

In contrast, DWI parameters showed significant differences between groups. Patients with MRF involvement had significantly lower minimum, mean, and maximum ADC values than those without MRF involvement (all $p<0.001$). Specifically, the mean minimum ADC value was $1.17\pm0.39\times10^{-3}$ mm^2/s in patients without MRF involvement versus $0.70\pm0.31\times10^{-3}$ mm^2/s in those with involvement. Corresponding mean ADC values were $1.51\pm0.49\times10^{-3}$ mm^2/s and $1.04\pm0.39\times10^{-3}$ mm^2/s, respectively, whereas maximum ADC values were $1.88\pm0.57\times10^{-3}$ mm^2/s and $1.43\pm0.55\times10^{-3}$ mm^2/s (Table 2).

ROC analysis demonstrated that minimum ADC had the highest diagnostic performance for predicting MRF involvement [area under the curve (AUC): 0.836]. Using the Youden index, the optimal cut-off value for minimum ADC was $\leq0.95\times10^{-3}$ mm^2/s, yielding a sensitivity of 86.3%, specificity of 69.2%, PPV of 64.7%, and NPV of 88.5%. For mean ADC, the optimal cut-off value was $\leq1.30\times10^{-3}$ mm^2/s (sensitivity: 82.4%, specificity: 59.0%, PPV: 56.8%, NPV: 83.6%), whereas for maximum ADC, the optimal cut-off value was $\leq1.70\times10^{-3}$ mm^2/s (sensitivity: 74.5%, specificity: 61.5%, PPV: 55.9%, NPV: 78.7%) (Table 3 and Figure 4).

Table 1. Baseline demographic and MRI characteristics of the study cohort

Variable	Min-Max	IQR (Q1-Q3)	Median	Mean±SD/n (%)
Age (years)	32-84	55-73.5	64	63.5±11.6
Age <65	-	-	-	66 (51.2%)
Age ≥65	-	-	-	63 (48.8%)
Sex (Male)	-	-	-	79 (61.2%)
Sex (Female)	-	-	-	50 (38.8%)
Minimum ADC	0.10-2.10	0.70-1.30	0.90	0.98±0.42
Mean ADC	0.30-3.00	0.95-1.60	1.30	1.32±0.50
Maximum ADC	0.40-3.30	1.20-2.10	1.70	1.70±0.60
Mucin content in tumor - Type 1	-	-	-	76 (58.9%)
Mucin content in tumor - Type 2	-	-	-	46 (35.7%)
Mucin content in tumor - Type 3	-	-	-	7 (5.4%)
Distance of tumor to MRF (mm)	1.0-26.5	3.5-11.0	8.0	8.49±5.77
Mesorectal fascia involvement (-)	-	-	-	78 (60.5%)
Mesorectal fascia involvement (+)	-	-	-	51 (39.5%)

MRI: Magnetic resonance imaging, MRF: Mesorectal fascia, SD: Standard deviation, IQR: Interquartile range, ADC: Apparent diffusion coefficient

Table 2. Comparison of demographic and MRI characteristics according to mesorectal fascia involvement

Variable	MRF Involvement (-) (n=78) Mean±SD / n (%)	Median	MRF Involvement (+) (n=51) Mean±SD/n (%)	Median	p-value
Age (years)	64.7±11.4	65.0	61.6±11.7	62.0	0.095
Age <65	37 (47.4%)	-	29 (56.9%)	-	0.295
Age ≥65	41 (52.6%)	-	22 (43.1%)	-	
Sex (Male)	49 (62.8%)	-	30 (58.8%)	-	0.649
Sex (Female)	29 (37.2%)	-	21 (41.2%)	-	
Minimum ADC	1.17±0.39	1.10	0.70±0.31	0.69	<0.001
Mean ADC	1.51±0.49	1.45	1.04±0.39	1.00	<0.001
Maximum ADC	1.88±0.57	1.90	1.43±0.55	1.40	<0.001
Mucin content in tumor - Type 1	47 (60.3%)	-	29 (56.9%)	-	0.701
Mucin content in tumor - Type 2	26 (33.3%)	-	20 (39.2%)	-	
Mucin content in tumor - Type 3	5 (6.4%)	-	2 (3.9%)	-	
Distance of tumor to MRF (mm)	8.3±5.8	8.0	8.8±5.8	7.3	0.643

MRF: Mesorectal fascia, SD: Standard deviation, ADC: Apparent diffusion coefficient, MRI: Magnetic resonance imaging

Table 3. ROC curve analysis of ADC parameters

Parameter	Area under the curve	95% confidence interval	Optimal cut-off	Sensitivity	Specificity	PPV	NPV
Minimum ADC	0.836	0.764-0.908	≤0.95	86.3%	69.2%	64.7%	88.5%
Mean ADC	0.786	0.705-0.866	≤1.30	82.4%	59.0%	56.8%	83.6%
Maximum ADC	0.717	0.626-0.809	≤1.70	74.5%	61.5%	55.9%	78.7%

ADC: Apparent diffusion coefficient, ROC: Receiver operating characteristic, PPV: Positive predictive value, NPV: Negative predictive value

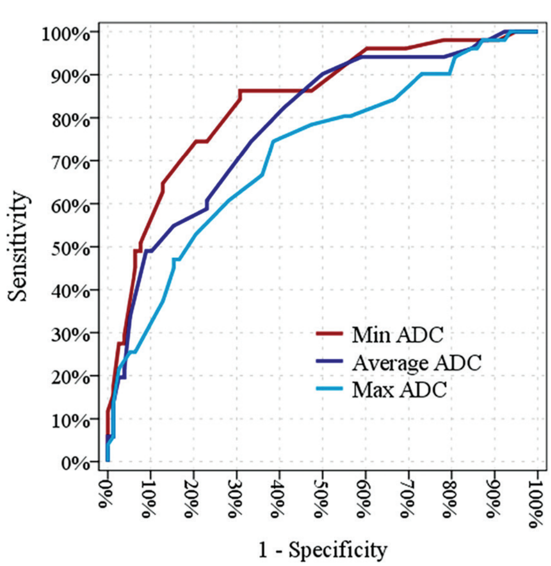

Figure 4. Receiver operating characteristic curves of minimum, average, and maximum ADC values for predicting mesorectal fascia involvement. Minimum ADC demonstrated the highest diagnostic performance compared with mean and maximum ADC values
ADC: Apparent diffusion coefficient

In univariate logistic regression analysis, all three ADC-derived parameters were statistically significant predictors of the outcome. Minimum ADC demonstrated the strongest association, with an odds ratio (OR) of 63.44 [95% confidence interval (CI): 13.01-309.26], followed by mean ADC (OR=14.75; 95% CI: 4.72-46.09) and maximum ADC (OR=4.42; 95% CI: 2.11-9.25). In multivariate logistic regression analysis, minimum ADC was identified as the sole independent predictor (OR=63.44; 95% CI: 13.01-309.26), whereas mean and maximum ADC were not included in the multivariate model because of multicollinearity with minimum ADC (Table 4).

Discussion

In this study, we investigated the diagnostic value of ADC measurements obtained from the tumor component closest to the MRF in predicting MRF involvement in patients with rectal cancer. Our results demonstrate that minimum, mean, and maximum ADC values were significantly lower in patients with MRF involvement than in those without involvement, whereas demographic factors, tumor mucin content, and tumor-MRF distance showed no significant differences between groups. Among the diffusion parameters, minimum

Table 4. Univariate and multivariate logistic regression analysis of ADC parameters and mesorectal fascia involvement

Variable	Univariate model OR	95% CI	p-value	Multivariate model OR	95% CI	p-value
Minimum ADC	63.44	13.01-309.26	0.000	63.44	13.01-309.26	<0.001
Mean ADC	14.75	4.72-46.09	0.000	-	-	-
Maximum ADC	4.42	2.11-9.25	0.000	-	-	-

OR: Odds ratio, CI: Confidence interval, ADC: Apparent diffusion coefficient

ADC emerged as the strongest and only independent predictor of MRF involvement in multivariate analysis.

Accurate preoperative assessment of MRF involvement is a cornerstone of rectal cancer staging, as it directly affects surgical planning, circumferential resection margin status, and the need for neoadjuvant therapy.[10,11] High-resolution T2-weighted MRI is currently regarded as the standard technique for evaluating the relationship between the tumor and the MRF. However, its accuracy may be limited in borderline cases and in tumors with heterogeneous morphology.[12,13] Therefore, the integration of functional imaging parameters such as DWI has gained increasing interest.

Diffusion-weighted MRI reflects tumor cellularity, extracellular space restriction, and microstructural complexity, which are key determinants of tumor aggressiveness.[14,15] Lower ADC values have consistently been associated with higher cellular density, increased nuclear-to-cytoplasmic ratio, and more aggressive tumor behavior.[16] In line with these concepts, our findings demonstrate significantly reduced ADC values in tumors with MRF involvement, supporting the hypothesis that local invasive potential is associated with restricted diffusion.

Notably, minimum ADC values showed superior performance compared with mean and maximum ADC values. Although all three parameters were significant in univariate analysis, only minimum ADC retained independent significance in the multivariate logistic regression model. This finding is consistent with previous studies suggesting that minimum ADC better reflects the most aggressive tumor subregion, capturing intratumoral heterogeneity more effectively than mean ADC values.[17-19] Mean ADC values may be influenced by necrotic or less cellular tumor areas, whereas minimum ADC highlights the region with the highest diffusion restriction, which is more relevant to invasive behavior.

ROC analysis further supported the diagnostic value of ADC measurements. Minimum ADC demonstrated the highest discriminative ability for MRF involvement, with an AUC of 0.836, followed by mean ADC (AUC=0.786) and maximum ADC (AUC=0.717). These results indicate that minimum ADC provides good diagnostic accuracy and may serve as a reliable imaging biomarker for predicting MRF involvement. Comparable AUC values have been reported in previous DWI-based studies assessing locally advanced rectal cancer and adverse prognostic features.[20,21]

An important observation in our study is the lack of significant differences between MRF-positive and MRF-negative groups regarding age, sex, tumor mucin content, and tumor-MRF distance. Interestingly, tumor-MRF distance did not show a statistically significant association with MRF involvement in our study. Although this parameter is traditionally considered a key morphologic predictor, its lack of significance may be explained by several factors.[9] First, distance measurements on MRI may not fully capture microscopic tumor infiltration or early MRF involvement. Second, tumor aggressiveness and biological behavior—reflected by diffusion characteristics such as ADC—may play a more critical role than purely anatomical proximity. Finally, measurement variability and tumor heterogeneity may also contribute to the limited discriminative value of distance alone. These findings highlight the added value of functional imaging parameters over conventional morphologic assessment.

Subgroup analyses further strengthened the robustness of minimum ADC as a predictive parameter. Minimum ADC remained significantly effective in distinguishing MRF involvement across age groups (<65 and ≥65 years) and both sexes. These findings suggest that the predictive performance of minimum ADC is consistent across clinically relevant subpopulations, enhancing its potential generalizability in routine clinical practice.

Tumor mucin content is known to influence ADC values due to increased extracellular water content in mucinous tumors, which typically results in higher ADC measurements.[4,22] In our study, minimum ADC did not demonstrate significant discriminative ability in tumors with low mucin content (Type 1), whereas it remained significant in tumors with moderate to high mucin content (Types 2-3). This observation may reflect increased intratumoral heterogeneity in higher-grade mucinous tumors, where solid tumor components coexist with mucinous areas, allowing minimum ADC to capture biologically aggressive regions more effectively. In contrast, low-mucin tumors may exhibit more homogeneous diffusion characteristics, which could reduce the ability of minimum ADC to differentiate invasive from noninvasive behavior in this subgroup. Clinicians should therefore exercise caution when applying minimum ADC thresholds to tumors with low mucin content, and additional imaging or histological characterization may be necessary in these cases. These findings are consistent with prior reports emphasizing the need for careful ROI placement in solid tumor components when evaluating ADC in mucinous rectal cancers.[23]

One of the key strengths of our study is the methodological approach to ADC measurement. By focusing on the tumor component closest to the MRF rather than sampling the entire tumor volume, we aimed to specifically target the region most relevant to local invasion. This targeted measurement strategy likely contributes to the strong association between minimum ADC and MRF involvement observed in our cohort and represents an important methodological contribution to the existing literature.

Study Limitations

Several limitations should be acknowledged. The retrospective and single-center design may limit generalizability. Although measurements were performed by two experienced radiologists with consensus reading, formal interobserver agreement analysis (e.g., intraclass correlation coefficient) was not conducted, and the reproducibility of ADC measurements could not be quantitatively assessed. Future prospective, multicenter studies with standardized acquisition protocols and volumetric ADC analysis are warranted to address these methodological gaps.

Although histopathological data were available, detailed pathological parameters such as tumor stage, grade, and lymphovascular invasion were not included in the present analysis, as the primary aim of the study was to evaluate the relationship between ADC measurements and MRF involvement. The multivariate model was primarily focused on diffusion-related parameters, and other potentially relevant clinicopathological variables such as tumor height, T stage, nodal status, extramural vascular invasion, and tumor size were not included. Inclusion of these variables in future studies may further improve model performance. Future studies incorporating comprehensive pathological correlations may further enhance the clinical value of these findings.

Conclusion

ADC measurements obtained from the tumor component closest to the MRF, particularly minimum ADC, may provide useful information for predicting MRF involvement in rectal cancer. Minimum ADC was identified as an independent imaging parameter with good diagnostic performance. These findings suggest that targeted ADC assessment could complement conventional MRI evaluation and may contribute to preoperative risk stratification and treatment planning. Validation through prospective multicenter studies remains necessary before routine clinical implementation.

Ethics

Ethics Committee Approval: The study was approved by the University of Health Sciences Türkiye, Adana City Training and Research Hospital Clinical Research Ethics Committee (approval no.: 742, dated: 25.09.2025) and conducted in accordance with the principles of the Declaration of Helsinki.

Informed Consent: The institutional review board approved this retrospective study and waived the requirement for informed consent.

Footnotes

Authorship Contributions

Surgical and Medical Practices: C.P., Concept: C.P., Design: C.P., O.D., Data Collection or Processing: C.P., Ş.G.T., Analysis or Interpretation: C.P., O.D., Literature Search: C.P., O.D., Writing: C.P.

Conflict of Interest: No conflict of interest was declared by the authors.

Financial Disclosure: The authors have no conflicts of interest including relevant financial interests, activities, relationships, and affiliations.

Artificial Intelligence Statement: Claude AI (Anthropic) was used solely for language editing and grammatical improvements. It was not used for data analysis, interpretation of results, or generation of scientific content. The authors reviewed and approved all changes and take full responsibility for the final content of the manuscript.

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DOI: 10.4274/tjcd.galenos.2026.2026-7-6
Turk J Colorectal Dis 2026;36(3):106-110

RESEARCH ARTICLE

The Relationship Between the Tumor-Stroma Ratio and Lymph Node Ratio and Survival in Colon Cancer: A Single-Center Experience

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ABSTRACT

Aim: This retrospective analysis aimed to examine the relationship between the tumor-stroma ratio (TSR) and lymph node ratio (LNR) in patients treated with curative-intent surgery for colon cancer and to determine the prognostic value of both parameters for overall survival (OS).

Method: This single-center study included consecutive patients with colon adenocarcinoma who underwent surgical resection between January 2019 and December 2025. The relationships of the TSR and LNR with OS and clinicopathological parameters were investigated.

Results: A total of 113 patients with colon cancer were included in the study. Survival status differed by TSR category. In the low-TSR group, 45 patients (71%) were alive, and 18 (29%) were deceased, whereas the corresponding numbers in the high-TSR group were 23 (46.0%) and 27 (54.0%), respectively. This difference was statistically significant (p=0.006). We also analyzed patients according to survival. Significant differences between survivors and non-survivors were observed in median age, total lymph node count, number of metastatic lymph nodes, and LNR (p=0.04, 0.008, 0.001). No significant association between TSR and LNR was found.

Conclusion: Both TSR and LNR have emerged as promising prognostic indicators. In the present study, both TSR and LNR were associated with OS.

Keywords: Colon cancer, tumor-stroma ratio, lymph node ratio, survival

Introduction

Among gastrointestinal malignancies, colorectal cancer represents a major global health burden, owing to its high incidence and considerable contribution to cancer-related mortality worldwide.[1] Although considerable progress has been made in diagnostic methods and treatment approaches, along with refinements in surgical techniques and approaches, patients with identical clinicopathological stages may exhibit substantial differences in survival outcomes. To better explain this phenomenon, recent research has increasingly focused on the tumor microenvironment and tumor biology, which have emerged as important determinants of clinical outcomes.[2]

Among the histomorphology parameters reflecting the tumor microenvironment, the tumor-stroma ratio (TSR) has emerged as one of the most extensively investigated prognostic parameters. By quantifying the relative proportion of stromal tissue within the tumor, the TSR provides valuable insight into tumor-host interactions and has demonstrated considerable prognostic value in patients with colon cancer.[3] Previous studies have consistently linked a high TSR with more aggressive tumor behavior, including increased invasiveness, advanced pathological stage, a greater likelihood of lymph node involvement, and reduced survival among patients with colon cancer.[4,5]

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Received: 31.07.2026 **Accepted:** 16.09.2026 **Publication Date:** 28.09.2026

Cite this article as: Peltek Özer S, Tatar C, Özer B, Boran Ç. The relationship between the tumor-stroma ratio and lymph node ratio and survival in colon cancer: a single-center experience. Turk J Colorectal Dis. 2026;36(3):106-110

Nodal involvement is a key prognostic factor in colon cancer. Despite these considerations, the N category in the existing tumor, node, metastasis staging framework is assigned according to the absolute count of metastatic lymph nodes.[6] However, the total lymph node yield after surgical resection may vary substantially because of differences in surgical technique, the quality of pathological macroscopic examination, and individual anatomical variability, thereby affecting the accuracy of nodal staging. Accordingly, the lymph node ratio (LNR), calculated by dividing the number of metastatic lymph nodes by the total number of lymph nodes examined, has increasingly been recognized as a more objective and reproducible prognostic indicator.[7] We also emphasize that inadequate lymph node retrieval is a clinically relevant factor that may influence staging and subsequent treatment decisions, including adjuvant chemotherapy. However, all surgical procedures were performed with the same surgical unit in the present case.

Accumulating evidence has demonstrated that an elevated LNR is associated with more advanced disease, higher recurrence rates, and poorer survival outcomes in patients with colon cancer.[8]

A biological relationship between lymph node metastasis and the stromal composition of the tumor has been proposed. The tumor stroma is thought to provide a permissive microenvironment that facilitates tumor cell migration and promotes metastatic dissemination. Furthermore, stromal remodeling, angiogenesis, and the activation of cancer-associated fibroblasts have been implicated in lymphatic spread, suggesting that the tumor microenvironment plays a pivotal role in the metastatic process.[9] However, TSR and lymph node involvement have been demonstrated in various other tumor types.

Despite the growing body of evidence supporting the individual prognostic significance of the LNR and TSR, studies evaluating the relationship between these two parameters are scarce, and their combined prognostic impact on survival remains largely unexplored. The present study aims to examine the relationship between the LNR and TSR in patients undergoing curative resection for colon cancer and to assess the prognostic value of both parameters in predicting overall survival (OS).

Materials and Methods

Consecutive patients with colon adenocarcinoma who underwent curative-intent surgical resection at Bolu Abant İzzet Baysal University, İzzet Baysal Training and Research Hospital between January 2019 and December 2025 were retrospectively evaluated in this single-center study. Clinical characteristics and histopathological findings were retrospectively obtained through a review of institutional electronic health records and pathology archives. The study was approved by the Non-Interventional Clinical Research Ethics Committee of Bolu Abant İzzet Baysal University (approval number: 2026/296, date: 23.06.2026).

Patient-related demographic and clinical characteristics, histopathological findings, and follow-up data were retrospectively retrieved from institutional electronic records and pathology archives. Eligibility required histopathological confirmation of primary conventional-type colon adenocarcinoma, surgical resection of the tumor, and the availability of survival data.

Exclusion criteria comprised incomplete clinical or histopathological documentation, lack of available pathological specimens, and inadequate follow-up information. Additional exclusion criteria included synchronous malignancies, receipt of neoadjuvant therapy, palliative surgery for metastatic disease, and histological subtypes other than conventional adenocarcinoma, such as mucinous adenocarcinoma or signet-ring cell carcinoma. In addition, patients who died within the 1st postoperative month were also excluded. Patient age, sex, tumor location, total number of examined lymph nodes, number of metastatic lymph nodes, and survival data were recorded. The TSR was retrospectively determined using hematoxylin and eosin-stained histopathological slides. The TSR was evaluated at the invasive tumor front by identifying the microscopic field containing both tumor cells and stromal tissue with the highest proportion of stroma. The percentage of the stromal component within this field was estimated visually at x100 magnification. A 50% cut-off value was used in accordance with the methodology commonly adopted in the literature. Based on the proportion of stromal tissue, the cases were divided into two categories: high TSR, defined as a stromal area of ≥50%, and low TSR, defined as a stromal area of <50% (Figure 1). All types of collagen present in the stromal areas, including keloid-like, mature, and immature collagen, were included in the assessment. Areas affected by crush artifacts, necrosis, and granulocytic infiltration were excluded from assessment. In addition, regions lacking direct tumor-stroma interaction were not considered; only stromal areas immediately adjacent to tumor cells were evaluated.

For each patient, the LNR was derived by dividing the number of lymph nodes with metastatic involvement by the overall number of lymph nodes examined. OS was measured from the date of surgery until death from any cause, with surviving patients censored at their most recent follow-up.

Statistical Analysis

All statistical procedures were performed with IBM SPSS Statistics for Windows, version 25.0 (IBM Corp., Armonk, NY, USA). The Kolmogorov-Smirnov test was applied to assess whether continuous variables conformed to a normal distribution. Data meeting the normality assumption were summarized as mean ± standard deviation, with group differences assessed by the Independent Samples t-test. For variables with non-normal distributions, values were reported as median and range (minimum-maximum), and comparisons were performed using the Mann-Whitney U test. Categorical variables were summarized as frequencies and percentages, and differences between groups were assessed by the chi-square test. Associations between study variables were examined using Pearson's or Spearman's correlation coefficients, depending on the distribution of the data. Receiver operating characteristic curve analysis was used to determine the sensitivity and specificity of the study variables in predicting survival. A multivariable logistic regression model was used to identify factors independently associated with survival status. Statistical testing was performed on a two-tailed basis, with a p-value of <0.05 regarded as the threshold for statistical significance.

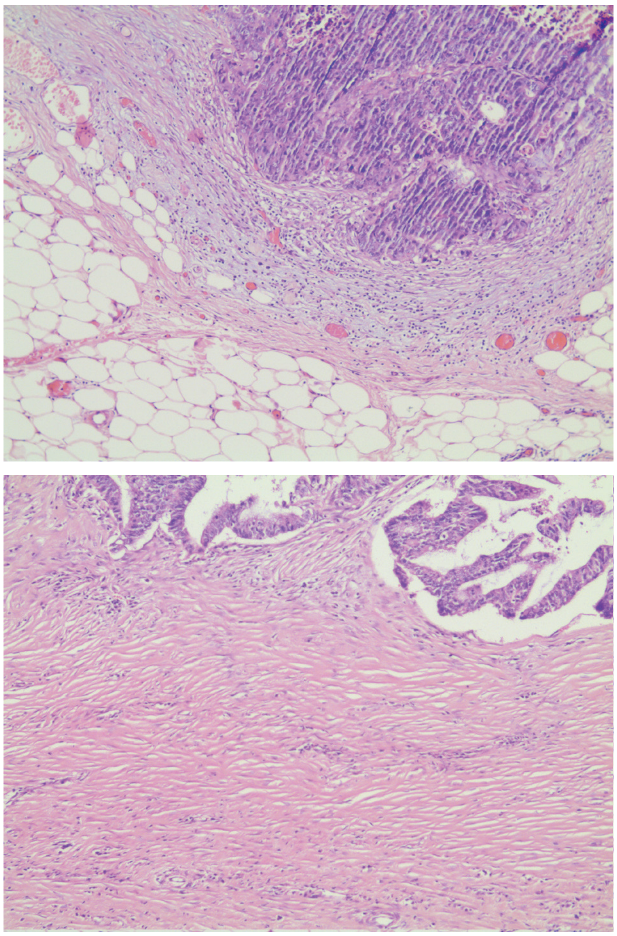
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Figure 1. a) Low tumor-stroma ratio (<50%), H&E ×100. b) High tumor-stroma ratio (≥50%), H&E ×100
H&E: Hematoxylin and eosin

Results

The study cohort comprised 113 patients with colon cancer. The sigmoid colon represented the most common tumor site, accounting for 39 cases (34.5%). The remaining tumors were distributed across the rectosigmoid colon (n=32, 28.3%), cecum (n=21, 18.6%), descending colon (n=14, 12.4%), transverse colon (n=4, 3.5%), and ascending colon (n=3, 2.7%). The mean ages of the low- and high-TSR groups were 67 years and 70 years, respectively (p=0.074). Approximately 38% of the low-TSR and 36% of the high-TSR groups were women (p=0.84). Total lymph node count, metastatic lymph node count, LNR, and survival times (in months) were not statistically different among study groups. Survival status differed significantly between the TSR groups. In the low-TSR group, 45 (71%) patients were alive, and 18 (29%) had died, whereas in the high-TSR group, 23 (46.0%) patients were alive, and 27 (54.0%) had died. This difference reached statistical significance (p=0.006). Table 1 summarizes the baseline clinicopathological features of patients in the low- and high-TSR groups.

The cohort was further stratified by survival status. Comparison of survivors and non-survivors revealed statistically significant differences in age (p=0.04), the number of lymph nodes examined (p=0.008), the number of metastatic lymph nodes (p=0.001), and the LNR (p=0.001). The comparative analysis of survival groups is presented in Table 1.

Table 1. Associations of the tumor-stroma ratio (TSR) with clinicopathological characteristics and survival outcomes

Parameters		High TSR (≥50%)	Low TSR (<50%)	p (<0.05)	Survival		p (<0.05)
					Alive	Deceased	
Age (years)		70 (±9)	67 (±11)	0.074	66 (±11)	71 (±9)	0.048
Gender	Female	18 (36%)	24 (38%)	0.084	29 (43%)	13 (29%)	0.133
	Male	32 (64%)	39 (62%)		39 (57%)	32 (71%)	
Total lymph node count (min-max)		19 (8-53)	18 (4-51)	0.161	17 (4-39)	20 (10-53)	0.008
Metastatic lymph node count (min-max)		3.5 (1-25)	2 (1-34)	0.061	2 (1-9)	8 (1-34)	0.001
Lymph node ratio		0.16 (0.04-0.80)	0.12 (0.03-0.82)	0.211	0.13 (±0.12)	0.37 (±0.20)	0.001
Survival times (months)		24 (3-72)	20 (3-72)	0.448	19 (3-50)	24 (3-72)	0.325
Survival status	Alive	23 (46%)	45 (71%)	0.006			
	Deceased	27 (54%)	18 (29%)				

Receiver operating characteristic curve analysis demonstrated that an LNR threshold of >0.16 predicted mortality with a sensitivity of 80% and a specificity of 79% [area under the curve: 0.84; p=0.04; 95% confidence interval (CI): 0.75-0.92] (Figure 2).

In logistic regression analysis, considering total lymph node count, metastatic lymph node count, and TSR, only the metastatic lymph node count remained an independent predictor of mortality (p=0.009, odds ratio: 1.7, 95% CI: 1.03-2.26).

Discussion

Our study showed that a high TSR was associated with high mortality rates and the LNR was significantly associated with mortality. The prognosis of colon cancer is influenced by a variety of factors, including the patient's metabolic status, the pathological and molecular characteristics of the tumor, and the quality of surgical management. In particular, histopathological and molecular biomarkers have emerged as increasingly important prognostic indicators in recent years.[10]

In recent years, the TSR has gained increasing attention as a prognostic biomarker and can be readily determined by pathologists using a standardized assessment of routine histopathological sections. In a recent meta-analysis of 21 studies comprising 7,934 patients with colorectal cancer, a high TSR was identified as a significant indicator of unfavorable outcomes across multiple survival endpoints, including overall, disease-free, cancer-specific, and recurrence-free survival.[11] Similar evidence was provided by Kristensen et al.,[12] who demonstrated that, among patients with stage II colon cancer, a high TSR was associated with a significantly less favorable prognosis than a low TSR. These findings add further support to the prognostic relevance of TSR in colon cancer.[12] With the continued progress of digital pathology technologies, fully automated artificial intelligence-based evaluation of the TSR has shown that a high TSR is an independent prognostic indicator associated with poorer disease-free survival and OS in patients with colon cancer.[13] Our results were consistent with previous evidence, showing a significantly higher mortality rate in the high-TSR group than in the low-TSR group.

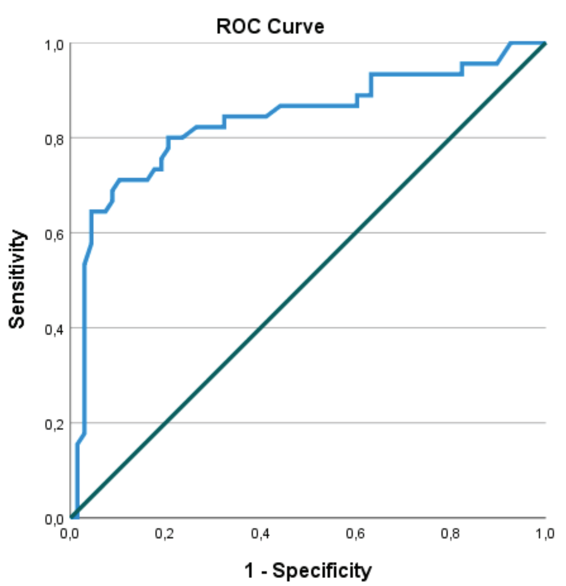

Figure 2. ROC curve of the lymph node ratio for predicting mortality in patients with colon cancer
ROC: Receiver operating characteristic

Elevated LNR values have been associated with an unfavorable prognosis across a variety of malignancies. Several observational studies have reported that higher LNR values are associated with decreased long-term survival across various cancer types, including colorectal, esophageal, breast, and head and neck cancers.[14-16] In a meta-analysis by Ichhpuniani et al.[8] that included 97,631 patients with colon cancer, a higher LNR was found to be significantly associated with reduced OS. In line with previous reports, OS was less favorable among patients with elevated LNR values in our cohort. Moreover, after adjustment for other variables in the multivariable logistic regression model, metastatic lymph node count remained independently associated with mortality.

The TSR is recognized as a marker reflecting the tumor microenvironment, whereas the LNR reflects the nodal tumor burden. These two biomarkers have predominantly been investigated separately, with most studies focusing on their individual prognostic impact on OS. Studies evaluating the combined prognostic value of TSR and LNR are limited. Although no statistically significant association was identified between TSR and LNR in our cohort, the LNR values tended to be higher among patients with a high TSR than among those with a low TSR.

Study Limitations

Several limitations should be considered when interpreting our findings. The retrospective, single-institution nature of the study and the relatively small sample size may limit the extent to which these results can be generalized to broader patient populations. Second, analyses of disease-free and cancer-specific survival could not be performed due to the unavailability of these data.

Conclusion

A growing number of biomarkers have been introduced for the diagnosis, management, and follow-up of patients with colon cancer. Among these, the TSR and LNR have emerged as promising prognostic indicators. In the present study, both TSR and LNR were associated with OS. Further large-scale, multicenter studies evaluating the combined prognostic value of these two biomarkers are warranted to validate our findings and clarify their potential role in prognostic stratification of patients with colon cancer.

Ethics

Ethics Committee Approval: The study was approved by the Non-Interventional Clinical Research Ethics Committee of Bolu Abant İzzet Baysal University (approval number: 2026/296, date: 23.06.2026).

Informed Consent: A retrospective, single-center study.

Footnotes

Authorship Contributions

Surgical and Medical Practices: C.T., B.Ö., Concept: S.P.Ö., Ç.B., Design: S.P.Ö., C.T., Analysis or Interpretation: Ç.B., Literature Search: S.P.Ö., Writing: S.P.Ö.

Conflict of Interest: No conflict of interest was declared by the authors.

Financial Disclosure: The authors have no conflicts of interest including relevant financial interests, activities, relationships, and affiliations.

Declaration Regarding the Use of AI and AI-Assisted Technologies: The authors declare that no artificial intelligence (AI) or AI-assisted technologies were used in the preparation of this manuscript.

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DOI: 10.4274/tjcd.galenos.2026.2026-3-2
Turk J Colorectal Dis 2026;36(3):111-114

CASE REPORT

Double Superior Mesenteric Vein—An often Underrecognized Entity of Surgical Significance: A Case Report

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ABSTRACT

Double superior mesenteric vein (DSMV) is a surgically underrecognized variant of the SMV having very few reports in surgical literature and even fewer intraoperative images. Due to increasing trend of right hemicolectomy with complete mesocolic excision and central venous ligation, exposure of the distal SMV is being performed more regularly. We describe the discovery of DSMV during an extended right hemicolectomy, with intraoperative photograph and preoperative computed tomography images. Being unaware of this variation can cause inadvertent injury to the SMV, significant bleeding and postoperative morbidity. We also review the current knowledge and provide a few clues for intraoperative identification.

Keywords: Double superior mesenteric vein, hemicolectomy, complete mesocolic excision

Introduction

Surgeons are familiar with the anatomy of the superior mesenteric vein (SMV) at the splenoportal junction.[1] However, anatomical variations of the more proximal SMV are rarely encountered, as exposure in this area is usually unnecessary in colonic surgery. Yet, with the recent concepts of complete mesocolon excision (CME) and central venous ligation (CVL) for colon cancers,[2,3] this area is being exposed more frequently during surgery. Variations of the colonic vessels are well described in the literature,[4] but reports of variations in the SMV using intraoperative imaging are limited. Here, we report such a case of a double SMV discovered intraoperatively and confirmed retrospectively on contrast-enhanced computed tomography (CECT) scan images. We also provide a brief overview of the surgical literature on anatomical variations of the proximal SMV. This research was conducted at a tertiary-care research and teaching institute. Informed written patient consent was obtained, and a waiver from the institutional ethics committee was sought for publication of anonymized patient data.

Case Report

A 48-year-old man presented with colicky abdominal pain lasting for 3 months, constipation, and passing blood in the stools. Abdominal CECT showed a colonic mass in the hepatic flexure. Pericolic lymph nodes were enlarged. Colonoscopy showed an ulceroproliferative growth causing luminal narrowing. Biopsy was reported as "signet ring cell adenocarcinoma". Clinical staging was cT3N2M0. An extended right hemicolectomy using CME with CVL was planned.

Intraoperative Procedure

A midline incision was used. Following assessment of intraperitoneal spread, exposure of the SMV was initiated from the root of the mesentery. The main trunk of the middle colic artery was ligated very close to its origin, and the middle colic vein (MCV) was ligated at its draining point on the SMV. The SMV was gradually cleared distally, ligating venous tributaries. However, even after exposing the SMV for a good length, neither the almost constant ileocolic vein (ICV) nor the ileocolic artery (ICA) was found. At this stage, another rather large venous structure was identified to the right of the presumed SMV, and

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Received: 04.04.2026 **Accepted:** 11.06.2026 **Epub:** 25.09.2026 **Publication Date:** 28.09.2026

Cite this article as: Ray R, Baruah TD, Ghosh S, Raj M. Double superior mesenteric vein—an often underrecognized entity of surgical significance: a case report. Turk J Colorectal Dis. 2026;36(3):111-114

the possibility of a double SMV was considered. Thereafter, mesocolic clearance was performed along the medial (right) border of the new vein [right SMV (RSMV)], and the right colic vein (RCV) was identified and ligated. More caudally, the ICV drained into the RSMV, which was then ligated. The ICA was found to traverse beneath the RSMV, originate from the superior mesenteric artery (SMA) on the medial border of the left trunk of the SMV, and was ligated. Thereafter, the extended right hemicolectomy was performed according to standard procedure, and the specimen was delivered with a complete mesocolic envelope. The appearance of the SMV trunks following resection is shown in Figure 1. There was no intraoperative venous injury in this case.

A retrospective review of the preoperative CT images confirmed our finding that the SMV divides into two trunks just below the root of the mesentery, with the SMA running between them (Figure 2). This has been recently classified as a type IIa variant.[5]

The postoperative period was uneventful except for a minor superficial wound infection. The patient was discharged on postoperative day 7 and is undergoing regular follow-up, receiving adjuvant therapy.

Discussion

Although previously described in a few anatomical or radiological studies, anatomical variations of the proximal SMV are not commonly encountered by colorectal surgeons, as exposure of the trunk of the SMV lower down is rarely required during operations such as right hemicolectomy with D2 lymphadenectomy.[6] However, anatomical variations of the proximal SMV are not infrequent and are significant from a surgical perspective. Recently, more radical D3 lymphadenectomy, employing the concepts of CME[2] and CVL, is being performed more widely, as studies have shown it is associated with higher lymph node yield and improved survival.[7,8] This newer technique of CME/CVL has led to renewed recognition of the not-infrequent presence of double SMV trunks. A search of the surgical literature in PubMed using the terms “double” and “superior mesenteric vein” did not yield many studies on this variant, although it has been reported in the anatomy literature.[1] One study[9] from 2010 using three-dimensional (3D) portography reported the presence of two SMV trunks in 23.5% of patients. Another study[10] estimated its presence in only 9.1% of patients. A recent series from China[5] estimated that double SMVs are present in 19% of patients and classified them into four types: Ia, Ib, IIa, and IIb. In type Ia, the right and left SMVs drain independently into the portal vein. In type Ib, the MCV drains into the right SMV. In type IIa, the most common variation [as in our case (Figure 3)], two SMV trunks join to form a common trunk, with the main colonic branches draining into the right SMV. In type IIb, the MCV drains into the left SMV. It was also reported that in one case, the right SMV was inadvertently injured. Injury or ligation of one of the main draining vessels of th bowel is not without its significant consequences. In addition to intraoperative hemorrhage, venous congestion of the small bowel may occur postoperatively, leading to significant

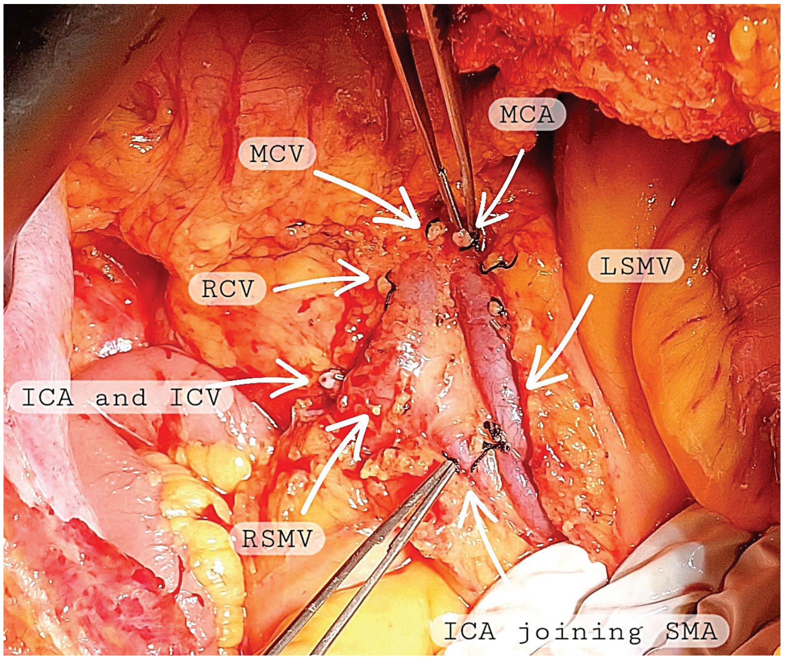

Figure 1. Intraoperative photograph showing double superior mesenteric veins after resection of the specimen
MCV: Middle colic vein, MCA: Middle colic artery, RCV: Right colic vein, ICA and ICV: Ileocolic artery and ileocolic vein, RSMV: Right superior mesenteric vein, LSMV: Left superior mesenteric vein, SMA: Superior mesenteric artery

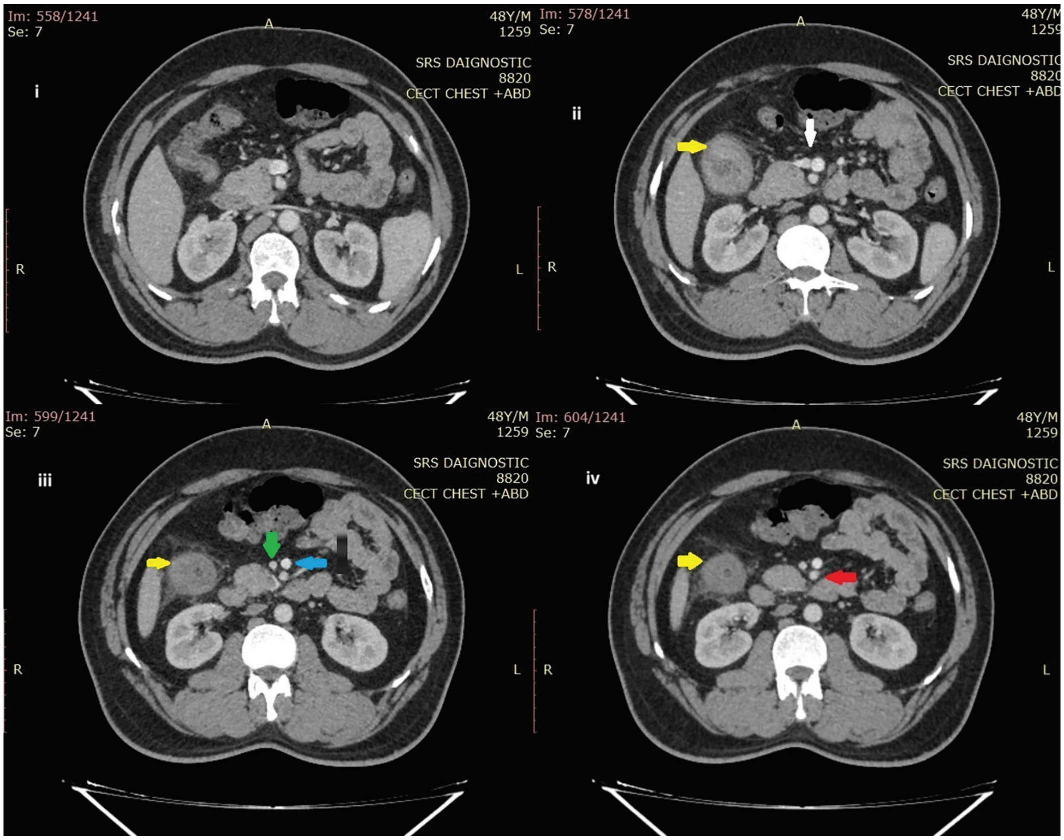

Figure 2. (i-iv) Sequential axial abdominal computed tomography sections showing division of the superior mesenteric vein (SMV) into two trunks and their relationship with the superior mesenteric artery (SMA). Yellow arrow: Colonic mass at hepatic flexure. White arrow: Bifurcation of the SMV into right and left trunks. Light green arrow: Right branch of SMV. Light blue arrow: Left branch of SMV. Red arrow: SMA running between and posterior to the right and left SMVs

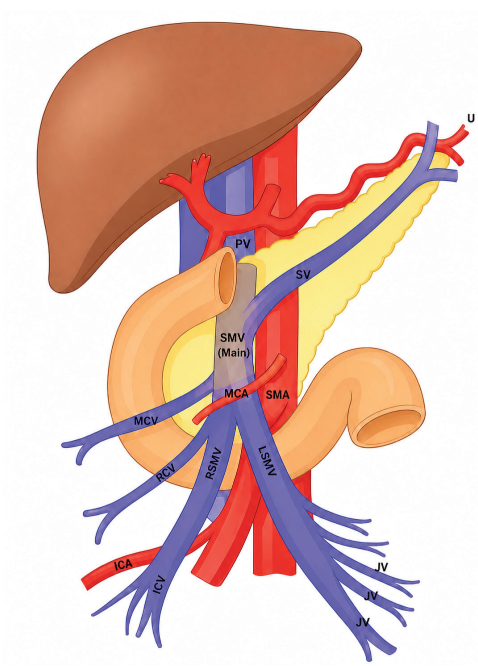

Figure 3. Schematic of the most common variant
MCV: Middle colic vein, MCA: Middle colic artery, RCV: Right colic vein, ICA and ICV: Ileocolic artery and ileocolic vein, RSMV: Right superior mesenteric vein, LSMV: Left superior mesenteric vein, SMA: Superior mesenteric artery

morbidity and even mortality.[11] Such incidences can occur more frequently if the left SMV trunk is mistaken for the main SMV trunk. In such a case, the right trunk, when present, falls inside the mesocolic excision boundary and is highly liable to injury during mesocolic excision. In our case, the recognition of another large venous trunk, with the RCV and ICV draining into it and the ICA passing beneath it, facilitated its discovery and prevented injury. The fact that the variation was not detected on the preoperative CT scan also indicates that preoperative CT scans must be evaluated effectively. Based on our experience, we summarize a few intraoperative clues that can alert the surgeon to the possibility of the presence of double SMV trunks if discovered intraoperatively:

Intraoperative findings indicating the possibility of double SMV trunks:

1. Ileocolic artery passing under a large venous trunk and traced on both sides,

2. Not finding the constant ICV even after exposure of a significant length of the SMV,

3. Middle colic vein crossing the presumed SMV and draining toward the left (type IIb),

4. Another large venous tributary draining into the presumed SMV on the left side.

In such cases, we recommend intraoperative review of the CT scan to confirm the findings. Preoperatively, these variations can be well ascertained in a good-quality triphasic CT scan. Preoperative vascular mapping with 3D reconstruction images may further help in proper delineation of this variant whenever required.

Conclusion

The presence of double trunks of the SMV is an underrecognized finding, present in 9.1-23.5% of patients, and of surgical significance. Unfamiliarity with this variation can lead to inadvertent injury during mesocolic excision, with significant consequences. We recommend paying greater attention to imaging to identify this variation preoperatively. Preoperative vascular mapping may further help delineate this anatomical abnormality.

Ethics

Informed Consent: Written informed consent was obtained from the patient for presentation and publication of all patient-related material.

Footnotes

Authorship Contributions

Surgical and Medical Practices: R.R., T.D.B., S.G., M.R., Concept: R.R., S.G., M.R., Design: R.R., T.D.B., S.G., Data Collection or Processing: R.R., T.D.B., S.G., M.R., Analysis or Interpretation: R.R., T.D.B., S.G., M.R., Literature Search: R.R., T.D.B., M.R., Writing: R.R., T.D.B., S.G., M.R.

Conflict of Interest: There is no conflict of interest.

Financial Disclosure: This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

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DOI: 10.4274/tjcd.galenos.2026.2025-9-3
Turk J Colorectal Dis 2026;36(3):115-120

CASE REPORT

Appendiceal Perforation by Fish Bones: Imaging-Surgical Correlation and Laparoscopic Management in a Three-Case Series

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ABSTRACT

Appendiceal perforation caused by ingested fish bones is rare but clinically significant. Although the presentation often mimics acute appendicitis, sharp foreign bodies may traverse the gastrointestinal tract and cause occult injury. In populations with high fish consumption, maintaining a high index of suspicion and performing careful intraoperative assessment are essential. We report three male patients aged 31-44 years with appendiceal perforation caused by fish bones, none of whom recalled foreign body ingestion. Computed tomography (CT) reports consistently described a linear radiopaque object, with complete imaging documentation available for one patient. All patients underwent emergency laparoscopic appendectomy, confirming isolated fish bone perforation without additional intra-abdominal injuries. Recovery was uneventful, and discharge occurred within 1-3 days. Because most patients are unaware of ingestion, CT plays a pivotal role in diagnosis, and careful laparoscopic exploration remains important to avoid missed injuries or retained foreign bodies. CT combined with thorough intraoperative inspection enables accurate diagnosis and safe, effective laparoscopic management with rapid postoperative recovery.

Keywords: Appendectomy, appendiceal diseases, appendicitis, foreign bodies, laparoscopy

Introduction

Appendiceal perforation caused by ingested fish bones is an uncommon but clinically important condition that may closely mimic routine acute appendicitis. Because most patients do not recall foreign body ingestion and clinical manifestations are often nonspecific, preoperative diagnosis remains challenging, and the underlying etiology may only be recognized intraoperatively.[1,2] In regions with frequent dietary fish consumption, sharp fish bones represent a relevant source of occult gastrointestinal injury and perforation.[3] The appendix, as a narrow, blind-ending structure with limited motility, may serve as a site of foreign body impaction and subsequent inflammation or perforation.[4]

With the increasing use of computed tomography (CT) in the evaluation of acute abdominal pain, preoperative identification of appendiceal foreign bodies has become more feasible. Nevertheless, awareness of this entity remains limited due to its rarity and close resemblance to conventional acute appendicitis. In this study, we present three cases of appendiceal perforation caused by fish bones, focusing on CT-based diagnosis, imaging-surgical correlation, operative findings, and clinical outcomes. By highlighting reproducible diagnostic and intraoperative features, this report aims to provide practical insights for surgeons and radiologists encountering atypical presentations of acute appendicitis.

Case Report

This study was conducted in accordance with the Declaration of Helsinki. Ethical approval was obtained from the Institutional Review Board of the study hospital. Written informed consent was obtained from all patients specifically for the publication of this case series and any accompanying images. Three cases of appendiceal perforation caused by

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Received: 08.10.2025 **Accepted:** 26.06.2026 **Epub:** 25.09.2026 **Publication Date:** 28.09.2026

Cite this article as: Ngo DQ, Tran LH, Nguyen NT. Appendiceal perforation by fish bones: imaging-surgical correlation and laparoscopic management in a three-case series. Turk J Colorectal Dis. 2026;36(3):115-120

ingested fish bone were identified between 2023 and 2025 (Table 1 and Figures 1-3). These cases shared several notable common features while demonstrating distinct individual characteristics (Table 2).

In all cases included in this study, gastrointestinal symptoms were carefully elicited and thoroughly examined by gastrointestinal surgeons. Particular attention was paid to dietary habits, especially frequent fish consumption, defined as eating fish three or more times per week. At our hospital, most patients underwent abdominal ultrasonography and were further evaluated with CT when clinical findings remained unclear and ultrasound was insufficient to establish a definitive diagnosis.

The standard surgical approach for appendectomy at our hospital is laparoscopic appendectomy, with the appendiceal stump routinely managed using a Roeder knot. Abdominal drainage is not routinely performed during laparoscopic appendectomy, even in cases with peritonitis. Although drainage is not routinely used in our practice, a drain was selectively placed in Case 2 according to the surgeon's intraoperative judgment. All resected appendiceal specimens were sent for histopathological examination. Routine postoperative follow-up was scheduled approximately 1 week after surgery, with selective use of ultrasonography and blood tests when clinically indicated.

Table 1. Patient timeline

	Symptom onset duration	Hospital admission (MM/DD/YYYY)	Abdominal and pelvic CT-scan	Surgery	Discharge	Follow-up duration
Case 1	1 day	08/10/2023	Same day	Same day	Day 1	2 years
Case 2	2 days	09/28/2023	Same day	Day 1	Day 4	2 years
Case 3	2 hours	09/04/2025	Same day	Same day	Day 1	4 months

CT: Computed tomography

Table 2. Clinical characteristics, radiologic and intraoperative findings, and outcomes of appendiceal perforation caused by fish bones

	Case 1	Case 2	Case 3
Patient information			
Age (years)	31	44	32
Sex	Male	Male	Male
Symptom duration	1 day	2 days	2 hours
Symptoms			
- Abdominal pain	Right iliac fossa	Right iliac fossa	Right iliac fossa
- Other symptoms (such as fever, vomiting, diarrhea, distension)	No	No	No
Past medical history	Unremarkable	Well-controlled hypertension	Unremarkable
Past surgery	No	No	No
Frequent fish consumption	Yes	Yes	Yes
Ingesting a fish bone	No	No	No
Clinical findings			
Heart rate (bpm)	86	54	80
Blood pressure (mmHg)	110/60	130/80	130/80
Temperature (°C)	37	37	37
Abdominal tenderness	Right iliac fossa	Right iliac fossa	Right iliac fossa
Guarding	(+)	(-)	(-)
Diagnostic assessment			
White blood cell count (1,000/µL)	10.9	9.8	11.2
C-reactive protein (mg/L)	4	4.3	4

Table 2. Continued

	Case 1	Case 2	Case 3
Ultrasound	Appendiceal diameter: 5 mm (base) and 7 mm (tip); wall thickness 2.5 mm; gas-filled and compressible	Not performed	Appendix poorly visualized
Contrast-enhanced computed tomography of the abdomen			
- Diameter of appendix	9 mm	7-8 mm (body) and 10-11 mm (tip)	6 mm
- Appendiceal wall thickness	3 mm	2.5 mm	2 mm
- Free air	No	No	No
- Free fluid	No	No	No
- Abscess	No	No	No
- Foreign body size	19 mm in length (slender)	24 mm in length (slender)	14 mm in length (slender)
- Foreign body location	Appendiceal body	Near the appendiceal tip	Near the appendiceal tip
Therapeutic intervention			
Antibiotic	Ceftriaxone and metronidazole	Ceftriaxone and metronidazole	Cefazolin
Surgery			
- Surgical approach	Laparoscopic	Laparoscopic	Laparoscopic
- Number of trocar	3	3	3
- Foreign body	Fish bone (~20 mm)	Fish bone (~30 mm)	Fish bone (~20 mm)
- Location perforation	Appendiceal body	Near the appendiceal tip	Near the appendiceal tip
- Enteric leakage	No	No	No
- Additional perforations	No	No	No
- Surgical method	Appendectomy	Appendectomy	Appendectomy
- Appendiceal stump closure	Roeder knot	Roeder knot	Roeder knot
- Irrigation	No	Yes	No
- Drain	No	1	No
- Operative time (min)	60	35	85
Follow-up and outcomes			
Histopathology	Perforated acute appendicitis	Perforated acute appendicitis	Perforated acute appendicitis
Length of stay (days)	1	3	1
Outcomes	Complete resolution of symptoms at 1-week follow-up, with no postoperative complications during 2 years of follow-up	Complete resolution of symptoms at 1-week follow-up, with no postoperative complications during 2 years of follow-up	Complete resolution of symptoms at 1-week follow-up, with no postoperative complications during 4 months of follow-up
White blood cell count (1,000/µL)	Not performed	7.7 (1 week postoperatively)	Not performed
C-reactive protein (mg/L)	Not performed	4 (1 week postoperatively)	Not performed
Ultrasound	Not performed	No abnormalities detected (1 week postoperatively)	No abnormalities detected (1 week postoperatively)
Adverse events	No	No	No

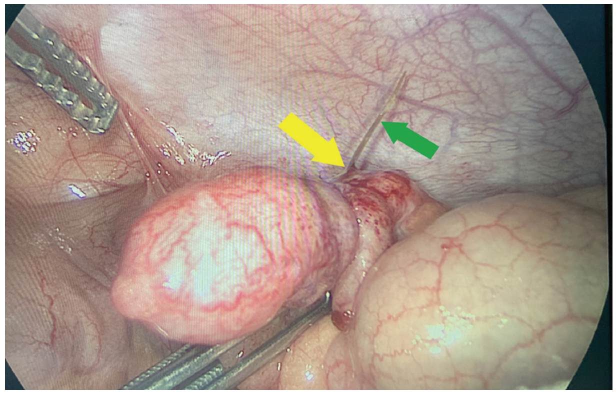

Figure 1. Laparoscopic intraoperative view in Case 1, a 31-year-old male patient, showing the appendix in the right iliac fossa, with a fish bone (green arrow) penetrating the appendiceal wall and causing perforation of the appendiceal body (yellow arrow)

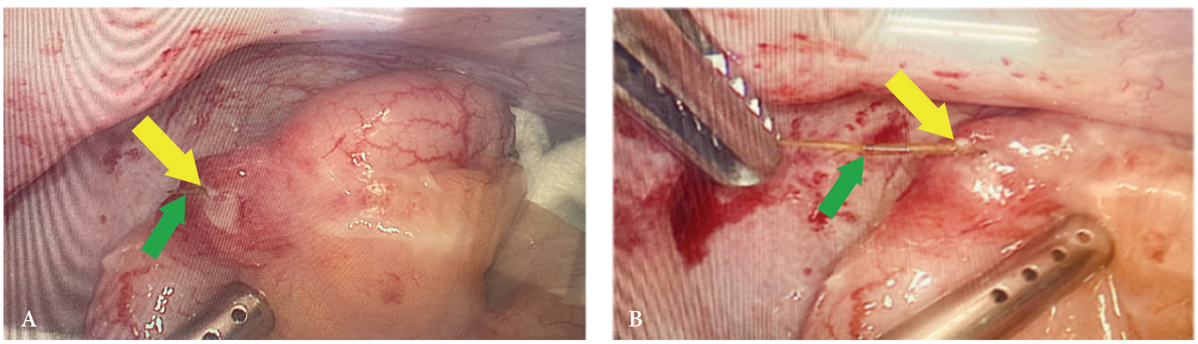

Figure 2. (A) Laparoscopic intraoperative view in Case 2, a 44-year-old male patient, showing the appendix in the right iliac fossa, with a fish bone (green arrow) penetrating the appendiceal wall and causing perforation near the appendiceal tip (yellow arrow). (B) The fish bone (green arrow) after removal from the appendix

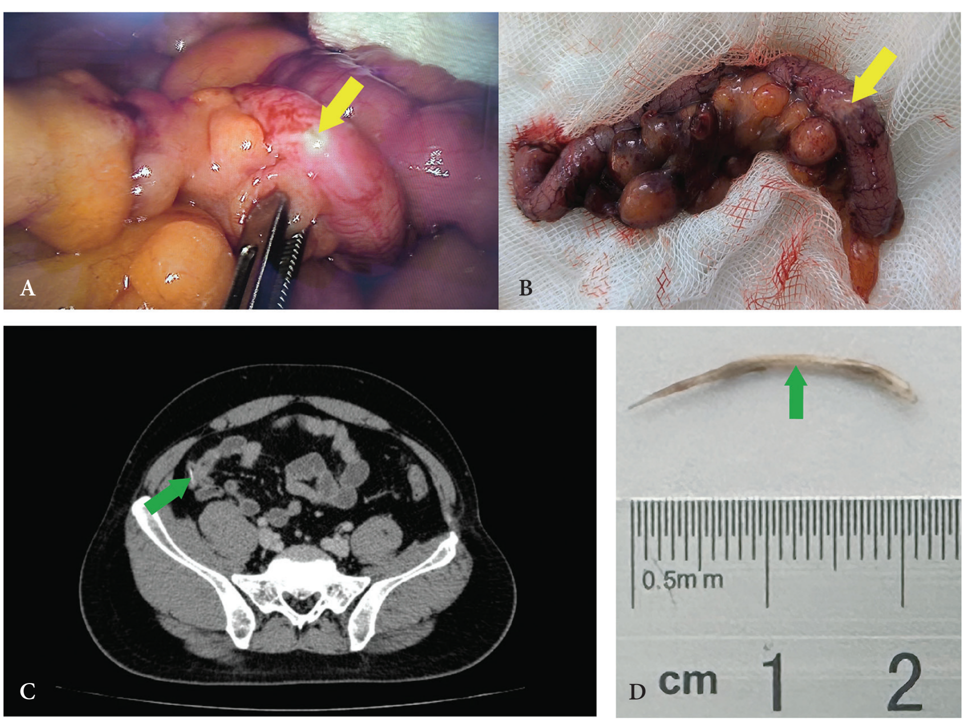

Figure 3. (A) Laparoscopic intraoperative view in Case 3, a 32-year-old male patient, showing perforation near the appendiceal tip (yellow arrow) with surrounding fibrinous exudate. (B) Gross appearance of the resected appendix following appendectomy. (C) Preoperative contrast-enhanced computed tomography demonstrating a linear, slender foreign body (green arrow) penetrating the appendiceal wall. (D) The retrieved fish bone (green arrow) after longitudinal incision of the appendix, measuring approximately 20 mm in length

In all cases, the foreign bodies measured longer after surgical removal than on CT. This discrepancy may be related to differences in the measurement method. The foreign bodies were slightly curved; after removal, their entire length could be measured directly from one end to the other. In contrast, measurements on CT imaging planes may capture only part of a curved foreign body rather than its entire length, potentially resulting in an underestimation of its actual length.

Discussion

Analysis of these three cases revealed several clinically relevant features of appendiceal perforation caused by ingested fish bones. All patients were men and aged 31-44 years, consistent with previous reports by Hoang et al.[1] and Kim et al.[5] Nevertheless, this apparent male predominance should be interpreted cautiously because prior studies have also documented cases in older and female patients.[2] Clinically, all patients presented with right lower quadrant pain mimicking typical acute appendicitis, yet none had fever or marked inflammatory responses. These findings correlated with intraoperative observations demonstrating localized appendiceal perforation without diffuse peritoneal contamination. Notably, none of the patients recalled ingesting a foreign body despite frequent fish consumption, in agreement with previous studies indicating that foreign body ingestion is often unrecognized before presentation.[3]

A notable finding in our series was that CT successfully identified the perforating foreign body in all three cases, enabling definitive preoperative diagnosis despite inconclusive initial clinical assessment and ultrasonography. Previous imaging studies have demonstrated that CT has high diagnostic accuracy for sharp gastrointestinal foreign bodies, with a reported specificity around 93%.[6] These findings highlight the important role of CT in patients with atypical presentations that do not fulfill classic criteria for acute appendicitis. In addition to direct visualization of the foreign body, CT also allows evaluation of associated complications such as mural injury, inflammation, abscess formation, and perforation.[6] Once the perforating object is identified, laparoscopic appendectomy can generally be performed similarly to standard appendicitis. Nevertheless, careful history taking and thorough intraoperative exploration remain important because multiple ingested foreign bodies may occasionally occur, although no such cases were observed in our series.

All retrieved foreign bodies were fish bones, consistent with previous reports identifying bony structures as the most common perforating agents.[7,8] A proposed mechanism involves gravitational migration of the foreign body into the appendiceal lumen combined with limited appendiceal motility, resulting in impaction, mucosal injury, inflammation, and eventual perforation.[4] Although uncommon, other sharp foreign bodies such as chicken bones and toothpicks have also been reported to cause appendiceal perforation.[2] Hu et al.[3] further noted that sharp objects accounted for 55% of ingested foreign bodies associated with gastrointestinal perforation. Compared with perforations at other gastrointestinal sites, appendiceal perforation is relatively favorable because treatment can usually be limited to laparoscopic appendectomy without bowel resection or stoma formation. In our series, histopathological examination showed only acute inflammatory changes without malignancy. All patients recovered uneventfully and were discharged within 1-3 postoperative days, consistent with previous reports demonstrating favorable outcomes after laparoscopic management of foreign body-related appendiceal perforation.[1]

Although appendiceal perforation caused by fish bones has previously been described in isolated case reports, this three-case series demonstrates reproducible clinical, radiologic, and intraoperative patterns across multiple patients.[2,4] This imaging-surgical correlation reinforces the practical value of CT in identifying atypical appendiceal perforation and facilitating appropriate surgical planning.[6] Rather than representing isolated observations, this series highlights clinically reproducible features that may improve diagnostic awareness among surgeons and radiologists evaluating atypical presentations of acute appendicitis.

Several limitations of this study should be considered when interpreting the results. The small sample size and single-center design may limit the generalizability of the findings and restrict the extent to which the results can be extrapolated to broader populations. In addition, the retrospective study design carries an inherent risk of selection and information bias due to reliance on previously recorded data. Moreover, the lack of a comparison group prevents definitive assessment of associations and limits causal inference. In addition, although CT imaging represents a central diagnostic aspect of this study, CT images were available for only one case because imaging data from the earlier cases could not be fully retrieved from the institutional archive. This limited radiologic documentation should therefore be acknowledged as a study limitation. Further large-scale, multicenter prospective studies incorporating appropriate control groups are needed to confirm the present findings.

Conclusion

Appendiceal perforation caused by ingested fish bones is an uncommon but clinically important condition. Careful history taking, particularly regarding dietary habits in populations with frequent fish consumption, remains essential, although most patients do not recall ingesting a foreign body. CT plays a pivotal role in establishing the preoperative diagnosis and should be considered when foreign body-related perforation is suspected. Thorough intraoperative exploration is also important to exclude additional injuries or retained foreign bodies. Laparoscopic appendectomy provides a safe and effective treatment, with favorable outcomes and rapid postoperative recovery, as demonstrated in our series.

Ethics

Informed Consent: Written informed consent was obtained from all patients specifically for the publication of this case series and any accompanying images.

Footnotes

Authorship Contributions

Surgical and Medical Practices: D.Q.N., L.H.T., N.T.N., Concept: D.Q.N., L.H.T., N.T.N., Design: D.Q.N., L.H.T., N.T.N., Data Collection or Processing: D.Q.N., L.H.T., N.T.N., Analysis or Interpretation: D.Q.N., L.H.T., N.T.N., Literature Search: D.Q.N., L.H.T., N.T.N.,Writing: D.Q.N., L.H.T., N.T.N.

Conflict of Interest: The authors declare that they have no conflicts of interest relevant to the content of this article.

Financial Disclosure: This research did not receive any specific grant from funding agencies in the public, commercial, or notfor-profit sectors.

Declaration Regarding the Use of AI and AI-Assisted Technologies: During manuscript preparation, ChatGPT (OpenAI) was used solely at the final proofreading stage, after the manuscript had been fully written by the authors, to identify and correct errors in English grammar, spelling, and punctuation. The AI tool was not involved in generating, developing, or writing any part of the manuscript or its scientific content. All corrections were reviewed and approved by the authors, who take full responsibility for the final content.

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