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

Cenk Parlatan[1], Şeyda Gökçe Turunç[2], Okan Dilek[2]

[1]Başkent University, Adana Dr. Turgut Noyan Application and Research Center, Department of Radiology, Adana, Türkiye
[2]University of Health Sciences Türkiye, Adana City Hospital, Clinic of Radiology, Adana, Türkiye

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 $\leq 0.95\times10^{-3}$ mm^2/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.

Address for Correspondence: Cenk Parlatan, MD, Başkent University, Adana Dr. Turgut Noyan Application and Research Center, Department of Radiology, Adana, Türkiye
E-mail: cenkparlatan@gmail.com **ORCID ID:** orcid.org/0000-0001-9272-3895
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]

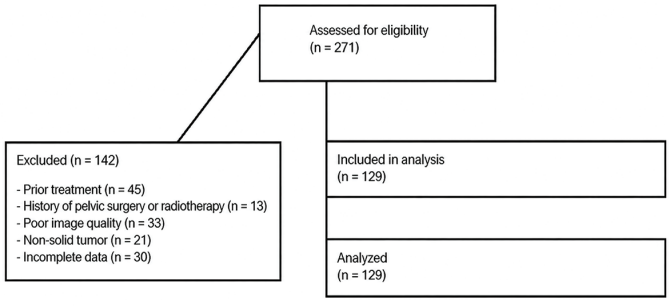

Figure 1. Flow diagram of patient selection

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)

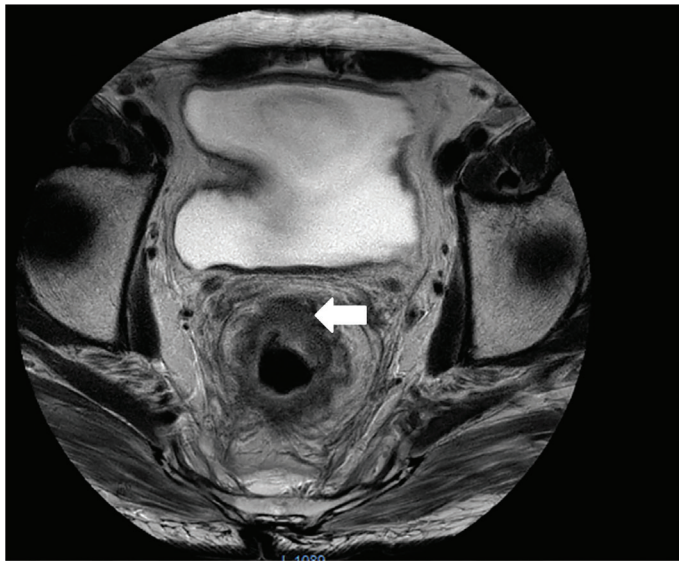

Figure 2. Axial high-resolution T2-weighted MRI of a 56-year-old female patient showing a rectal tumor (arrow). The tumor-mesorectal fascia relationship is demonstrated and used as a reference for ROI placement on the solid tumor component for ADC measurements, avoiding non-solid areas
MRI: Magnetic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

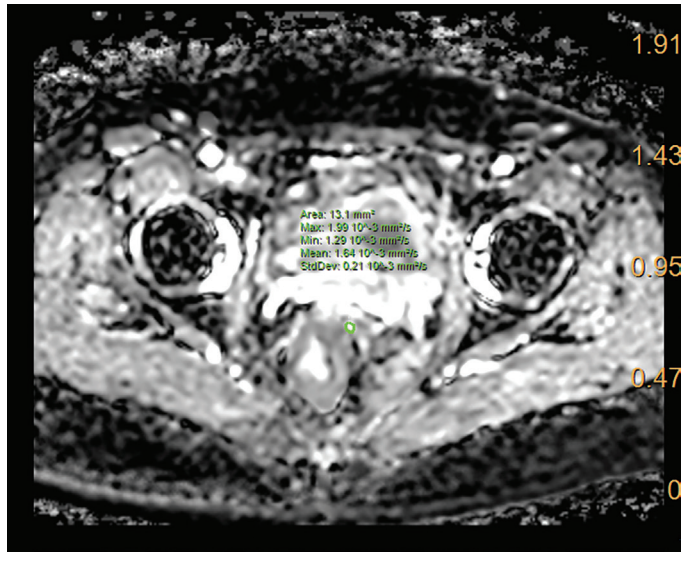

Figure 3. Axial apparent diffusion coefficient (ADC) map of the same patient shown in Figure 2, demonstrating ROI placement on the solid tumor component. Quantitative ADC measurements (minimum, mean, and maximum) were obtained from this region
ROI: Region of interest

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±0.42×10^{-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±0.50×10^{-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±0.60×10^{-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±0.39×10^{-3} mm^2/s in patients without MRF involvement versus 0.70±0.31×10^{-3} mm^2/s in those with involvement. Corresponding mean ADC values were 1.51±0.49×10^{-3} mm^2/s and 1.04±0.39×10^{-3} mm^2/s, respectively, whereas maximum ADC values were 1.88±0.57×10^{-3} mm^2/s and 1.43±0.55×10^{-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 ≤0.95×10^{-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 ≤1.30×10^{-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 ≤1.70×10^{-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

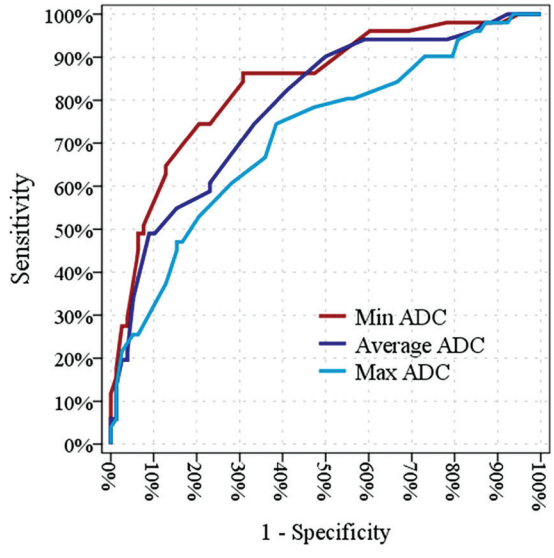

Figure 4. Receiver operating characteristic curves of minimum, average, and maximum ADC values for predicting mesorectal fascia involvement. Minimum ADC demonstrated the highest diagnostic performance compared with mean and maximum ADC values
ADC: Apparent diffusion coefficient

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.

REFERENCES

1. Tapan U, Ozbayrak M, Tatlı S. MRI in local staging of rectal cancer: an update. Diagn Interv Radiol. 2014;20:390-398.
2. Brown G, Radcliffe AG, Newcombe RG, Dallimore NS, Bourne MW, Williams GT. Preoperative assessment of prognostic factors in rectal cancer using high-resolution magnetic resonance imaging. Br J Surg. 2003;90:355-364.
3. Schurink NW, Lambregts DMJ, Beets-Tan RGH. Diffusion-weighted imaging in rectal cancer: current applications and future perspectives. Br J Radiol. 2019;92:20180655.
4. Kargol J, Rudnicki W, Kenig J, Filipowska J, Kaznowska E, Kluz T, Guz W, Łuczyńska E. Diffusion-weighted magnetic resonance imaging of 103 patients with rectal adenocarcinoma identifies the apparent diffusion coefficient as an imaging marker for tumor invasion and regional lymph node involvement. Med Sci Monit. 2021;27:e934941.
5. Nasu K, Kuroki Y, Minami M. Diffusion-weighted imaging findings of mucinous carcinoma arising in the ano-rectal region: comparison of apparent diffusion coefficient with that of tubular adenocarcinoma. Jpn J Radiol. 2012;30:120-127.
6. Sun Y, Tong T, Cai S, Bi R, Xin C, Gu Y. Apparent diffusion coefficient (ADC) value: a potential imaging biomarker that reflects the biological features of rectal cancer. PLoS One. 2014;9:e109371.

7. Huang A, Yang Y, Shi JY, Li YK, Xu JX, Cheng Y, Gu J. Mucinous adenocarcinoma: a unique clinicopathological subtype in colorectal cancer. World J Gastrointest Surg. 2021;13:1567-1583.
8. Nagtegaal ID, Odze RD, Klimstra D, Paradis V, Rugge M, Schirmacher P, Washington KM, Carneiro F, Cree IA; WHO Classification of Tumours Editorial Board. The 2019 WHO classification of tumours of the digestive system. Histopathology. 2020;76:182-188.
9. Taylor FG, Quirke P, Heald RJ, Moran B, Blomqvist L, Swift I, St Rose S, Sebag-Montefiore DJ, Tekkis P, Brown G; MERCURY study group. One millimetre is the safe cut-off for magnetic resonance imaging prediction of surgical margin status in rectal cancer. Br J Surg. 2011;98:872-879.
10. Beets-Tan RGH, Lambregts DMJ, Maas M, Bipat S, Barbaro B, Curvo-Semedo L, Fenlon HM, Gollub MJ, Gourtsoyianni S, Halligan S, Hoeffel C, Kim SH, Laghi A, Maier A, Rafaelsen SR, Stoker J, Taylor SA, Torkzad MR, Blomqvist L. Magnetic resonance imaging for clinical management of rectal cancer: updated recommendations from the 2016 European Society of Gastrointestinal and Abdominal Radiology (ESGAR) consensus meeting. Eur Radiol. 2018;28:1465-1475. Erratum in: Eur Radiol. 2018;28:2711.
11. Fernandes MC, Gollub MJ, Brown G. The importance of MRI for rectal cancer evaluation. Surg Oncol. 2022;43:101739.
12. Iafrate F, Laghi A, Paolantonio P, Rengo M, Mercantini P, Ferri M, Ziparo V, Passariello R. Preoperative staging of rectal cancer with MR imaging: correlation with surgical and histopathologic findings. Radiographics. 2006;26:701-714.
13. Wolberink SV, Beets-Tan RG, Nagtegaal ID, Wiggers T. Preoperative assessment of the circumferential margin in rectal cancer is more informative in treatment planning than the T stage. Tech Coloproctol. 2006;10:171-176.
14. Le Bihan D. Apparent diffusion coefficient and beyond: what diffusion MR imaging can tell us about tissue structure. Radiology. 2013;268:318-322.
15. Vermoolen MA, Kwee TC, Nievelstein RA. Apparent diffusion coefficient measurements in the differentiation between benign and malignant lesions: a systematic review. Insights Imaging. 2012;3:395-409.
16. Padhani AR, Liu G, Koh DM, Chenevert TL, Thoeny HC, Takahara T, Dzik-Jurasz A, Ross BD, Van Cauteren M, Collins D, Hammoud DA, Rustin GJ, Taouli B, Choyke PL. Diffusion-weighted magnetic resonance imaging as a cancer biomarker: consensus and recommendations. Neoplasia. 2009;11:102-125.
17. Hirano M, Satake H, Ishigaki S, Ikeda M, Kawai H, Naganawa S. Diffusion-weighted imaging of breast masses: comparison of diagnostic performance using various apparent diffusion coefficient parameters. AJR Am J Roentgenol. 2012;198:717-722.
18. Surov A, Meyer HJ, Wienke A. Associations between apparent diffusion coefficient (ADC) and KI 67 in different tumors: a meta-analysis. Part 2: ADC_{min}. Oncotarget. 2018;9:8675-8680.
19. Blažić I, Maksimović R, Gajić M, Šaranović Đ. Apparent diffusion coefficient measurement covering complete tumor area better predicts rectal cancer response to neoadjuvant chemoradiotherapy. Croat Med J. 2015;56:460-469.
20. Yacheva A, Dardanov D, Zlatareva D. The multipurpose usage of diffusion-weighted MRI in rectal cancer. Medicina (Kaunas). 2023;59:2162.
21. Peng Y, Luo Y, Hu X, Shen Y, Hu D, Li Z, Kamel I. Quantitative T2*-weighted imaging and reduced field-of-view diffusion-weighted imaging of rectal cancer: correlation of r2* and apparent diffusion coefficient with histopathological prognostic factors. Front Oncol. 2021;11:670156.
22. Zhang J, Ge Y, Zhang H, Wang Z, Dou W, Hu S. Quantitative T2 mapping to discriminate mucinous from nonmucinous adenocarcinoma in rectal cancer: comparison with diffusion-weighted imaging. Magn Reson Med Sci. 2022;21:593-598.
23. Lambregts DM, Beets GL, Maas M, Curvo-Semedo L, Kessels AG, Thywissen T, Beets-Tan RG. Tumour ADC measurements in rectal cancer: effect of ROI methods on ADC values and interobserver variability. Eur Radiol. 2011;21:2567-2574.