EJMI

DOI: 10.14744/ejmi.269296
EJMI 2026;10(3):296–302

Research Article

Evaluation of the Relationship Between SUVmax Measured on F-18 FDG PET/CT, Disease Stage, and Serum Tumor Markers in Colorectal Adenocarcinomas

Zeynep Akar ,[1] Ali Şahin[2]

[1]Department of Nuclear Medicine, Balikesir Ataturk City Hospital, Balikesir, Türkiye
[2]Department of Nuclear Medicine, Faculty of Medicine, Ataturk University, Erzurum, Türkiye

Abstract

Objectives: This study aimed to investigate the relationship between the maximum standardized uptake value (SUVmax) measured by Fluorine-18 fluorodeoxyglucose positron emission tomography/computed tomography (F-18 FDG PET/CT) and disease stage, presence of distant metastasis, and serum tumor markers in patients with colorectal adenocarcinoma.

Methods: This retrospective study included 92 patients with histopathologically confirmed colorectal cancer who underwent F-18 FDG PET/CT for staging purposes between January 1, 2005, and February 1, 2015. Demographic characteristics, clinical nodal status, histopathological findings, serum tumor markers.[carcinoembryonic antigen (CEA) and carbohydrate antigen 19-9 (CA19-9)], and complete blood count parameters were recorded. Neutrophil-lymphocyte ratio (NLR), platelet-lymphocyte ratio (PLR), lymphocyte-monocyte ratio (LMR), and systemic immune-inflammatory index (SII) were calculated from peripheral blood counts. SUVmax values were determined for the primary tumor in PET/CT images, and the presence of metastasis was evaluated. The diagnostic performance of parameters in predicting metastasis was examined using receiver operating characteristic (ROC) curve analysis, and related factors were evaluated using univariate and multivariate logistic regression analyses.

Results: Of the patients, 66.3% were male, and 47.8% had stage 4 disease. In ROC analysis, the area under the curve (AUC) for primary tumor SUVmax was 0.667 (p=0.006) with a cut-off of 11.24 for predicting metastasis. CA19-9 (AUC: 0.707; p=0.001), NLR (AUC: 0.705; p=0.001), PLR (AUC: 0.646; p=0.016), and SII (AUC: 0.736; p<0.001) were significantly associated with metastasis. In univariate analysis, patients with positive lymph nodes had approximately a 7-fold increased risk of metastasis (OR: 7.18; p<0.001). SUVmax >= 11.24 (OR: 2.82; p=0.018), CA19-9 >= 89.8 (OR: 2.38; p=0.048), NLR >= 3.84 (OR: 5.47; p<0.001), PLR >= 238.3 (OR: 3.22; p=0.007), and SII >= 1462.1 (OR: 7.09; p<0.001) were identified as predictive factors for metastasis. In patients with LMR >= 0.25, an inverse relationship with metastasis was observed (OR: 0.21; p=0.001). In multivariate analysis, clinical nodal positivity (OR: 11.20; p<0.001), primary tumor SUVmax >= 11.24 (OR: 6.26; p=0.003), and SII >= 1462.1 (OR: 13.84; p<0.001) were identified as independent predictive factors for the presence of metastasis.

Conclusion: In colorectal cancer patients, the primary tumor SUVmax value obtained from F-18 FDG PET/CT, when evaluated together with systemic inflammation markers and clinical nodal status, significantly contributes to predicting the presence of distant metastasis. In particular, the combined use of SUVmax and SII may provide valuable clinical guidance in preoperative risk stratification and treatment planning.

Keywords: Colorectal adenocarcinoma, F-18 FDG PET/CT, neoplasm staging, suvmax, systemic ımmune-ınflammatory ındex (sıı), tumor markers

Cite This Article: *Akar Z, Şahin A. Prognostic Evaluation of the Relationship Between SUVmax Measured on F-18 FDG PET/CT, Disease Stage, and Serum Tumor Markers in Colorectal Adenocarcinomas. EJMI 2026;10(3):296–302.*

Address for correspondence: Zeynep Akar MD, Department of Nuclear Medicine, Balikesir Ataturk City Hospital, Balikesir, Türkiye
Phone: +90 507 502 65 17 **E-mail:** drzeynepakar@gmail.com

Submitted Date: April 7, 2026 **Revised Date:** July 3, 2026 **Accepted Date:** August 3, 2026

©Copyright 2026 by Eurasian Journal of Medicine and Investigation - Available online at www.ejmi.org
OPEN ACCESS This work is licensed under a Creative Commons Attribution-NonCommercial 4.0 International License.

Colorectal cancer ranks as the third most commonly diagnosed malignancy and remains a major contributor to cancer-related deaths.[1] Accurate identification of metastases and precise staging are considered critical factors in clinical management for determining appropriate treatment modalities, such as surgery, palliative systemic therapies, or metastasis ablation.[2]

The main purpose of systemic imaging in colorectal cancer is to evaluate the primary tumor locally, determine regional lymph node status, identify distant metastases, and select the patient group that may require surgery. For this purpose, F-18 FDG PET/CT, a hybrid method that combines structural and functional imaging data, makes significant contributions in colorectal cancer, especially in cases of suspected limited metastatic disease, preoperative evaluation, resolution of ambiguous lesions during initial staging, and suspicion of recurrence with elevated tumor markers.[3]

PET/CT is still not routinely offered as an imaging modality due to its high cost and insufficient accessibility.[4] However, with increasing technological advancements, AI-integrated PET/CT modalities, and decreasing costs, PET/CT may become one of the standard diagnostic evaluation tests in the future.[5,6]

SUVmax, a commonly used parameter in PET/CT imaging of cancer, is a semi-quantitative measure reflecting the highest FDG uptake within a lesion, and its relationship with prognosis, stage, and biological characteristics has been investigated in various studies.[7] Similarly, in cancer biology, the diagnostic potential of inflammation, tumor microenvironment status, blood parameters, and the presence of metastasis is actively being investigated.

It is known that systemic inflammation can be assessed using simple indices derived from peripheral blood cells, including the neutrophil-to-lymphocyte ratio (NLR), platelet-to-lymphocyte ratio (PLR), lymphocyte-to-monocyte ratio (LMR), and systemic immune-inflammation index (SII). Studies have reported that these indices are associated with clinicopathological characteristics, the presence of distant metastasis, and prognosis in colorectal cancer.[8,9] However, there are a limited number of studies showing that diagnostic PET/CT SUVmax values, along with peripheral blood parameters, can predict the presence of distant metastases in these patients.[10]

The present analysis explored the association between SUVmax values derived from F-18 FDG PET/CT imaging and disease stage, along with circulating tumor marker concentrations, in colorectal adenocarcinoma.

Methods

Study Design and Patient Group

Patients with a diagnosis of colon cancer who underwent FDG-PET imaging at the Department of Nuclear Medicine, XXXX University Faculty of Medicine, between January 01, 2005, and February 01, 2015, were included in this retrospective study. Patients with a histopathological diagnosis of colon adenocarcinoma confirmed by colonoscopic biopsy and who underwent F-18 FDG PET/CT for pre-treatment staging were included in the study. Patients without prior PET/CT examination, those with incomplete clinical or laboratory data, those with a concomitant secondary malignancy, and those with non-sensitive tumor markers (CEA<5 ng/mL and CA19-9 <= 37 U/mL) were excluded from the study.

Demographic data (age, sex), clinical findings (stage, clinical nodal status), pathological features (tumor localization, histological grade), and laboratory parameters of the patients were retrospectively recorded from the hospital archives. Serum tumor markers, CEA and CA19-9, measured before PET/CT scans were recorded. In addition, complete blood count parameters obtained before PET/CT scans were evaluated.

Before initiating the study, approval was formally obtained from the Ethics Committee for Non-Interventional Clinical Research, Faculty of Medicine, Atatürk University (approval date: February 19, 2015; session no: 1; decision no: 09) and accepted as a thesis study by the Department of Internal Medicine (session no: 4; decision no: 34; date: December 17, 2014). All study procedures complied with the guidelines of the Declaration of Helsinki.

F-18 FDG PET/CT Imaging Protocol

All patients were fasted for at least 6 hours before imaging. Blood glucose levels were measured prior to scan administration, and F-18 FDG was administered intravenously to patients within appropriate glycemic limits. After injection, patients rested in a quiet and dimly lit environment for approximately 60 minutes to minimize muscle activity.

Imaging was performed using a PET/CT scanner extending from the base of the skull to the mid-thigh level. First, low-dose computed tomography (CT) images were obtained for attenuation correction and anatomical correlation. PET emission images were then acquired for the same anatomical region, and the PET and CT datasets were fused and evaluated. Disease staging and identification of metastatic spread were performed using these PET/CT images.

Evaluation of PET/CT Images

Experienced nuclear medicine specialists assessed the images using visual inspection alongside semi-quantitative

methods. Foci showing significantly increased FDG uptake compared to surrounding tissues were considered pathological. After identifying the primary tumor lesion, a region of interest (ROI) was drawn over the lesion, and SUVmax was calculated. The SUVmax value was obtained by normalizing the highest pixel activity within the lesion relative to the injected activity and the patient's total body weight. The presence of distant metastases was evaluated according to PET/CT findings, and patients were categorized based on metastatic status.

Statistical Analysis

All statistical evaluations were conducted using SPSS software (version 24.0; SPSS Inc., Chicago, IL, USA) in combination with Microsoft Excel 2019 (Version 2503, 32-bit). Receiver operating characteristic (ROC) curve analysis was used to evaluate the diagnostic performance of laboratory and imaging parameters in predicting the presence of metastasis and to determine optimal cut-off values. The optimal cut-off value was determined using the Youden index, after which the corresponding sensitivity and specificity values were calculated.[11]

For variables that did not reach statistical significance in the ROC analysis, the median value was accepted as the cut-off and included in the analyses, following methods used in previous studies.[12] To explore factors related to metastasis, univariate logistic regression analysis was conducted. Variables with statistical significance ($p<0.05$) were then incorporated into a multivariate logistic regression model. The multivariate model was constructed using the Forward-LR (stepwise) method, and results were reported as odds ratios (OR) and 95% confidence intervals (CI). A two-sided p-value of<0.05 was considered statistically significant, and a Type I error level below 5% was set as the significance criterion.

Results

A total of 92 colon cancer patients were included in the study. Of these patients, 34 (37.0%) were under 60 years of age, and 61 (66.3%) were male. According to body mass index, 37 (40.2%) patients had a BMI<25 kg/m2, and the cancer was located in the left colon in 33 (35.9%) patients and in the right colon in 59 (64.1%) patients. Histological grade distribution was determined as grade 1–2 in 42 (45.7%) patients and grade 3 in 50 (54.3%) patients. Overall, 48 (52.2%) patients were <= stage 3, and 44 (47.8%) were stage 4. Clinical nodal status was positive in 28 (30.4%) patients, CEA was elevated in 46 (50.0%) patients, CA19-9 was >= 89.8 U/mL in 55 (59.8%) patients, and primary tumor SUVmax was >= 11.24 in 53 (57.6%) patients (Table 1).

Table 1. Patient characteristics

Age	**<60**	**34**	**37.0**
	≥60	58	63.0
Sex	Male	61	66.3
	Female	31	33.7
BMI	<25	37	40.2
	≥25	55	59.8
Tumor location	Left	33	35.9
	Right	59	64.1
Grade	1-2	42	45.7
	3	50	54.3
Stage	≤3	48	52.2
	4	44	47.8
Clinical node	Positive	28	30.4
	Negative	64	69.6
CEA (median)	<24.2	46	50.0
	≥24.2	46	50.0
CA19-9	<89.8	37	40.2
	≥89.8	55	59.8
Primary SUVmax	<11.24	39	42.4
	≥11.24	53	57.6

BMI: Body mass index; CEA: Carcinoembryonic antigen; CA19-9: Carbohydrate antigen 19-9; SUVmax: Maximum standardized uptake value.

ROC analysis was performed to assess parameters for metastasis detection. CEA showed no significant discriminative ability (AUC: 0.467, p=0.590). In contrast, SUVmax (AUC: 0.667, cut-off: 11.24), CA19-9 (AUC: 0.707, cut-off: 89.8), and NLR (AUC: 0.705, cut-off: 3.84) demonstrated moderate performance. PLR showed lower accuracy (AUC: 0.646), while LMR had poor discriminative value (AUC: 0.297). Among all parameters, SII yielded the highest diagnostic performance (AUC: 0.736, cut-off: 1462.1), with a sensitivity of 79.5% and a specificity of 64.6% (Table 2) (Fig. 1).

In univariate analysis, clinical nodal positivity (OR: 7.18, 95% CI: 2.41–21.34, p<0.001), primary SUVmax >= 11.24 (OR: 2.82, 95% CI: 1.19–6.67, p=0.018), CA19-9 >= 89.8 (OR: 2.38, 95% CI: 1.01–5.63, p=0.048), NLR >= 3.84 (OR: 5.47, 95% CI: 2.22–13.50, p<0.001), PLR >= 238.3 (OR: 3.22, 95% CI: 1.37–7.57, p=0.007), and SII >= 1462.1 (OR: 7.09, 95% CI: 2.77–18.18, p<0.001) were found to be predictive of metastasis. LMR >= 0.25 was associated with a lower incidence of metastasis (OR: 0.21, 95% CI: 0.09–0.51, p=0.001). Being 60 years of age or older (OR: 1.53, p=0.329), female sex (OR: 1.38, p=0.372), BMI >= 25 kg/m2 (OR: 1.13, p=0.767), left-sided tumor (OR: 0.79, p=0.597), high histological grade (grade 3) (OR: 1.25, p=0.344), and CEA >= 24.2 (OR: 0.70, p=0.404) were not predictive factors for metastasis (Table 3).

Table 2. ROC curve analysis values and optimal cut-off points for the detection of metastasis

Variable	AUC (95% CI)	p	Cut-off	Sensitivity (%)	Specificity (%)
CEA	0.467 (0.348–0.587)	0.590	—	—	—
Colon SUVmax	0.667 (0.557–0.778)	0.006	11.24	70.5	54.2
CA19-9	0.707 (0.601–0.814)	0.001	89.8	70.5	52.1
NLR	0.705 (0.598–0.812)	0.001	3.84	75.0	64.6
PLR	0.646 (0.534–0.759)	0.016	238.3	65.9	62.5
LMR*	0.297 (0.189–0.404)	0.001	0.25	70.8	65.9
SII	0.736 (0.635–0.837)	<0.001	1462	79.5	64.6

AUC: Area under the curve; CI: Confidence interval; CEA: Carcinoembryonic antigen; SUVmax: Maximum standardized uptake value; CA19-9: Carbohydrate antigen 19-9; NLR: Neutrophil-to-lymphocyte ratio; PLR: Platelet-to-lymphocyte ratio; LMR: Lymphocyte-to-monocyte ratio; SII: systemic immune-inflammation index; ROC: Receiver operating characteristic. *For LMR, the curve has been reversed.

In multivariate analysis, clinical nodal positivity (OR: 11.20, 95% CI: 2.96–42.38, p<0.001), primary SUVmax >= 11.24 (OR: 6.26, 95% CI: 1.87–20.93, p=0.003), and SII >= 1462.1 (OR: 13.84, 95% CI: 4.02–47.63, p<0.001) were found to be significantly associated with metastasis (Table 3).

Discussion

In this study, we investigated the predictive properties of primary SUVmax parameters from PET/CT, along with serum tumor markers (CEA, CA19-9) and inflammation-related parameters, for metastasis detection.

In the univariate analysis, clinical nodal positivity (OR: 7.18, p<0.001), primary SUVmax >= 11.24 (OR: 2.82, p=0.018), CA19-9 >= 89.8 (OR: 2.38, p=0.048), NLR >= 3.84 (OR: 5.47, p<0.001), PLR >= 238.3 (OR: 3.22, p=0.007), and SII >= 1462.1 (OR: 7.09, p<0.001) were significantly associated with the presence of metastasis. An LMR value >= 0.25 was inversely correlated with the presence of metastasis (OR: 0.21, p=0.001). In contrast, age >= 60 years, female sex, BMI >= 25 kg/m2, left-sided tumor, high histological grade, and CEA >= 24.2 did not show a significant association in predicting the presence of metastasis. In multivariate analysis, clinical nodal positivity (OR: 11.20, p<0.001), primary SUVmax >= 11.24 (OR: 6.26, p=0.003), and SII >= 1462.1 (OR: 13.84, p<0.001) demonstrated independent predictive value for the presence of metastasis.

Table 3. Univariate and multivariate logistic regression analysis for detection of metastasis in colon cancer

Variable	Category	Univariate OR (95% CI)	p	Multivariate OR (95% CI) *	p
Age	<60 vs ≥60	1.53 (0.65–3.60)	0.329		
Sex	Female vs Male	1.38 (0.68–2.79)	0.372		
BMI	<25 vs ≥25	1.13 (0.49–2.62)	0.767		
Tumor location	Left vs Right	0.79 (0.34–1.86)	0.597		
Grade	1–2 / 3	1.25 (0.78–2.01)	0.344		
Clinical node	Positive/Negative	7.18 (2.41–21.34)	<0.001	11.20 (2.96-42.38)	<0.001
Colon SUVmax	11.24 / ≥11.24	2.82 (1.19–6.67)	0.018	6.26 (1.87-20.93)	0.003
CEA (median)	<24.2 / ≥24.2	0.70 (0.31–1.60)	0.404		
CA 19-9	<89.8 / ≥89.8	2.38 (1.01–5.63)	0.048		
NLR	<3.84 / ≥3.84	5.47 (2.22–13.50)	<0.001		
PLR	<238.3 / ≥238.3	3.22 (1.37–7.57)	0.007		
LMR	<0.25 / ≥0.25	0.21 (0.09–0.51)	0.001		
SII	<1462 / ≥1462	7.09 (2.77–18.18)	<0.001	13.84 (4.02-47.63)	<0.001

OR: Odds ratio; CI: Confidence interval; BMI: Body mass index; CEA: Carcinoembryonic antigen; CA19-9: Carbohydrate antigen 19-9; NLR: Neutrophil-to-lymphocyte ratio; PLR: Platelet-to-lymphocyte ratio; LMR: Lymphocyte-to-monocyte ratio; SII: Systemic immune-inflammation index; SUVmax: Maximum standardized uptake value. Seven parameters that were statistically significant in the univariate analysis (clinical node, SUVmax, CA19-9, NLR, PLR, LMR, and SII) were included in the multivariate forward-LR analysis, and the statistically significant final step was presented as the final model.

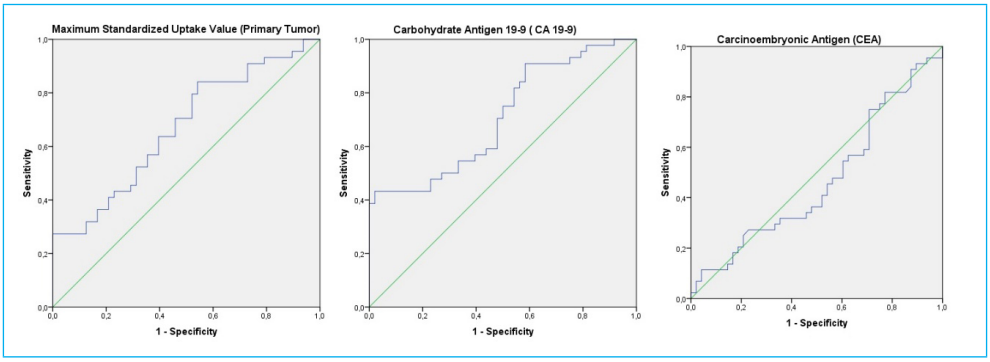

Figure 1. ROC-curve graph for metastasis detection of CEA, CA19-9 with primer SUVmax.

F-18 FDG PET/CT imaging is widely used in the detection and staging of many types of cancer, including lung cancer, breast cancer, and gastrointestinal cancers.[13–16] It also provides significant benefits in the diagnosis, staging, and follow-up of colorectal cancer.[17–19] This method, which allows for accurate preoperative visualization of cancer foci, can enable surgeons to perform more complete tumor resections, contributing to improved clinical outcomes and long-term survival.[20]

Semi-quantitative analyses performed with F-18 FDG PET/CT are increasingly used in predicting clinical outcomes and evaluating treatment response because changes in tumor metabolism can be observed before changes in tumor size.[20] Therefore, increases in tumor SUV values can indirectly provide information about the prognosis of the disease. The literature reports that preoperative SUVmax values are associated with prognosis and that patients with lower SUVmax values achieve longer survival.[21] It has also been shown that regional lymph node SUVmax values can serve as a prognostic marker.[22] Our findings support the potential of SUVmax measurements for clinical use, suggesting that preoperative SUVmax values alone can provide information about disease stage and, indirectly, patient prognosis.

CEA and CA19-9 are the most commonly used serum tumor markers in colorectal cancer, and elevated preoperative levels have been associated with poor prognosis.[23,24] Serum CEA levels have been reported to relate to tumor stage and metastasis, while CA19-9 levels correlate with disease stage. CEA and CA19-9 are the most studied tumor markers associated with gastrointestinal malignancies. Preoperative CEA levels are useful in predicting tumor prognosis, while postoperative CEA levels are useful in interpreting residual tumor tissue or recurrence/metastasis. In a study of 2,230 patients by Park et al.[25], preoperatively elevated CEA levels were identified as an independent poor prognostic factor. Harrison et al.[26] reached similar conclusions in their study. Although our study did not demonstrate the predictive significance of CEA values in univariate analyses regarding stage, it was concluded that CA19-9 alone serves as a predictive indicator of stage.

Increased metabolic activity in colorectal cancer leads to increased glucose transporter (GLUT-1) expression. Elevated GLUT-1 expression is associated with cellular proliferation and reflects a more aggressive tumor biology.[27] Conversely, inflammatory indices, particularly high NLR and PLR values, have been associated with increased neutrophil-mediated tumor growth, cytokine release, and suppression of T-lymphocyte-mediated antitumor immunity.[28, 29] Therefore, the literature has shown that both groups of markers are independently associated with prognosis and metastasis development.[30, 31]

However, studies evaluating metabolic imaging parameters and inflammatory markers within the same model remain limited. Figueiras et al.[32] showed in their study of colorectal cancer patients that FDG uptake is associated with the systemic inflammatory response. Similarly, Kwon et al.[33] suggested that metabolically active tumors are associated with systemic inflammation markers and that increased FDG uptake may reflect the host inflammatory response. Kido et al.[34] revealed a correlation between PET metabolic parameters and inflammation-based hematological indices, suggesting a possible link between metabolic tumor burden and peripheral inflammatory response. In our study, it was found that inflammation markers alone may be predictive for staging in colon cancer, and when all factors are considered together, primary tumor SUVmax, clinical node positivity, and SII play significant predictive roles.

Study Limitations

This study is subject to certain limitations, primarily due to its retrospective design and relatively small sample size. In addition, reliance on single-point measurements of imaging and laboratory data limits the ability to reflect the dynamic biological behavior of the disease, and the fact

that inflammatory hematological indices can be affected by various non-cancerous clinical conditions complicates the interpretation of results. Furthermore, the exclusion of patients with non-sensitive tumor markers (CEA<5 ng/mL and CA19-9 <= 37 U/mL) may have introduced selection bias, potentially limiting the generalizability of the findings to the broader colorectal cancer population. Moreover, the presence of distant metastasis was determined solely based on PET/CT findings without histopathological confirmation of metastatic lesions; therefore, the possibility of imaging-related misclassification cannot be completely excluded.

Nevertheless, analyzing the primary tumor SUVmax value obtained from PET/CT alongside easily accessible, low-cost parameters such as SII, NLR, and PLR, which can be calculated from routine blood counts, strengthens our study in terms of creating a clinically applicable and cost-effective predictive model.

CONCLUSION

The combined evaluation of primary tumor SUVmax values and systemic inflammation indicators significantly contributes to predicting the presence of distant metastases in colorectal cancer patients. The joint application of these parameters may support preoperative risk stratification and clinical treatment planning.

Disclosure

Ethics Committee Approval: The study, approval was formally obtained from the Ethics Committee for Non-Interventional Clinical Research, Faculty of Medicine, Atatürk University (approval date: February 19, 2015; session no: 1; decision no: 09) and accepted as a thesis study by the Department of Internal Medicine (session no: 4; decision no: 34; date: December 17, 2014).

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

Funding: The authors declare that they have no financial or personal relationships that could influence the work reported in this paper.

Use of AI for Writing Assistance: Academic language and translation assistance was received.

Author Contributions: Concept: ZA, AŞ; Design: ZA, AŞ; Supervision: ZA, AŞ; Fundings: ZA, AŞ; Materials: ZA, AŞ; Data Collection and/or Processing: ZA, AŞ; Analysis and/or Interpretation: ZA, AŞ; Literature Review: ZA, AŞ; Writing: ZA, AŞ; Critical Review: ZA, AŞ.

Peer-review: Externally peer-reviewed.

References

1. Siegel RL, Kratzer TB, Wagle NS, Sung H, Jemal A. Cancer statistics, 2026. CA Cancer J Clin 2026;76(1):e70043. [CrossRef]
2. Cervantes A, Adam R, Roselló S, Arnold D, Normanno N, Taïeb J, et al; ESMO Guidelines Committee. Electronic address: clinicalguidelines@esmo.org. Metastatic colorectal cancer: ESMO Clinical Practice Guideline for diagnosis, treatment and follow-up. Ann Oncol 2023;34(1):10–32. [CrossRef]
3. Chowdhury FU, Shah N, Scarsbrook AF, Bradley KM. [18F]FDG PET/CT imaging of colorectal cancer: a pictorial review. Postgrad Med J 2010;86(1013):174–82. [CrossRef]
4. Schmoll HJ, Van Cutsem E, Stein A, Valentini V, Glimelius B, Haustermans K, et al. ESMO Consensus Guidelines for management of patients with colon and rectal cancer. a personalized approach to clinical decision making. Ann Oncol 2012;23(10):2479–516. [CrossRef]
5. Zaharchuk G, Davidzon G. Artificial intelligence for optimization and interpretation of PET/CT and PET/MR images. Semin Nucl Med 2021;51(2):134–42. [CrossRef]
6. Li J, Goh W, Jhanjhi NZ. A systematic review of AI-Based image processing techniques for colon cancer diagnosis. 2025 International Conference on Emerging Trends in Networks and Computer Communications (ETNCC). Windhoek, Namibia: IEEE; 2025. p. 291–8. [CrossRef]
7. Boellaard R, Delgado-Bolton R, Oyen WJ, Giammarile F, Tatsch K, Eschner W, et al; European Association of Nuclear Medicine (EANM). FDG PET/CT: EANM procedure guidelines for tumour imaging: version 2.0. Eur J Nucl Med Mol Imaging 2015;42(2):328–54. [CrossRef]
8. Hanahan D, Weinberg RA. Hallmarks of cancer: the next generation. Cell 2011;144(5):646–74. [CrossRef]
9. Li MX, Liu XM, Zhang XF, Zhang JF, Wang WL, Zhu Y, et al. Prognostic role of neutrophil-to-lymphocyte ratio in colorectal cancer: a systematic review and meta-analysis. Int J Cancer 2014;134(10):2403–13. [CrossRef]
10. Sharma A, Mohan A, Bhalla AS, Sharma MC, Vishnubhatla S, Das CJ, et al. Role of various metabolic parameters derived from baseline 18F-FDG PET/CT as prognostic markers in non-small cell lung cancer patients undergoing platinum-based chemotherapy. Clin Nucl Med 2018;43(1):e8–17. [CrossRef]
11. Fluss R, Faraggi D, Reiser B. Estimation of the Youden Index and its associated cutoff point. Biom J 2005;47(4):458–72. [CrossRef]
12. Weir CB, Jan A. BMI classification percentile and cut off points. Treasure Island: StatPearls Publishing; 2021. p. 1–5.
13. Pieterman RM, van Putten JW, Meuzelaar JJ, Mooyaart EL, Vaalburg W, Koëter GH, et al. Preoperative staging of non-small-cell lung cancer with positron-emission tomography. N Engl J Med 2000;343(4):254–61. [CrossRef]
14. Maziak DE, Darling GE, Inculet RI, Gulenchyn KY, Driedger AA, Ung YC, et al. Positron emission tomography in staging early lung cancer: a randomized trial. Ann Intern Med 2009;151(4):221–8, W–48. [CrossRef]
15. Fuster D, Duch J, Paredes P, Velasco M, Muñoz M, Santamaria G, et al. Preoperative staging of large primary breast cancer

with [18F] fluorodeoxyglucose positron emission tomography/computed tomography compared with conventional imaging procedures. J Clin Oncol 2008;26(29):4746–51. [CrossRef]
16. Bombardieri E, Aliberti G, de Graaf C, Pauwels E, Crippa F. Positron emission tomography (PET) and other nuclear medicine modalities in staging gastrointestinal cancer. Semin Surg Oncol 2001;20(2):134–46. [CrossRef]
17. Akhurst T, Larson SM. Positron emission tomography imaging of colorectal cancer. Semin Oncol 1999;26(5):577–83.
18. Sanli Y, Kuyumcu S, Ozkan ZG, Kilic L, Balik E, Turkmen C, et al. The utility of FDG-PET/CT as an effective tool for detecting recurrent colorectal cancer regardless of serum CEA levels. Ann Nucl Med 2012;26(7):551–8. [CrossRef]
19. Han A, Xue J, Zhu D, Zheng J, Yue J, Yu J. Clinical value of (18) F-FDG PET/CT in postoperative monitoring for patients with colorectal carcinoma. Cancer Epidemiol 2011;35(5):497–500. [CrossRef]
20. Andersen KF, Skougaard K, Nielsen AL, Hendel HW. Impact of third-line treatment with irinotecan plus cetuximab on non-tumor standardized uptake values in patients with metastatic colorectal cancer. Oncol Lett 2012;4(1):131–4. [CrossRef]
21. Shi D, Cai G, Peng J, Li D, Li X, Xu Y, et al. The preoperative SUVmax for (18)F-FDG uptake predicts survival in patients with colorectal cancer. BMC Cancer 2015;15:991. [CrossRef]
22. Byun BH, Moon SM, Shin US, Lim I, Kim BI, Choi CW, et al. Prognostic value of 18F-FDG uptake by regional lymph nodes on pretreatment PET/CT in patients with resectable colorectal cancer. Eur J Nucl Med Mol Imaging 2014;41(12):2203–11. [CrossRef]
23. Reiter W, Stieber P, Reuter C, Nagel D, Lau-Werner U, Lamerz R. Multivariate analysis of the prognostic value of CEA and CA 19-9 serum levels in colorectal cancer. Anticancer Res 2000;20(6D):5195–8.
24. Sisik A, Kaya M, Bas G, Basak F, Alimoglu O. CEA and CA 19-9 are still valuable markers for the prognosis of colorectal and gastric cancer patients. Asian Pac J Cancer Prev 2013;14(7):4289–94. [CrossRef]
25. Park YJ, Park KJ, Park JG, Lee KU, Choe KJ, Kim JP. Prognostic factors in 2230 Korean colorectal cancer patients: analysis of consecutively operated cases. World J Surg 1999;23(7):721–6. [CrossRef]
26. Harrison LE, Guillem JG, Paty P, Cohen AM. Preoperative carcinoembryonic antigen predicts outcomes in node-negative colon cancer patients: a multivariate analysis of 572 patients. J Am Coll Surg 1997;185(1):55–9. [CrossRef]
27. Yang J, Wen J, Tian T, Lu Z, Wang Y, Wang Z, et al. GLUT-1 overexpression as an unfavorable prognostic biomarker in patients with colorectal cancer. Oncotarget 2017;8(7):11788–96. [CrossRef]
28. Ying HQ, Deng QW, He BS, Pan YQ, Wang F, Sun HL, et al. The prognostic value of preoperative NLR, d-NLR, PLR and LMR for predicting clinical outcome in surgical colorectal cancer patients. Med Oncol 2014;31(12):305. [CrossRef]
29. Zhang J, Zhang HY, Li J, Shao XY, Zhang CX. The elevated NLR, PLR and PLT may predict the prognosis of patients with colorectal cancer: a systematic review and meta-analysis. Oncotarget 2017;8(40):68837–46. [CrossRef]
30. Gawiński C, Mróz A, Roszkowska-Purska K, Sosnowska I, Derezińska-Wołek E, Michalski W, et al. A prospective study on the roles of the lymphocyte-to-monocyte ratio (LMR), neutrophil-to-lymphocyte ratio (NLR), and platelet-to-lymphocyte ratio (PLR) in patients with locally advanced rectal cancer. Biomedicines 2023;11(11):3048. [CrossRef]
31. Gawiński C, Michalski W, Mróz A, Wyrwicz L. Correlation between lymphocyte-to-monocyte ratio (LMR), neutrophil-to-lymphocyte ratio (NLR), platelet-to-lymphocyte ratio (PLR) and tumor-infiltrating lymphocytes (TILs) in left-sided colorectal cancer patients. Biology (Basel) 2022;11(3):385. [CrossRef]
32. Figueiras RG, Goh V, Padhani AR, Naveira AB, Caamaño AG, Martin CV. The role of functional imaging in colorectal cancer. AJR Am J Roentgenol 2010;195(1):54–66. [CrossRef]
33. Kwon SH, Hyun SH, Yoon JK, An YS, Oh YT, Choi JH, et al. The highest metabolic activity on FDG PET is associated with overall survival in limited-stage small-cell lung cancer. Medicine (Baltimore) 2016;95(5):e2772. [CrossRef]
34. Kido H, Kato S, Funahashi K, Shibuya K, Sasaki Y, Urita Y, et al. The metabolic parameters based on volume in PET/CT are associated with clinicopathological N stage of colorectal cancer and can predict prognosis. EJNMMI Res 2021;11(1):87. [CrossRef]