

Deficient Mismatch Repair, Mucinous Histology, and Systemic Inflammation Are Associated with Nodal Overstaging on Preoperative Computed Tomography in Right-Sided Colon Cancer: A Propensity Score–Matched Study

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Abstract

Background

Accurate preoperative nodal staging is increasingly important as neoadjuvant immunotherapy emerges for mismatch repair-deficient (dMMR) colon cancer. CT-based N-overstaging may be more frequent in dMMR than in mismatch repair-proficient (pMMR) tumors; however, because dMMR status, mucinous histology, and systemic inflammation often coexist in right-sided colon cancer, we assessed their associations with nodal misclassification.

Methods

We retrospectively reviewed patients who underwent resection for right-sided colon adenocarcinoma. Patients with dMMR tumors were propensity score-matched to those with pMMR tumors based on age and sex, with exact matching on pT, pN, and mucinous histology. Clinicopathological, molecular, and inflammation-related factors were evaluated using logistic regression.

Results

The matched cohort comprised 80 dMMR and 78 pMMR patients. Among 106 pathologically node-negative patients, N-overstaging occurred in 29 (53.7%) dMMR and 19 (36.5%) pMMR tumors ($P = 0.076$). After multivariable adjustment, dMMR status (adjusted odds ratio [aOR], 2.49; 95% confidence interval [CI], 1.02–6.11; $P = 0.046$), mucinous histology (aOR, 4.65; 95% CI, 1.02–21.24; $P = 0.047$), and modified Glasgow Prognostic Score (mGPS) 1–2 vs 0 (aOR, 5.42; 95% CI, 1.87–15.75; $P = 0.002$) were associated with N-overstaging. Among 52 pathologically node-positive patients, N-understaging was less frequent in dMMR than pMMR tumors (11.5% vs 34.6%; $P = 0.048$), and elevated mGPS was associated with lower odds of N-understaging ($P = 0.030$).

Conclusions

dMMR status, mucinous histology, and elevated mGPS emerged as independent indicators of CT-based N-overstaging in right-sided colon cancer. These tumor- and host-related factors may inform preoperative nodal assessment.

Background

Colorectal cancer (CRC) remains one of the leading causes of cancer-related mortality worldwide [1]. Approximately 10–20% of nonmetastatic CRC, compared with only about 5% of metastatic CRC, are mismatch repair-deficient (dMMR) and/or microsatellite instability-high (MSI-H) [2, 3]. These tumors arise either from germline pathogenic variants in MMR genes, as observed in Lynch syndrome, or from

sporadic mechanisms, most commonly *MLH1* promoter hypermethylation, which is frequently accompanied by the BRAF V600E mutation. MMR/MSI status is also a clinically important biomarker because dMMR/MSI-H tumors are highly sensitive to immune checkpoint inhibitors (ICIs) [3, 4].

Accurate preoperative staging, particularly the assessment of regional lymph node involvement, is essential for treatment planning in patients with localized colon cancer. Its clinical importance has further increased with the emergence of neoadjuvant immunotherapy for dMMR/MSI-H colon cancer. In the NICHE-2 trial, neoadjuvant nivolumab plus ipilimumab showed high pathological response rates in patients with nonmetastatic, locally advanced dMMR colon cancer, together with encouraging survival outcomes [5]. Accordingly, clinical staging is increasingly important for identifying patients with locally advanced disease who may be considered for neoadjuvant treatment. Conversely, many patients with pathologically node-negative dMMR/MSI-H colon cancer have favorable outcomes after curative surgery alone [6]. Therefore, preoperative N-overstaging, defined as radiologically positive nodal disease in the absence of pathological nodal metastasis, may overestimate disease extent and influence treatment decision-making and should not be regarded as merely a radiological discrepancy.

Accurate preoperative nodal staging by CT remains challenging [7], and prior studies suggest that the direction of nodal misclassification differs according to MMR/MSI status. N-overstaging has been reported more frequently in dMMR/MSI-H tumors [8–11], whereas understaging may occur more often in proficient mismatch repair (pMMR) or microsatellite stable (MSS) tumors [12]. Conventional CT assessment of regional lymph nodes relies largely on morphological features, and reactive enlargement of benign nodes may therefore be misinterpreted as metastatic involvement. This limitation may be particularly relevant in dMMR/MSI-H CRC, which is characterized by prominent antitumor immune activation and lymphocytic infiltration [13]. Moreover, nonmetastatic regional lymph nodes in dMMR/MSI-H CRC may be immunologically active and contribute to antitumor immune responses [14]. Although these observations provide a plausible biological basis for CT-based N-overstaging in dMMR/MSI-H CRC, a direct link between nodal immune activation, reactive enlargement, and overstaging has not been established.

However, the reported association between MMR/MSI status and N-overstaging may be influenced by clinicopathological factors that frequently coexist with dMMR/MSI-H CRC. These tumors predominantly arise in the proximal colon and more frequently exhibit mucinous or poorly differentiated histology, BRAF V600E mutation, and prominent lymphocytic infiltration [4, 15]. Some of these characteristics are not specific to dMMR/MSI-H tumors. For example, BRAF V600E is also present in a subset of pMMR/MSS tumors, where it is similarly associated with mucinous or poorly differentiated histology and right-sided location [16]. In addition, dMMR/MSI-H CRC has been associated with systemic inflammation, as reflected by C-reactive protein (CRP)-based scores and peripheral blood inflammatory markers [17]. Consequently, N-overstaging may be associated not only with dMMR/MSI-H status itself but also with coexisting tumor characteristics, host inflammatory status, or their combined effects.

Because mucinous histology, BRAF V600E mutation, and systemic inflammatory status are associated with dMMR/MSI-H tumors and frequently coexist in right-sided colon cancer, their relative associations with CT-based nodal misclassification remain unclear. In particular, it is uncertain whether dMMR/MSI-H status remains associated with N-overstaging after accounting for these tumor- and host-related factors. Accordingly, we restricted the cohort to right-sided colon cancer and matched dMMR and pMMR tumors for pathological T category, pathological nodal status, and mucinous histology to reduce confounding by disease extent and by a histological phenotype enriched in dMMR/MSI-H tumors. We therefore conducted a propensity score–matched study restricted to right-sided colon cancer to determine whether dMMR/MSI-H status was associated with preoperative CT-based N-overstaging and to identify additional clinicopathological, molecular, and inflammation-related markers associated with this outcome. We also explored factors associated with N-understaging among patients with pathologically node-positive tumors.

Methods

Study Design

This single-center retrospective cohort study was conducted at Fukushima Medical University Hospital. Consecutive patients who underwent surgical resection for primary right-sided colon adenocarcinoma between January 2010 and December 2025 were screened for eligibility. Right-sided colon cancer was defined as a tumor arising in the cecum, ascending colon, hepatic flexure, or transverse colon. Tumors were staged according to the 8th edition of the UICC TNM classification [18].

Patients were eligible if they had (i) histologically confirmed primary adenocarcinoma of the right-sided colon with pathological T1–T4 disease, irrespective of nodal or distant metastatic status, and (ii) undergone resection of the primary tumor with regional lymph node dissection. Patients were excluded if they had (i) received any systemic anticancer chemotherapy or radiotherapy before primary tumor resection or (ii) lacked the clinical, radiological or pathological data required for the planned analyses. MMR/MSI status was determined by MMR-IHC and/or MSI testing, as described below. For simplicity, dMMR/MSI-H and pMMR/MSS groups are hereafter referred to as dMMR and pMMR, respectively. All eligible patients with dMMR tumors were included in the matched analysis. A matched comparison cohort of patients with pMMR tumors was selected using propensity score matching. To balance pathological T and N categories and mucinous histology between the dMMR and pMMR groups, exact matching was applied for pathological T category, pathological N category, and mucinous histology, while age and sex were included as covariates in the propensity score model.

This study was approved by the Institutional Ethics Committee of Fukushima Medical University (approval number REC2024-041) and was conducted in accordance with the Declaration of Helsinki. The requirement for written informed consent was waived because of the retrospective nature of the study.

Assessment of MMR/MSI Status

MMR/MSI status was assessed by immunohistochemistry (IHC) for the four MMR proteins, MLH1, MSH2, MSH6, and PMS2 (MMR-IHC), and/or PCR-based MSI testing, as previously described [19, 20]. MMR-IHC results were obtained from routine clinical testing or from our previous institutional studies using archived formalin-fixed, paraffin-embedded tumor specimens. Tumors showing loss of expression of at least one MMR protein were classified as dMMR, whereas tumors with intact expression of all four proteins were classified as pMMR. MSI testing results were obtained from medical records; tumors reported as MSI-high were classified as MSI-H, whereas those reported as MSI-low, MSI-negative, or microsatellite stable were classified as MSS.

Data collection and calculation of inflammation- and nutrition-related markers

Demographic, clinicopathological, molecular, and laboratory data were retrospectively obtained from electronic medical records. The variables collected included age at surgery, sex, primary tumor location, histological subtype, pathological T and N categories, UICC stage, lymphatic and venous invasion, and preoperative serum levels of carcinoembryonic antigen (CEA) and carbohydrate antigen 19 – 9 (CA19-9). BRAF V600E mutation status was obtained from clinically performed molecular testing and recorded when available. Preoperative hematologic and biochemical data were used to calculate inflammation- and nutrition-related markers. The modified Glasgow Prognostic Score (mGPS) was assigned as follows: 0, CRP $\leq$ 0.5 mg/dL; 1, CRP $>$ 0.5 mg/dL and serum albumin $\geq$ 3.5 g/dL; and 2, CRP $>$ 0.5 mg/dL and serum albumin $<$ 3.5 g/dL [21]. The Prognostic Nutritional Index (PNI), Geriatric Nutritional Risk Index (GNRI), hemoglobin–albumin–lymphocyte–platelet (HALP) score, neutrophil-to-lymphocyte ratio (NLR), and platelet-to-lymphocyte ratio (PLR) were calculated according to previously reported formulae [22, 23].

Imaging assessment and definitions of nodal staging

Preoperative abdominopelvic CT scan, with or without intravenous contrast enhancement, was reviewed for each patient. All scans were independently assessed by two evaluators who were blinded to the pathological findings. Disagreements were resolved by consensus. Patients with at least one regional lymph node measuring $\geq$ 5 mm in short-axis diameter on CT were classified as radiologically node-positive, whereas those without such lymph nodes were classified as radiologically node-negative. This threshold was prespecified based on the criteria used by Linhares et al. for CT staging of dMMR colon cancer [24], which were adapted from the PROSPECT trial [25]. N-overstaging was defined as radiologically node-positive disease in patients with pathologically node-negative tumors. Conversely, N-understaging was defined as radiologically node-negative disease in patients with pathologically node-positive tumors.

Statistical analysis

Continuous variables were summarized as medians and interquartile ranges (IQRs), and categorical variables as numbers and percentages. Continuous variables were compared using the Mann–Whitney U test. Categorical variables were compared using the chi-squared test or Fisher's exact test when any expected cell count was less than 5.

Factors associated with preoperative CT-based N-overstaging were examined among patients with pathologically node-negative tumors using univariable and multivariable logistic regression analyses. PNI, GNRI, HALP score, NLR, and PLR were dichotomized at their respective median values. CEA and CA19-9 were dichotomized at 5 ng/mL and 37 U/mL, respectively, and mGPS was analyzed as scores of 1–2 versus 0. MMR status was included a priori in the multivariable model as the primary variable of interest. Variables with $P < 0.05$ in the univariable analyses were also included. Accordingly, the final multivariable model included MMR status, mucinous histology, mGPS, and CEA. Because of the small number of N-understaging events among patients with pathologically node-positive tumors, associations with N-understaging were evaluated using Firth penalized logistic regression. A multivariable model was not constructed because of the limited number of N-understaging events relative to the number of candidate variables.

All tests were two-sided, and $P < 0.05$ was considered statistically significant. Statistical analyses were performed using R software (version 4.6.0).

Results

Patient Characteristics

We identified 80 eligible patients with dMMR right-sided colon adenocarcinoma and selected 78 patients with pMMR tumors as a propensity score–matched comparison cohort. Matching incorporated exact matching for pathological T category, pathological N category, and mucinous histology, with age and sex included in the propensity score model. The final matched cohort comprised 158 patients.

The baseline characteristics of the matched cohort are summarized in Table 1. The dMMR and pMMR groups were well-balanced for age, sex, pathological T category, pathological N category, and mucinous histology. The median age was 74 years in both groups, and the proportion of male patients was 40.0% and 39.7%, respectively. Pathological nodal involvement was observed in 32.5% of the dMMR group and 33.3% of the pMMR group. The number of examined lymph nodes was significantly higher in the dMMR group than in the pMMR group (median 27 [IQR 19–34] vs 21 [IQR 14–31]; $P = 0.022$). Contrast-enhanced CT was performed in 85.0% and 84.6% of patients, respectively. Although the prevalence of mucinous adenocarcinoma was similar between the groups by design, the overall histological distribution differed significantly ($P = 0.003$), mainly because poorly differentiated adenocarcinoma was more frequent in the dMMR group than in the pMMR group (16.2% vs 1.3%). BRAF V600E mutation status also differed significantly between the groups ($P < 0.001$), with mutations identified in 22 dMMR tumors and one

pMMR tumor; however, BRAF status was unavailable in 79 patients (50.0%). The frequencies of lymphatic and venous invasion did not differ significantly between the groups.

No statistically significant between-group differences were observed in preoperative laboratory findings, including inflammation- and nutrition-related markers and serum tumor markers. Specifically, PNI, GNRI, HALP score, NLR, PLR, mGPS, CEA, and CA19-9 did not differ significantly between the dMMR and pMMR groups.

Preoperative CT-based nodal overstaging and understaging according to MMR status

Preoperative CT-based and pathological nodal classifications according to MMR status are summarized in Table 2. Among the 106 patients with pathologically node-negative tumors, N-overstaging was more frequent in the dMMR group than in the pMMR group, although the difference did not reach statistical significance (29 of 54 [53.7%] vs. 19 of 52 [36.5%]; $P = 0.076$). Among the 52 patients with pathologically node-positive tumors, N-understaging was significantly less frequent in the dMMR group than in the pMMR group (3 of 26 [11.5%] vs. 9 of 26 [34.6%], $P = 0.048$). When N-overstaging and N-understaging were combined, nodal misclassification occurred in 60 of the 158 patients (38.0%). Its frequency did not differ significantly between the dMMR and pMMR groups (32 of 80 [40.0%] vs 28 of 78 [35.9%]; $P = 0.595$).

Factors associated with preoperative CT-based N-overstaging

Univariable and multivariable logistic regression analyses of factors associated with preoperative CT-based N-overstaging were performed among the 106 patients with pathologically node-negative tumors in the matched cohort (Table 3). In the univariable analyses, mucinous histology (odds ratio [OR] 4.82, 95% confidence interval [CI] 1.24–18.70, $P = 0.023$), mGPS 1–2 (OR 4.09, 95% CI 1.59–10.53, $P = 0.003$), and CEA > 5 ng/mL (OR 3.36, 95% CI 1.17–9.63, $P = 0.024$) were significantly associated with N-overstaging. dMMR status also showed a non-significant trend toward an association with N-overstaging in the univariable analysis (OR 2.01, 95% CI 0.93–4.38, $P = 0.077$). BRAF V600E mutation status, PNI, GNRI, HALP score, NLR, PLR, and CA19-9 were not significantly associated with N-overstaging.

The multivariable model included dMMR status, mucinous histology, mGPS, and CEA. After multivariable adjustment, dMMR status (adjusted OR, 2.49; 95% CI, 1.02–6.11; $P = 0.046$), mucinous histology (adjusted OR, 4.65; 95% CI, 1.02–21.24; $P = 0.047$), and mGPS 1–2 (adjusted OR, 5.42; 95% CI, 1.87–15.75; $P = 0.002$) remained associated with CT-based N-overstaging. CEA > 5 ng/mL was not significantly associated with N-overstaging after adjustment (adjusted OR, 2.44; 95% CI, 0.74–8.00; $P = 0.143$).

Factors associated with preoperative CT-based N-understaging

Univariable Firth penalized logistic regression analyses of factors associated with preoperative CT-based N-understaging were performed among the 52 patients with pathologically node-positive tumors in the matched cohort (Table 4). In the univariable analysis, mGPS 1–2 was associated with lower odds of N-understaging (OR 0.22, 95% CI 0.04–0.87, $P = 0.030$). dMMR status was associated with a lower estimated odds of N-understaging, although the association was not statistically significant (OR, 0.27; 95% CI 0.06–1.01; $P = 0.053$). BRAF V600E mutation also showed a non-significant trend toward lower odds of N-understaging (OR, 0.11; 95% CI < 0.01–1.12; $P = 0.065$). Mucinous histology, PNI, GNRI, HALP score, NLR, PLR, CEA, and CA19-9 were not significantly associated with N-understaging. A multivariable model was not constructed because only 12 N-understaging events were observed.

Discussion

In this propensity score–matched study of patients with right-sided colon adenocarcinoma, we compared preoperative CT-based nodal classification with postoperative pathological nodal status between dMMR and pMMR tumors. The matched design balanced key pathological characteristics, and we further evaluated clinicopathological and host inflammatory factors associated with CT-based nodal misclassification. Among patients with pathologically node-negative tumors, CT-based N-overstaging was more frequent in the dMMR group than in the pMMR group, although the unadjusted between-group difference was not statistically significant. After multivariable adjustment, dMMR status, mucinous adenocarcinoma, and mGPS 1–2 remained associated with higher odds of CT-based N-overstaging. Among patients with pathologically node-positive tumors, CT-based N-understaging was less frequent in the dMMR group than in the pMMR group. In univariable analyses, dMMR status showed a non-significant trend toward lower odds of N-understaging, whereas mGPS 1–2 was associated with reduced odds of N-understaging. These reciprocal patterns suggest that dMMR status and elevated mGPS may be associated with a greater likelihood of CT-detected nodal positivity, while mucinous histology may represent an additional factor specifically associated with N-overstaging.

Our findings are broadly consistent with an emerging body of evidence indicating that MMR/MSI status is associated not only with the occurrence of CT-based nodal misclassification in colon cancer but also with its direction. Linhares et al. reported that N-understaging was more frequent in pMMR tumors, whereas N-overstaging was more frequent in dMMR tumors [24]. Platt et al. and Chen et al. similarly associated dMMR status with N-overstaging among incorrectly N-staged tumors [26] and in patients with right-sided colon cancer [8], respectively. Moreover, a large National Cancer Database study reported an association between MSS tumors and N-understaging [12]. Our study adds to this literature by examining a propensity score–matched cohort of patients with right-sided colon adenocarcinoma, with exact matching for pathological T category, N category, and mucinous histology, thereby reducing confounding by disease extent and the higher prevalence of mucinous histology in dMMR tumors. It also extends previous work by evaluating histological and systemic inflammatory characteristics alongside MMR/MSI status within the same analytical framework. Beyond dMMR status, mucinous adenocarcinoma and mGPS 1–2 were also associated with N-overstaging after multivariable adjustment. Evidence linking systemic inflammation-related markers to radiological nodal staging

remains limited. Although Platt et al. found CRP, neutrophil count, and platelet count to be associated with pathological nodal status in dMMR colon cancer [26], their study did not specifically assess radiological-pathological nodal discordance. Our findings complement these observations by showing that mGPS 1–2 was associated with higher odds of N-overstaging and, in the univariable analysis of pathologically node-positive tumors, with lower odds of N-understaging. Collectively, these findings support a broader interpretation of MMR-related nodal misclassification as a phenomenon associated not only with MMR status but also with tumor phenotype and host systemic inflammatory status.

One possible biological interpretation is that the immune-active phenotype of dMMR/MSI-H tumors may influence the appearance of regional lymph nodes independently of metastatic involvement. Their high mutational and neoantigen burden is associated with prominent lymphocytic infiltration within the primary tumor. Inamori et al. demonstrated shared T-cell receptor repertoires between primary tumors and nonmetastatic regional lymph nodes in dMMR/MSI-H CRC, supporting active antitumor immune responses in tumor-draining lymph nodes [14]. This immune activity may lead to reactive nodal enlargement, and because conventional CT nodal assessment relies largely on lymph node size, enlarged benign nodes may be misclassified as metastatic. The association between mGPS 1–2 and N-overstaging may be consistent with a link between local tumor-associated immune activation and systemic inflammation; however, mGPS is an indirect and nonspecific marker that may also be influenced by tumor burden, nutritional status, comorbidities, or unrelated inflammatory conditions. Mucinous histology may likewise be associated with local immune alterations that are not fully explained by MMR status. Williams et al. reported an association between mucinous histology and a tumor-infiltrating lymphocyte (TIL)-high phenotype among pMMR tumors [27], while Elomaa et al. showed that mucinous differentiation was associated with distinct immune-cell patterns, including increased immature monocytic cell infiltration, increased M2-like macrophage infiltration in pMMR tumors, and reduced T-cell densities in dMMR tumors [28]. These findings provide a possible biological context for the association between mucinous adenocarcinoma and N-overstaging after adjustment for MMR status. Nevertheless, imaging evidence is limited and not entirely consistent. Liu et al. reported smaller regional lymph nodes in pathologically node-negative mucinous rectal adenocarcinoma than in conventional rectal adenocarcinoma on magnetic resonance imaging [29]. Although differences in anatomical site and imaging modality may account for this discrepancy, their findings suggest that the association between mucinous histology and N-overstaging cannot be explained by nodal size alone and should therefore be regarded as hypothesis-generating.

Accurate preoperative nodal assessment has become increasingly important with the emergence of neoadjuvant immunotherapy for localized dMMR colon cancer. The high pathological response rates reported with nivolumab plus ipilimumab in NICHE-2 and with single-cycle pembrolizumab in RESET-C have strengthened interest in preoperative immune checkpoint blockade, while also emphasizing the need for appropriate patient selection based on reliable clinical staging [5, 30]. In dMMR tumors, CT-based N-overstaging may overestimate disease extent and contribute to potentially unnecessary treatment escalation in patients with pathologically node-negative disease. Conversely, the greater tendency toward N-understaging in pMMR tumors may result in underestimation of disease extent and

complicate the identification of patients who could benefit from intensified perioperative management. Our findings suggest that MMR status, mucinous histology, and mGPS may provide useful clinical information when interpreting CT-based nodal findings. However, these factors should not be used in isolation to alter treatment decisions, because their incremental diagnostic value, optimal thresholds, and external validity have not been established. Further studies should therefore develop and prospectively validate integrated diagnostic approaches combining more refined CT criteria with radiomics, molecular characteristics, and blood-based biomarkers. Such multimodal models may ultimately improve discrimination between reactive and metastatic lymph nodes and reduce both N-overstaging and N-understaging.

This study has several limitations. First, its single-center retrospective design and the nonuniform implementation of MMR/MSI testing over the long study period may have introduced selection bias. Second, radiological nodal positivity was defined using a single short-axis diameter threshold of 5 mm. Although this threshold was prespecified based on previous studies [24, 25] and applied uniformly to dMMR and pMMR tumors, MMR-specific criteria may provide different diagnostic performance [9, 31]. In addition, incorporating morphological features such as irregular borders and heterogeneous enhancement, rather than relying on size alone, has been associated with lower rates of N-overstaging [11]. Third, radiological and pathological nodal findings were compared at the patient level without node-by-node correspondence. Thus, we could not determine whether the enlarged nodes identified on CT corresponded to histologically benign nodes, and the contribution of reactive nodal enlargement to N-overstaging could not be directly established. Fourth, the modest sample size limited statistical precision, particularly for the N-understaging analysis, which included only 12 events. Finally, mGPS is an indirect and nonspecific measure of systemic inflammation that may be influenced by tumor burden, nutritional status, comorbidities, and unrelated inflammatory conditions. Its association with N-overstaging therefore cannot be interpreted as direct evidence of regional nodal immune activation. These findings should be considered hypothesis-generating and require validation in larger multicenter cohorts.

Conclusions

In summary, dMMR status, mucinous histology, and elevated mGPS were associated with preoperative CT-based N-overstaging in right-sided colon cancer after multivariable adjustment. These findings suggest that MMR status, histological subtype, and systemic inflammation, as reflected by mGPS, may provide useful information when interpreting radiologically suspicious regional lymph nodes. Further validation in larger, multicenter cohorts is needed to determine whether incorporating these factors into preoperative nodal assessment can improve staging accuracy and support patient selection for neoadjuvant treatment.

Abbreviations

aOR

adjusted odds ratio
CA19-9
carbohydrate antigen 19 – 9
CEA
carcinoembryonic antigen
CI
confidence interval
CRC
colorectal cancer
CRP
C-reactive protein
CT
computed tomography
dMMR
deficient mismatch repair
GNRI
Geriatric Nutritional Risk Index
HALP
hemoglobin–albumin–lymphocyte–platelet
ICI
immune checkpoint inhibitor
IHC
immunohistochemistry
IQR
interquartile range
mGPS
modified Glasgow Prognostic Score
MMR
mismatch repair
MSI
microsatellite instability
MSI-H
microsatellite instability-high
MSS
microsatellite stable
NLR
neutrophil-to-lymphocyte ratio
OR
odds ratio
PLR

platelet-to-lymphocyte ratio
pMMR
proficient mismatch repair
PNI
Prognostic Nutritional Index
TIL
tumor-infiltrating lymphocyte
TNM
tumor–node–metastasis
UICC
Union for International Cancer Control.

Declarations

Ethics approval and consent to participate:

This study was approved by the Institutional Ethics Committee of Fukushima Medical University (approval number REC2024-041) for a retrospective analysis of the collected data in accordance with the Declaration of Helsinki. Because of the retrospective nature of the study, the requirement for written informed consent was waived, and an opt-out informed consent procedure was used for the collection and use of participant data for research purposes.

Consent for publication:

Not applicable.

Availability of data and materials:

The data underlying this study are available on reasonable request, subject to institutional and ethical restrictions. Further enquiries can be directed to the corresponding author.

Competing interests:

The authors declare that they have no competing interests.

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Authors' contributions:

MH and HO collected the data. MH analyzed the data and drafted the manuscript. MH, HO, TK, CT, SF, TS, MI, DU, SC, TM, and KK contributed to patient management, discussed the results, critically revised the manuscript, and approved the final version.

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Tables

Tables 1 to 4 are available in the supplementary files section

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