

Pre- and postoperative neutrophil and lymphocyte count and neutrophil-to-lymphocyte ratio in patients with colorectal cancer

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Abstract. Colorectal cancer (CRC) is one of the most common malignant cancers worldwide. Patients with CRC are diagnosed based on various predictors, including performance status, clinicopathological factors and TNM classification. The aim of the present study was to analyze the neutrophil and lymphocyte counts, as well as the neutrophil-to-lymphocyte ratio (NLR) in pre- and postoperative blood samples of patients with CRC in correlation with specific anatomical variables and disease-free survival (DFS). The variables pre- and postoperative neutrophil count (preNEU and postNEU, respectively), lymphocyte count and NLR were significantly higher in cancer patients than those noted in healthy subjects (all $P < 0.001$). PreNEU count correlated with tumor size, necrosis and tumor budding ($R = 0.204$, $P = 0.014$; $R = 0.189$, $P = 0.023$; $R = -0.174$, $P = 0.036$, respectively). Moreover, postNEU was associated only with the histological type ($R = 0.174$; $P = 0.047$). The PreLYMPH count was correlated with distant metastasis ($R = -0.153$, $P = 0.046$). PreNLR and postNLR were associated with the expression of various histological markers of disease progression. Analysis of DFS indicated that the postNEU count in the low group exhibited a tendency to lower DFS duration, although the results were not significant ($P = 0.055$). In conclusion, the present study indicated a significant correlation between the factors analyzed in blood samples of CRC patients and the disease progression markers.

Introduction

Colorectal cancer (CRC) is one of the most common malignant cancers worldwide (1). Currently, patients with CRC are diagnosed based on various predictors, including performance status, clinicopathological factors and TNM classification (2). Moreover, systemic immune response may be a useful determinant of the tumor stage (3). Certain studies have confirmed that immune system factors are actively involved in the development and invasion of CRC cells (4). These factors include the levels of serum white blood cells, the number of neutrophils, lymphocytes and platelets, and the expression levels of acute-phase proteins (5). It has also been demonstrated that high serum levels of acute-phase proteins, such as C-reactive protein (CRP), are significantly correlated with poor survival of patients with CRC (6). Rasic *et al* (7) demonstrated that the serum level of CRP was an independent predictor of the CRC stage. Yamamoto *et al* (8) indicated that the combination of pre- and postoperative CRP levels was predictive of the prognosis of CRC patients who underwent surgery. Recent studies suggested that the combination of the acute-phase factors and systemic whole-blood parameters, such as neutrophil-to-lymphocyte ratio (NLR), platelet-to-lymphocyte ratio (PLR) and prognostic nutritional index may have prognostic significance in the progression of CRC (9,10). Zhou *et al* (11) confirmed that patients with a higher postoperative NLR, neutrophil count and monocyte-to-lymphocyte ratio, PLR and systemic immune inflammation index, exhibited shorter progression-free survival. Moreover, it has been shown that a high NLR is a prognostic factor for poor survival in mismatch repair-proficient CRC subjects (12). In light of this evidence, neutrophil count, lymphocyte count and NLR were assessed in blood samples collected pre- and postoperatively from patients with CRC. These indices were analyzed in association with disease-free survival (DFS) and with specific clinicopathological variables.

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Materials and methods

Patients. The medical records of 144 patients diagnosed with CRC (56 women and 88 men; mean age, 63 years; range,

32-86 years) were analyzed. The patients underwent surgery at the Department of Oncological Surgery, in the Comprehensive Cancer Center of Bialystok, between April 2014 and December 2016. All the patients were subjected to routine diagnostic laboratory examinations, such as electrocardiography, spirometry and arterial blood gas measurements, as well as X-ray imaging and computerized tomography of the chest. The clinical efficiency was assessed with the 5-point scale of Zubroda (World Health Organization) (13). The clinical staging of CRC was performed according to the TNM classification (2). The type of pre/postoperative therapy was selected on the basis of the current recommendations for CRC treatment. Patients diagnosed with neoplasms in the rectum (n=53) received preoperative therapy; specifically, they received radiotherapy (n=39), chemotherapy (n=7) and radiochemotherapy (n=7). A radiation dose of 25 Gy to the pelvic area was administered to the patients in fractions of 5 Gy over 1 week. Patients with tumors localized in other areas received neither inflammatory nor immunosuppressive therapy. The response to preoperative therapy was estimated according to the Response Evaluation Criteria in Solid Tumors v1.1 (14). A total of 26 patients were diagnosed with stable disease and 27 with partial response to treatment. Histopathological examination of 4- μ m sections stained with hematoxylin and eosin (cat. no. 468802128; POCH S.A.) was performed. The routine histopathological assessment of the sections took into consideration the type of tumor growth, tumor size, histological type and percentage of the mucinous component, grade of malignancy and pTNM stage. In addition, the presence of venous, lymphatic and perineural invasion was assessed, and specific features of lymph node invasion were characterized, such as the number of resected and invaded lymph nodes, the presence of micro- and macrometastases, invasion of the lymph node pouch (passage of cancer cells through the lymph node capsule and subsequent infiltration of the local fat tissue) and the presence of distant metastases. The methodology used was similar to that of our previous study (15).

The present study was performed according to the principles outlined in the Declaration of Helsinki for human experimentation and the protocol was approved by the Bioethics Committee of the Medical University of Bialystok (approval no. R-I-002/353/2016). Written informed consent was obtained from all participants.

Blood samples. Blood samples were obtained within 3 days prior to and following surgical treatment. Venous blood samples were also obtained from 42 healthy control subjects (21 women and 21 men; mean age, 45 years; range, 25-65 years). The differential white blood cell count was analyzed using the Sysmex XN-1000 apparatus (Sysmex Corporation) based on the manufacturer's protocol.

The absolute neutrophil and lymphocyte counts were measured prior to and following surgery. The NLR was defined as the absolute neutrophil count divided by the absolute lymphocyte count. Receiver operating characteristic (ROC) curve analysis was used to investigate the cut-off values of the pre- and postoperative neutrophil count (preNEU/postNEU), lymphocyte count (preLYMPH/postLYMPH) and NLR (preNLR/postNLR). The significance of the correlations was evaluated by constructing ROC curves.

The scores of neutrophil count/lymphocyte count/NLR were defined as 1 or 2 when patients exhibited low or high levels of the analyzed parameters, respectively, as determined in the blood samples collected pre- and postoperatively.

Follow-up data. The patients were followed up during the last 2-3 years. They were monitored by physical examination, colonoscopy and the measurement of the carcinoembryonic antigen (CEA) and carbohydrate antigen (CA) 19-9 levels. In addition, radiological imaging was performed, which included computerized tomography of the chest, abdomen and pelvis, bone scan and positron emission tomography scans. Local and distant recurrence was defined as pathological evidence of tumor spread in the region of the anastomosis (local recurrence) and/or the presence of cancer cells outside of the primary tumor at other sites, including the lungs, bones and brain (distant recurrence). These indices were confirmed by the aforementioned techniques.

Statistical analysis. Statistical analysis was conducted using the STATISTICA 12.0 program (Statsoft, Inc.). The Mann-Whitney U test was used to compare the differences between the groups. Correlations between the parameters were calculated by the Spearman's correlation coefficient tests. DFS was calculated from the date of diagnosis to the date of disease progression (local or distant relapse). DFS was estimated using Kaplan-Meier analysis and the survival curves were compared using log-rank tests. $P < 0.05$ was considered to indicate a statistically significant difference.

Results

Estimation of cut-off values of neutrophil count, lymphocyte count and NLR. The preNEU and postNEU were significantly higher in cancer patients compared with those in healthy subjects ($P \leq 0.001$). Similarly, the preLYMPH/postLYMPH and preNLR/postNLR in the blood samples were significantly higher in cancer patients compared with those in healthy volunteers (both $P \leq 0.001$; Table I). The cut-off values of the preNEU and postNEU were 4.9 and 5.4, respectively (sensitivity and specificity: preNEU, 70.5 and 59.5%; and postNEU, 62.67 and 92.11%, respectively). The low preNEU group included 115 subjects, whereas the high group included 29 subjects. The low postNEU group included 91 patients and the high postNEU group included 53 patients. The cut-off values of the preLYMPH and postLYMPH were 1.9 and 1.6, respectively, with a sensitivity and specificity of 81.76 and 69.05% (preLYMPH) and of 65.79 and 81.63% (postLYMPH), respectively. The low preLYMPH group included 108 cases, whereas the high group included 36 cases. A total of 70 cases with low postLYMPH and 74 with high postLYMPH were observed. Moreover, the cut-off values of preNLR and postNLR were 2.5 and 3.3, respectively, with a sensitivity and specificity of 100% (Fig. 1A-F). The preNLR value was low in 99 cases and high in 45 cases. The low group of postNLR included 65 cases, whereas 79 cases were included in the high postNLR group.

Correlation between neutrophil count, lymphocyte count, NLR and clinicopathological variables. PreNEU was

Table I. ROC curve of pre- and postoperative neutrophil count, lymphocyte count and NLR.

	PreNEU	PostNEU	PreLYMPH	PostLYMPH	PreNLR	PostNLR
Cut-off value	4.9	5.4	1.9	1.6	2.5	3.3
AUC	0.690	0.820	0.814	0.789	1.000	1.000
Sensitivity (%)	70.5	62.67	81.76	65.79	100	100
Specificity (%)	59.5	92.11	69.05	81.63	100	100
Disease prevalence (%)	77.7	79.8	79.1	75.6	78.9	77.8
P-value	≤0.001	≤0.001	≤0.001	≤0.001	≤0.001	≤0.001

ROC, receiver operating characteristics; AUC, area under the ROC curve; preNEU, preoperative neutrophil count; postNEU, postoperative neutrophil count; preLYMPH, preoperative lymphocyte count; postLYMPH, postoperative lymphocyte count; preNLR, preoperative neutrophil-to-lymphocyte ratio; postNLR, postoperative neutrophil-to-lymphocyte ratio.

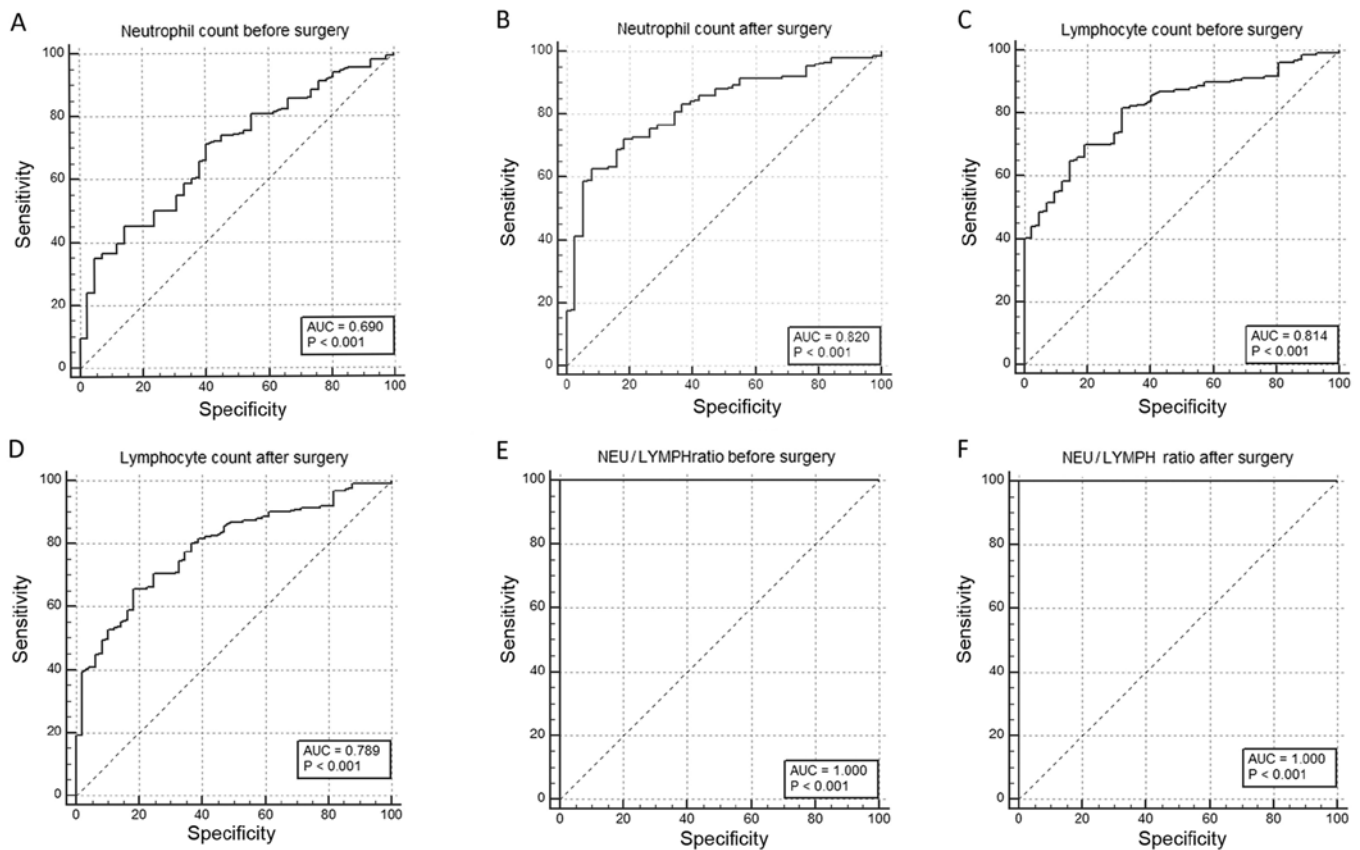


Figure 1. ROC curve of pre- and postoperative neutrophil count, lymphocyte count and NLR. Analysis of ROC curve according to investigated parameters in blood samples before and after surgery: (A and B) neutrophil count, (C and D) lymphocyte count and (E and F) NLR. NEU, neutrophil count; LYMPH, lymphocyte count; ROC, receiver operating characteristics; AUC, area under the ROC curve; NLR, neutrophil-to-lymphocyte ratio.

correlated with tumor size, necrosis and tumor budding (R=0.204, P=0.014; R=0.189, P=0.023; and R=-0.174, P=0.036, respectively). Moreover, the postNEU value was significantly associated only with histological type (R=0.174, P=0.047). PreLYMPH was correlated with distant metastasis (R=-0.153, P=0.046). PreNLR was correlated with age and lymphatic invasion (R=-0.225, P=0.007; R=0.181, P=0.030; Table II). Moreover, postNLR was associated with specific variables of tumor progression, such as tumor growth, lymph node metastasis, number of invaded lymph nodes and invasion of the node pouch (R=0.212, P=0.016;

R=0.200, P=0.023; R=0.175, P=0.047; and R=0.232, P=0.008, respectively; Table III). The results indicated no correlation between the analyzed parameters and preoperative treatment.

Prognostic values of neutrophil count, lymphocyte count and NLR. The mean DFS of preNEU was 11.67 months in the low group and 9.97 months in the high group. Moreover, the mean DFS of postNEU was 9.57 in the low group and 11.79 in the high group. The postNEU in the low group was associated with a shorter DFS (P=0.055). The mean DFS of

Table II. Correlation between neutrophil and lymphocyte count and clinicopathological characteristics.

Parameters	Neutrophil count						Lymphocyte count						
	Preoperative			Postoperative			Preoperative			Postoperative			
	L	H	R P-value	L	H	R P-value	L	H	R P-value	L	H	R P-value	
Age, years													
<60	24	14	-0.127	16	18	-0.163	27	11	-0.043	13	22	-0.095	
>60	79	27	0.126	59	37	0.062	79	26	0.557	47	48	0.279	
Sex													
Female	44	10	0.141	31	21	0.032	45	11	0.129	21	31	-0.073	
Male	59	31	0.092	44	34	0.711	61	26	0.123	39	39	0.403	
Localization													
Right colon	12	5	-0.047	10	7	-0.123	13	3	-0.053	7	10	0.106	
Transverse colon	3	2	0.587	3	1	0.175	4	3	0.539	2	2	0.598	
Left colon	12	2		10	3		12	0		8	5		
Sigmoid colon	15	6		12	8		16	6		9	11		
Rectum	55	19		36	31		54	22		30	37		
Tumor growth													
Expanding	82	33	-0.087	61	46	-0.030	87	31	0.037	52	56	0.131	
Infiltrative	21	5	0.297	14	9	0.731	19	6	0.654	8	14	0.134	
Tumor size, cm													
<2.5	20	4	0.204	13	8	0.011	17	7	-0.026	12	9	0.094	
2.5-5.0	71	23	0.014	50	39	0.894	71	24	0.756	40	49	0.283	
>5.0	12	11		12	8		18	6		8	12		
TNM stage													
1	15	9	-0.086	21	12	-0.037	29	9	-0.084	13	19	-0.091	
2	55	12	0.303	13	14	0.629	20	8	0.313	14	14	0.299	
3	20	4		29	24		31	19		22	30		
4	7	13		12	5		26	1		11	6		
Adenocarcinoma type													
Mucinous component	22	32	-0.057	10	15	0.174	24	5	-0.107	9	16	0.085	
Non-mucinous	81	6	0.496	65	40	0.047	82	32	0.200	51	54	0.331	
Grade of malignancy													
2	97	36	0.021	70	52	-0.030	100	35	0.021	55	67	-0.125	
3	6	2	0.798	5	3	0.726	6	2	0.796	5	3	0.153	

Table II. Continued.

Parameters	Neutrophil count						Lymphocyte count					
	Preoperative			Postoperative			Preoperative			Postoperative		
	L	H	R	L	H	R	L	H	R	L	H	R
			P-value			P-value			P-value			P-value
pT stage												
1	2	1	0.052	1	2	-0.042	2	1	-0.034	2	1	-0.049
2	42	13	0.529	29	20	0.629	41	13	0.683	21	27	0.575
3	57	23		43	33		60	23		35	42	
4	2	1		2	0		3	0		2	0	
Lymphatic invasion												
Absent	78	25	0.092	55	41	-0.014	80	25	0.058	45	51	0.010
Present	25	13	0.272	20	14	0.871	26	12	0.486	15	19	0.904
Lymph node metastasis												
Absent	58	25	-0.022	41	35	0.025	63	20	0.184	34	42	0.052
Present	45	13	0.541	34	20	0.775	43	17	0.827	26	28	0.554
Number of metastatic lymph nodes												
<5	30	9	-0.052	24	15	-0.041	31	10	0.031	19	20	0.014
>5	15	4	0.536	10	5	0.642	12	7	0.708	7	8	0.870
Lymph node pouch invasion												
Absent			-0.048	48	38	-0.053	71	23	0.023	40	46	-0.005
Present			0.568	23	17	0.541	35	14	0.782	20	24	0.948
Distant metastasis												
Absent	91	35	-0.075	65	51	-0.066	92	36	-0.153	52	64	-0.085
Present	12	3	0.369	10	4	0.450	14	1	0.046	5	6	0.334
Tumor budding												
Absent	54	27	-0.174	46	30	0.069	62	21	-0.007	35	40	-0.006
Present	49	11	0.036	29	25	0.433	44	16	0.927	25	30	0.938
Necrosis												
Absent	32	7	0.189	19	13	-0.105	27	12	-0.000	15	16	0.089
Focal	39	14	0.023	25	28	0.229	42	13	0.994	27	26	0.309
Moderate	25	9		21	10		27	7		15	11	
Extensive	7	8		10	4		10	5		3	17	

Bold print indicates statistical significance. L, low; H, high.

Table III. Correlation between NLR and clinicopathological characteristics.

Parameters	NLR					
	Preoperative		R P-value	Postoperative		R P-value
	L	H		L	H	
Age, years						
<60	23	15	-0.225	12	23	-0.114
>60	75	31	0.007	43	51	0.196
Sex						
Female	45	11	0.104	19	31	-0.046
Male	53	46	0.214	36	43	0.602
Localization						
Right colon	13	4	-0.132	9	8	-0.009
Transverse colon	4	2	0.128	2	2	0.922
Left colon	13	0		6	8	
Sigmoid colon	16	6		5	14	
Rectum	49	27		28	39	
Tumor growth						
Expanding	80	38	-0.030	49	59	0.212
Infiltrative	18	8	0.720	6	15	0.016
Tumor size, cm						
<2.5	16	8	0.004	9	11	0.111
2.5-5.0	65	31	0.961	36	50	0.207
>5.0	17	7		10	13	
TNM stage						
1	28	11	-0.065	18	18	0.124
2	16	12	0.438	11	15	0.161
3	39	21		19	31	
4	15	2		7	10	
Adenocarcinoma type						
Mucinous component	18	11	-0.018	10	58	-0.006
Non-mucinous	80	35	0.831	45	16	0.945
Grade of malignancy						
2	93	43	0.134	51	72	-0.015
3	5	3	0.108	4	2	0.866
pT stage						
1	1	2	-0.052	2	1	0.037
2	40	15	0.531	22	28	0.676
3	55	28		29	44	
4	2	1		2	1	
Lymphatic invasion						
Absent	76	30	0.181	41	57	0.023
Present	22	16	0.030	14	17	0.793
Lymph node metastasis						
Absent	56	28	-0.030	36	42	0.200
Present	42	18	0.715	19	32	0.023
Number of metastatic lymph nodes						
<5	30	11	-0.014	12	23	0.175
>5	12	7	0.861	7	9	0.047
Lymph node pouch invasion						
Absent	64	31	0.002	41	47	0.232
Present	34	15	0.981	14	27	0.008

Table III. Continued.

Parameters	NLR					
	Preoperative		R P-value	Postoperative		R P-value
	L	H		L	H	
Distant metastasis						
Absent	85	44	-0.104	49	66	-0.018
Present	13	2	0.212	6	9	0.832
Tumor budding						
Absent	57	27	-0.060	39	41	0.152
Present	41	19	0.474	16	33	0.084
Necrosis						
Absent	24	15	-0.004	19	15	-0.033
Focal	39	16	0.962	15	34	0.703
Moderate	27	8		14	19	
Extensive	8	7		7	6	

Bold print indicates statistical significance. L, low; H, high.

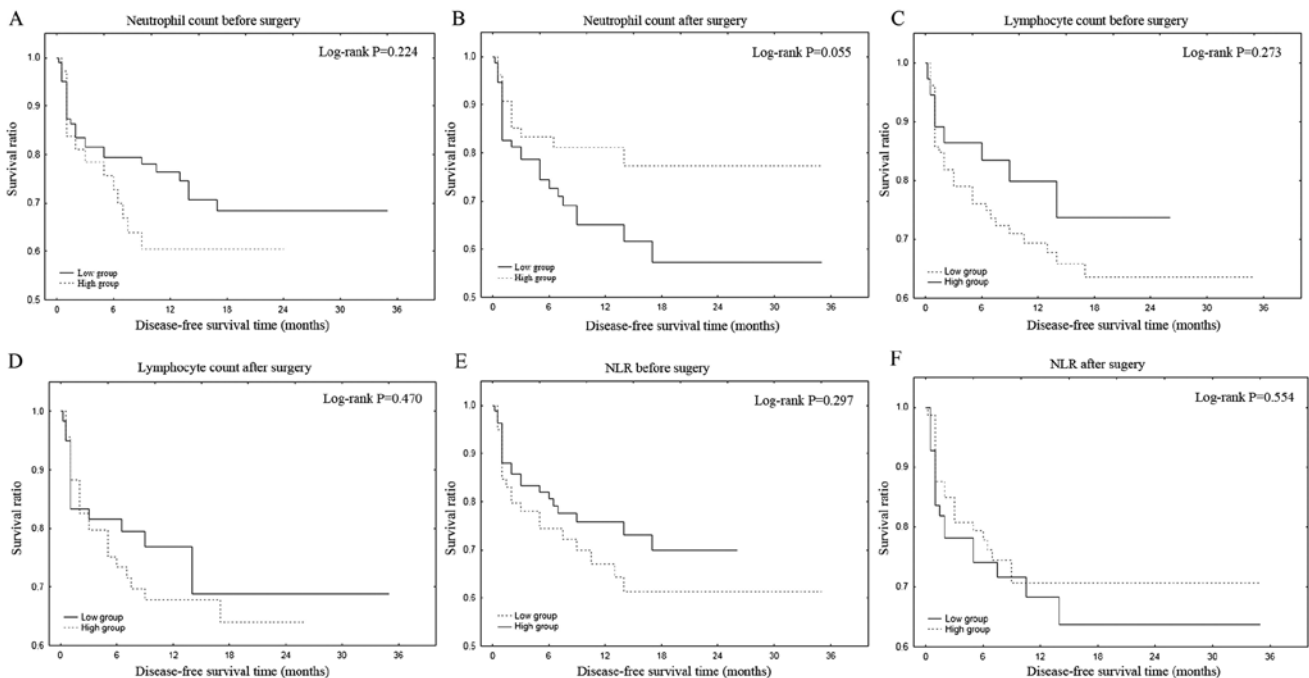


Figure 2. Disease-free survival curve according to Kaplan-Meier method. The association between neutrophil count, lymphocyte count and NLR in blood samples of patients with colorectal cancer before and after surgery and disease-free survival were examined by Kaplan-Meier survival analysis and log-rank test. The survival analysis revealed that only high vs. low neutrophil count before treatment exhibited a tendency to be associated with shorter disease-free survival (P=0.055). Analysis of survival time according to investigated parameters in blood samples before and after surgery: (A and B) neutrophil count, (C and D) lymphocyte count and (E and F) NLR. NLR, neutrophil-to-lymphocyte ratio.

the preLYMPH group was similar in both groups and was estimated to be 11 months. The mean DFS of postLYMPH was 11.06 in the low group and 10.42 in the high group. The mean DFS of NLR was similar in both groups and was estimated to be ~11 months for preNLR and ~10 months for postNLR. DFS did not differ significantly among the preNEU, preLYMPH, postLYMPH, preNLR and postNLR

groups (P=0.224, P=0.273, P=0.470, P=0.297 and P=0.554, respectively; Fig. 2A-F).

Discussion

The identification of chemotherapeutic targets for the treatment of advanced-stage CRC patients may increase the

survival time of these subjects. However, the examination of the molecular predictive factors is costly and requires sophisticated laboratory equipment. There is a continuous search for low-cost, easy-to-obtain specific parameters that can detect early recurrence of cancer and monitor treatment efficacy (1). In the present study, the diagnostic and predictive value of specific parameters, such as neutrophil count, lymphocyte count and the combination of those parameters (NLR), pre- and postoperatively were determined from whole blood samples of patients with CRC. Neutrophils have been reported to have multiple functions in different types of tumors (16). Neutrophils are functionally classified into two subtypes: Tumor-suppressing (N1) and tumor-promoting (N2) neutrophils. They are located at the margin of the tumor site and are present at the early stages of cancer progression. They can also infiltrate into the center of the tumor in advanced lesions. A specific classification of circulating neutrophils has been characterized in the whole blood of patients with cancer; these can be divided based on their density into high-density neutrophils (HDNs) and low-density neutrophils (LDNs) (17). HDNs are functionally similar to N1 neutrophils, while LDNs resemble N2 neutrophils (18). Type N1 neutrophils have potent antitumor activity and release immunostimulatory cytokines, such as interleukin-12 and tumor necrosis factor- α (19). In contrast to these observations, N2 phenotype cells induce strong immunosuppressive and tumor-promoting activity, which produces pro-angiogenic chemokines and cytokines that are involved in tumor cell proliferation, invasion and vascularization (20). In the present study, the cut-off values of preNEU and postNEU were examined in whole blood samples of patients with CRC. The cut-off values exhibited moderate sensitivity and specificity, with ~77-79% of disease prevalence. Moreover, preNEU was correlated with tumor size and the presence of necrosis. In the first step, neutrophils are able to produce reactive oxygen species and reactive nitrogen species that cause DNA damage and genetic instability in cancer cells (21). Furthermore, neutrophils can secrete various mediators, such as hepatocyte growth factor, that lead to tumor growth and progression (22). Neutrophils are also involved in remodeling of the tumor extracellular matrix by the release of matrix metalloproteinase-9 (23). The aforementioned properties of neutrophils were compared with tumor size and necrosis in previous studies and the data reported were consistent with our observations. However, the high neutrophil count noted in preoperative blood samples of patients with CRC exhibited a negative correlation with tumor budding. Tumor budding is defined as small clusters of cancer cells that are localized in the invasive margin of the primary tumor mass and they have important prognostic value. Ueno *et al* (24) demonstrated that tumor budding was observed in the margin of tumors with unfavorable fibrotic stroma. This cellular morphology was characterized by the presence of keloid-like collagen with random orientation of the fibrils and pervasive distribution of myofibroblasts. These histological characteristics of the tumor microenvironment likely determine the inhibition of the local and systemic immune response observed in patients with CRC. Moreover, high levels of neutrophil counts in whole blood samples were observed postoperatively in patients with non-mucinous CRC. The histological type of CRC was characterized by glandular cancer clusters in well-formed

rich stroma, as opposed to the mucinous cancer type that exhibits spontaneous formation of cancer cells in mucin. The presence of the rich stroma may affect the immune response development and its effectiveness.

Lymphocytes are also involved in the organization of the immune response in malignant neoplasms (25). Our previous study indicated that patients with CRC who did not have intraepithelial tumor-infiltrating lymphocytes (TILs) in the center of the primary tumor mass exhibited shorter DFS (26). Moreover, the infiltration and distribution of TILs in tumor tissues of patients with CRC were associated with the invasion and progression of the disease. In the present study, the correlation between preLYMPH and distant metastasis was confirmed. Therefore, the NLR may be a factor reflecting the balance between the tumor-promoting property of neutrophils and the host antitumor immune response of lymphocytes. A total of 144 samples of whole blood were obtained prior to and following surgery. A ROC curve was used to estimate the cut-off values of NLR. The present analysis indicated that the cut-off of preNLR was 2.5 and that of postNLR was 3.3. These results are consistent with the observations of other studies that reported variations in these parameters between 2.5 and 5.0 (27-29). The present study demonstrated high sensitivity and specificity with positive disease prevalence for ~78% of the participants. Zhou *et al* (30) reported that the sensitivity and specificity of NLR for CRC were 66.9 and 77.6%, respectively; moreover, the NLR values were significantly higher compared with those in healthy volunteers. Pedrazzani *et al* (31) observed that the distribution of NLR was different between CRC patients and control subjects. Moreover, the NLR value was correlated with age, TNM stage, systemic metastasis and serum CEA levels. In the present study, preNLR and postNLR were correlated with age and various morphological characteristics of disease progression, such as lymphatic invasion, tumor growth, lymph node metastasis, number of invaded lymph nodes and invasion of the lymph node pouch. Furthermore, Chen *et al* (32) highlighted that high NLR was more prevalent in the elderly (>60 years) population and that it was associated with larger tumor size, advanced pT stage and positive N and M. Özgehan *et al* (33) demonstrated that NLR was higher in CRC patients with T3/4-N1/2-M1 stage compared with the corresponding value noted in patients with T1/1-N0-M0.

The present study analyzed the DFS of CRC patients in association with neutrophil count, lymphocyte count and NLR. The patients with low postNEU exhibited a higher tendency for shorter DFS. These results did not confirm the association of DFS with preLYMPH and postLYMPH in CRC patients. However, Iseki *et al* (34) confirmed that patients with higher lymphocyte count demonstrated a tendency for higher 5-year relapse-free survival rate. Moreover, patients with a high preLYMPH exhibited significantly longer overall survival. An association between DFS and NLR was not observed in blood samples between pre- and postoperative CRC patients. Jankova *et al* (35) demonstrated that preNLR could predict overall survival, although it was not specific to recurrence and cancer-specific survival. In contrast to these observations, Ying *et al* (36) indicated that elevated NLR levels were of prognostic value for recurrence-free, overall and cancer-specific survival in CRC patients who had undergone surgery. Balde *et al* (37) reported that the high preNLR group exhibited

a higher recurrence rate compared with that of the low preNLR group. Li *et al* (38) demonstrated that a high preoperative NLR may be considered as a negative independent prognostic factor in non-metastatic rectal cancer. In addition, a previous study confirmed that a high preNLR was independently associated with poor prognosis of patients with CRC (39).

In conclusion, the findings of the present study indicated a significant correlation between specific blood indices in patients with CRC and disease progression markers, with only postNEU exhibiting a tendency of association disease prognosis. However, this preliminary evidence requires confirmation in studies with larger sample sizes.

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Availability of data and materials

The datasets used and/or analyzed during the present study are available from the corresponding author on reasonable request.

Authors' contributions

KJ collected data, performed analysis, wrote the manuscript, reviewed the literature, acquired the data and contributed to manuscript drafting; MK analysed and interpreted the pathological examination; WF, WK and LKK collected data; MG wrote the manuscript, reviewed the literature, acquired data and contributed to manuscript drafting. All authors reviewed and approved the final manuscript.

Ethics approval and consent to participate

The present study conformed to the principles outlined in the Declaration of Helsinki for human experimentation and the protocol was approved by the Bioethics Committee of the Medical University of Bialystok (approval no. R-I-002/353/2016). Written informed consent was obtained from all participants.

Patient consent for publication

Not applicable.

Competing interests

The authors declare that they have no competing interests.

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