

INTENSIVE CARE IN CARDIAC SURGERY

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Predictive significance of hematological indices in aortic reconstructive surgery: a prospective observational study

Предиктивная значимость гематологических индексов при реконструктивных операциях на аорте: проспективное наблюдательное исследование

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Abstract

Реферат

INTRODUCTION: Hematological indices are available, universal predictors and markers of infectious and non-infectious pathological conditions. **OBJECTIVE:** To determine the predictive ability of hematological indices in relation to the development of postoperative complications in patients undergoing reconstructive interventions on the aorta. **MATERIALS AND METHODS:** A prospective, observational, single-center study included 79 patients who underwent elective aortic surgery under cardiopulmonary bypass. Age of participants 57 (46.5; 64) years, Charlson comorbidity index 4 (2; 5), cardiopulmonary bypass duration 123 (101; 160) minutes, myocardial ischemia 91 (66; 115) minutes. The patients were divided into two groups: I — without complications, II — with complications. **RESULTS:** Neutrophil to lymphocyte ratio (NLR) on day 3 in group I was 6.17 (4.1; 8.7), in group II — 9.56 (6.68; 12.46), $p = 0.002$. NLR on day 6 in group I was 3.79 (2.77; 5.1), in group II — 6.0 (4.3; 9.1), $p = 0.001$. NLR > 7.5 on day 3 was a predictor of complications in the postoperative period, OR = 4.6 (95 % CI 1.8 — 11.9, $p = 0.002$). NLR on day 6 > 5.0 also showed a predictive ability: OR = 4.9 (95 % CI 1.9–12.7, $p = 0.001$). Platelet to lymphocyte ratio (PLR) on day 3 in group I was 103.88 (78.87; 133.57), by day 6 it increased to 117.5 (104.63; 160.78); in group II, there was practically no increase in PLR: from 122 (88.46; 160.25) to 127.06 (108.40; 154.14). Differences between the indicators in groups were not statistically significant. **CONCLUSIONS:** Hematological indices can be used as predictors of complications in patients after surgery on the aorta and its branches. Patients with NLR > 7.5 on day 3 and > 5.0 on day 6, regardless of comorbidities and age, may represent a previously unrecognized subgroup of patients with an increased risk of postoperative complications.

АКТУАЛЬНОСТЬ: Гематологические индексы являются доступными, универсальными предикторами и маркерами многих инфекционных и неинфекционных патологических состояний. **ЦЕЛЬ ИССЛЕДОВАНИЯ:** Определить предиктивную способность гематологических индексов в отношении развития послеоперационных осложнений у пациентов, перенесших реконструктивные вмешательства на аорте. **МАТЕРИАЛЫ И МЕТОДЫ:** В проспективное наблюдательное одноцентровое исследование включены 79 пациентов, перенесших плановое хирургическое вмешательство на аорте в условиях искусственного кровообращения (ИК). Возраст участников 57 (46,5–64) лет, индекс коморбидности Чарльсона 4 (2–5), ИК 123 (101–160) мин, ишемия миокарда (ИМ) 91 (66–115) мин. Пациенты были разделены на две группы: I — послеоперационный период протекал без осложнений, II — послеоперационный период протекал с осложнениями. **РЕЗУЛЬТАТЫ:** Отношение нейтрофилов к лимфоцитам (NLR) на 3-и сут в I группе составило 6,17 (4,1–8,7), во II — 9,56 (6,68–12,46), $p = 0,002$. NLR на 6-е сут в I группе составил 3,79 (2,77–5,10), во II — 6,0 (4,3–9,1), $p = 0,001$. Уровень NLR на 3-и сут $> 7,5$ являлся предиктором развития любых осложнений в послеоперационном периоде, отношение шансов (ОШ) = 4,6 (95 %-й доверительный интервал [95 % ДИ] 1,8–11,9, $p = 0,002$). Уровень NLR на 6-е сут $> 5,0$ также показал предикторную способность в отношении развития осложнений: ОШ = 4,9 (95 % ДИ 1,9–12,7, $p = 0,001$). Отношение тромбоцитов к лимфоцитам (PLR) на 3-и сут в I группе составило 103,88 (78,87–133,57), к 6-м сут выросло до 117,5 (104,63–160,78); во II группе повышения PLR практически не отмечалось.



с 122 (88,46–160,25) до 127,06 (108,40–154,14). Отличия между показателями в разных группах не были статистически значимыми ни на 3-и, ни на 6-е сут. **Выводы:** Гематологические индексы могут использоваться в качестве предикторов осложнений у пациентов после хирургического вмешательства на аорте и ее ветвях. Пациенты с уровнем NLR > 7,5 на 3-и сут и > 5,0 на 6-е сут, независимо от наличия сопутствующих заболеваний и возраста, могут представлять ранее не распознанную подгруппу пациентов с повышенным риском возникновения послеоперационных осложнений.

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KEYWORDS: lymphocyte, neutrophils, hematological indices, aortic surgery, sepsis, multiple organ dysfunction syndrome

КЛЮЧЕВЫЕ СЛОВА: отношение нейтрофилов к лимфоцитам, отношение тромбоцитов к лимфоцитам, гематологические индексы, хирургия аорты, сепсис, синдром полиорганной дисфункции.

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Introduction

Hematological indices (HI) are integral indicators, for the calculation of which data from a general blood test are used. Some of them have been well studied and have been used in clinical practice, for example, the leukocyte index of intoxication. HI discussed in this work have only recently begun to be discussed and are not yet routinely used. Neutrophil to lymphocyte ratio (NLR) and platelet to lymphocyte ratio (PLR) are simple and publicly available indicators, and therefore are being actively studied as reliable and accessible markers of inflammation. HI reflect

the dynamic relationship between the innate and adaptive cellular immune responses, as well as the cells participating in the blood coagulation system, in various pathological conditions. In a healthy population, NLR is positively correlated with age and body mass index [1]. Elevated HI levels may be predictive of bacterial coinfection in COVID-19 [2] and infections (especially pneumonia) in stroke patients. [3]. They are of no less interest in cardiology, since it is currently believed that chronic inflammation plays a significant role in the development of atherosclerosis and coronary artery disease (CAD) [4]. Higher levels of NLR and PLR are markers of poor development of collateral coronary blood flow in pa-

tients with CAD [5]; arterial wall stiffness in acute coronary syndrome (ACS) [6]; decreased aortic elasticity in patients with untreated essential hypertension [7], compared to patients without the listed pathological conditions [8]. There are studies demonstrating the value of NRL and PLR as predictors of poor outcome in patients with acute myocardial infarction [9–13], heart failure [14,15] and NLR levels in Takotsubo syndrome preceded by physical rather than emotional triggers [16]. Elevated NLR levels are associated with lower survival after coronary artery bypass grafting (CABG) [17], endovascular treatment of abdominal aortic aneurysm [18] and transcatheter aortic valve implantation (TAVI) [19].

Objectives

The purpose of this study is to determine whether NLR and PLR can be used as predictors of postoperative complications in patients undergoing surgery on the aorta and its branches.

Materials and methods

To carry out a prospective observational study, we used data collected as part of the scientific work “Modulation of Microbiota”, carried out on the basis of the Petrovsky National Research Centre of Surgery (extract from the meeting of the local ethics committee No. 7 dated April 15, 2021). The study included 81 patients who underwent surgery on the aorta and its branches under conditions of cardiopulmonary bypass (CPB) and myocardial ischemia (MI).

Criteria for inclusion in the study: age from 17 to 75 years; reconstructive surgical interventions on the aorta performed by one surgical team (headed by Corresponding Member of the Russian Academy of Sciences, Professor, Doctor of Medical Sciences Charchyan E.R.; Head of Cardiac Anesthesiology — Professor of the Russian Academy of Sciences, Doctor of Medical Sciences B.A. Axelrod); obtained voluntary informed consent of the patient to participate in the study.

Criteria for non-inclusion in the study: age under 17 or over 75 years; other cardiac surgeries performed at the Petrovsky National Research Centre of Surgery; reconstructive operations on the aorta performed by another surgical team; refusal of the patient to participate in the study; disorders of consciousness that prevent obtaining voluntary informed consent.

Criteria for exclusion from the study: transfer to another hospital in the postoperative period; refusal of the patient to further participate in the study at any stage. Two patients met the exclusion criterion: transfer to another hospital and the impossibility of further observation were associated with coronavirus infection.

In total, data from 79 patients were analyzed. Among them, 57 men and 22 women (28 %), age of participants 57 (46.5; 64), Charlson comorbidity index 4 (2; 5), CPB 123 (101; 160) minutes, MI 91 (66; 115) minutes. Five patients (6.3 %) were admitted to the hospital with a diagnosis of acute/subacute aortic dissection of DeBakey type I-II; the remaining patients underwent elective reconstructive surgery of the aorta. Among the interventions performed, 32 % were hybrid operations, including prosthesis of the ascending aorta and/or aortic arch and stenting of the descending aorta, 27 % — prosthesis of one or more sections of the thoracic aorta, 18 % — replacement of the aortic valve and ascending aorta using the Bentall-DeBono method, 11 % — replacement of the root and ascending aorta using the David method. Moreover, 44 % of operations were performed under conditions of hypothermia (26–23 °C); in 24 % of cases, interventions on heart valves were also performed, and in 15 %, myocardial revascularization was performed. All patients were observed for at least 24 hours after surgery in the ICU.

Concomitant pathologies are presented in Table 1.

The differences in HI values depending on the presence or absence of each of the listed pathologies, as well as the influence of demographic indicators (gender and age group), were studied.

The primary end point of the study was the presence of one or more complications in the postoperative period: local inflammatory processes (pneumonia, mediastinitis) (n = 22); sepsis, multiple organ dysfunction syndrome (n = 5); various complications of non-infectious origin (n = 16) — these patients made up group II (43 patients). Complications of non-infectious origin included: acute cerebrovascular accidents (n = 1), hemodynamic significant rhythm disorders (n = 4), surgical bleeding (n = 8), disturbances of myocardial contractility (n = 2), vocal cord paresis (n = 1). (Group I included patients whose postoperative period proceeded without complications (control group) (n = 36).

In accordance with national clinical guidelines [20], the diagnosis of pneumonia was made when fresh focally infiltrative changes in the lungs appeared according to X-ray examination in combination with two or more clinical and laboratory signs (acute fever of 38.0 °C and above; cough with sputum; physical signs — focus of crepitus/fine-bubble rales, bronchial breathing, shortening of percussion sound; leukocytosis $> 10 \times 10^9 / l$ and/or band shift $> 10 \%$). The diagnosis of mediastinitis was established in cooperation with surgeons based on examination of the postoperative wound during dressing and bacteriological examination of discharge from the wound. When two or more functional systems (cardiovascular, respiratory, renal-hepatic) were dysfunctional, multiple organ dysfunction syndrome (MODS) was identified. In the presence of a focus of infection or suspicion of infection in combination with MODS (+2 points according to SOFA), a diagnosis of sepsis was established.

Table 1. Structure of comorbidity in the study cohort

Concomitant disease	Number of patients	%
Heart valve disease	55	69.6
Multifocal atherosclerosis	24	30.4
Coronary artery disease	20	25.3
Hypertensive disease	57	72.2
Heart rhythm disturbances such as atrial fibrillation, atrial flutter, or frequent ventricular extrasystole	14	17.7
Conduction disorders in the form of 2–3 degree AV block, blockade of one of the branches of the His bundle	4	5.1
Connective tissue dysplasia	10	12.7
Chronic kidney disease	16	20.3
Diabetes mellitus type II	7	8.9
Diseases of the gastrointestinal tract, including gastritis, duodenitis, gastroduodenitis, gastric and/or duodenal ulcers in remission	48	60.8

On the third and sixth postoperative days, in complete blood count, the absolute level of neutrophils, lymphocytes, and platelets was assessed, and the neutrophil-to-lymphocyte ratio (NLR) and platelet-to-lymphocyte ratio (PLR) were calculated. NLR and PLR are dimensionless quantities. An indicator reflecting the dynamic changes in NLR and PLR was also calculated using the formula $\Delta \text{Indicator} = (\text{Indicator on day 6} - \text{Indicator on day 3}) / \text{Indicator on day 3} \times 100\%$. Before surgery, after surgery upon admission to the ICU and 6 hours after surgery, the levels of procalcitonin (PCT, < 0.05 ng/ml), tumor necrosis factor alpha (TNF- α , < 50 pg/l), interleukin-6 (IL-6, < 7 pg/ml) and interleukin-10 (IL-10, < 9.1 pg/ml) were assessed in the blood of patients.

Statistical analysis

Microsoft Excel was used to create a database and graphic materials. Statistical data processing was carried out using IBM SPSS Statistics 26. For each quantitative indicator, the nature of the distribution was determined using the Kolmogorov-Smirnov test. All quantitative data with a distribution other than normal are presented as median (Q2) and interquartile range (Q1; Q3). To assess differences between two independent samples, the Mann-Whitney test was used, between related samples — the Wilcoxon test, and between three independent samples — the Kruskal-Wallis test. Correlation analysis was performed by calculating the Spearman correlation coefficient (ρ). Using logistic regression, we assessed the influence of independent variables on binary coded dependent variables. The odds ratio (OR), 95 % confidence interval (CI) and significance of the effect p were calculated. In all cases, the results of statistical analysis were considered significant at $p < 0.05$.

Results

No differences were found in the HI level depending on gender, as well as the presence of concomitant diseases. Despite the fact that there were no differences in the absolute number of neutrophils, lymphocytes and platelets in age groups, the HI values differed on the 3rd postoperative day (Table 2). In young patients (18–44 years old, $n = 16$) NLR was 5.82 (3.92; 8.91), middle-aged patients (45–59 years old, $n = 29$) — 7.33 (4.89; 9.64), elderly patients (60–74 years old, $n = 33$) — 10.20 (6.53; 13.36). In different age groups, PLR levels on day 3 varied: 81.93 (70.34; 99.56) in young patients; 108.75 (92.35; 133.00) in middle-aged patients and 130.77 (97.08; 164.73) in elderly patients ($p = 0.008$). On postoperative day 6, no differences in HI levels were found. At the same time, the dynamics of HI significantly varied in different age groups: ΔNLR –17 % (–28 %; 5 %) among young patients, –25 % (–52 %; 20 %) in middle-aged patients and –53 % (–63 %; –15 %) in elderly patients ($p = 0.022$); ΔPLR 45 % (16 %; 73 %), 15 % (–5 %; 55 %) and 2 % (–31 %; 44 %) respectively, ($p = 0.034$), see Figure 1.

The greatest decrease (–26 %) in the level of neutrophils was noted from 3 to 6 day in elderly patients. The absolute value of lymphocytes decreased by 20–30 % in all age groups, and platelets increased by 40 %.

Patients with complications ($n = 43$) were characterized by longer CPB and MI and larger volumes of intraoperative blood loss and blood loss through drains in the ICU. They did not differ significantly in age and CCI (Table 3). These patients had higher concentrations of some biomarkers 6 hours after admission to the ICU: PCT (0.44 (0.16, 1.11) ng/ml versus 0.11 (0.06, 0.25) ng/ml in patients without complications, $p < 0.001$; TNF- α (7.10 (5.33, 8.38) pg/ml versus 5.20 (4.43, 6.93) pg/ml, $p = 0.009$). Noteworthy was

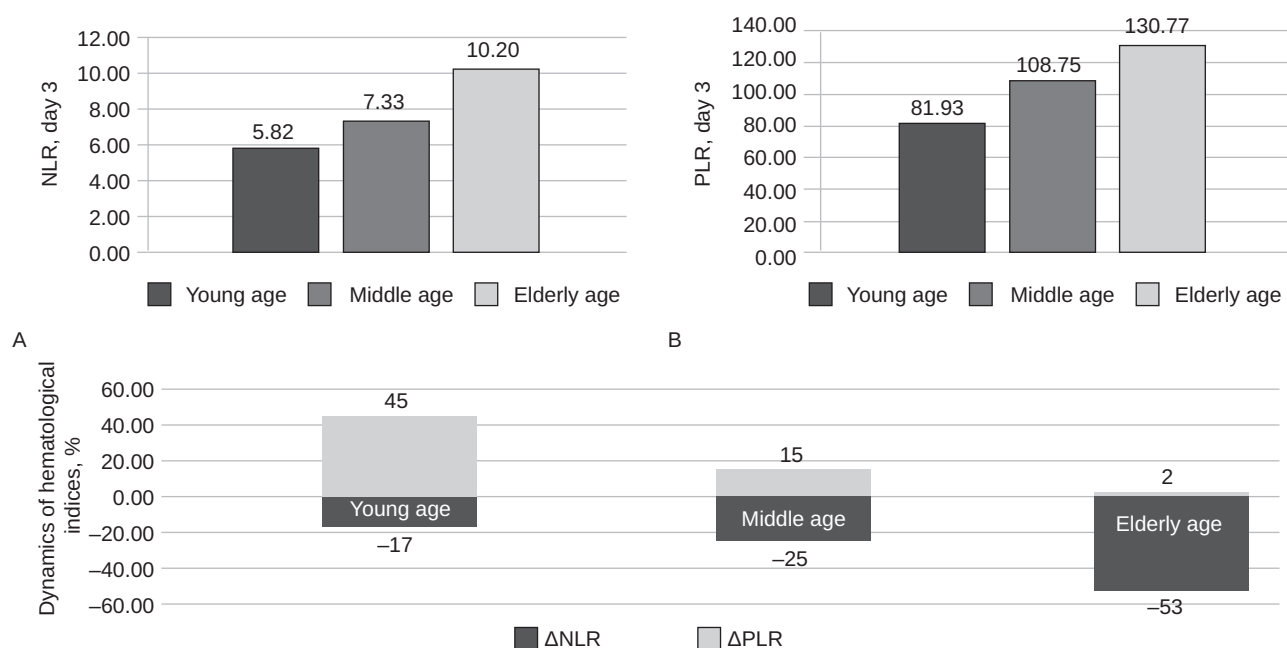


Fig. 1. (A) NLR on postoperative day 3 in different age groups; (B) PLR on postoperative day 3 in different age groups; (C) — dynamics of hematological indices in different age groups, %

HI — Hematological indices.

the high level of IL-6 in the preoperative period — 8.20 (2.68; 18.95) pg/ml compared to 2.25 (1.50; 7.33) pg/ml in patients without complications, $p = 0.009$; as well as a more significant increase in IL-6 immediately after surgery — 128.15 (65.03; 223.33) pg/ml versus 51.30 (34.10; 85.00) pg/ml, $p < 0.001$. Consequently, the length of stay in the ICU, in the surgical department and in the hospital was also higher in group II.

The NLR level was higher in the group of patients with complications throughout the entire postoperative peri-

od. NLR tended to decrease in both groups (Figure 2). PLR in both groups did not differ significantly, however, the index increased in the postoperative period in group I, while in group II there was no increase in PLR over time (Figure 3).

Using binary logistic regression, it was revealed that the NLR level on day 3 > 7.5 was a predictor of the development of any complications in the postoperative period, OR = 4.6 (95 % CI 1.8–11.9, $p = 0.002$). NLR level on day 6 > 5.0 also showed predictive ability for the development

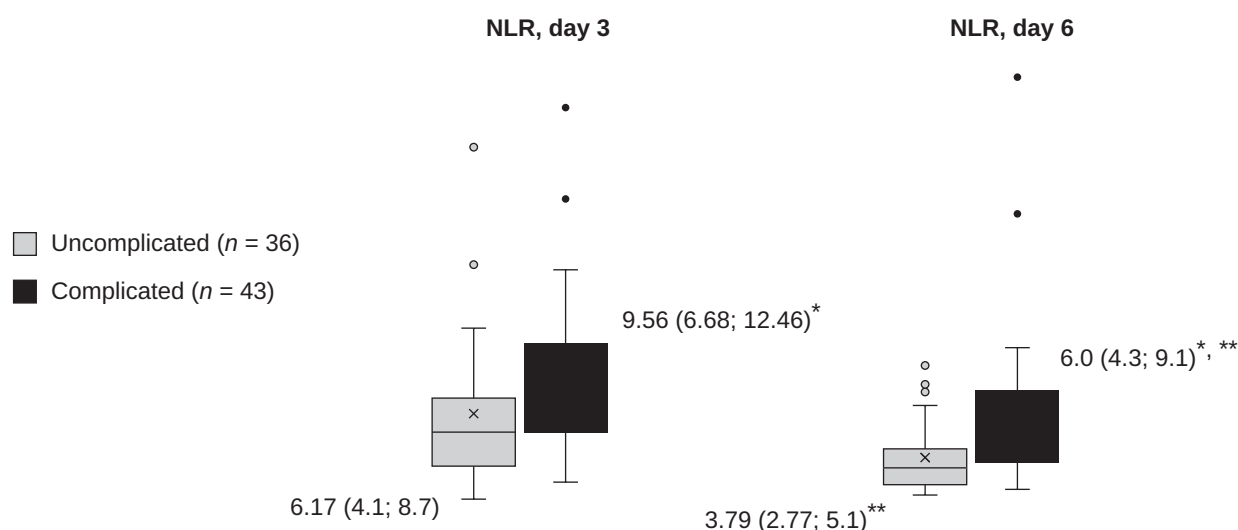


Fig. 2. Comparison of NLR in groups of patients with and without complications during the postoperative period

* $p < 0.05$ when compared with the control group;

** $p < 0.05$ when compared within the group with the previous measurement.

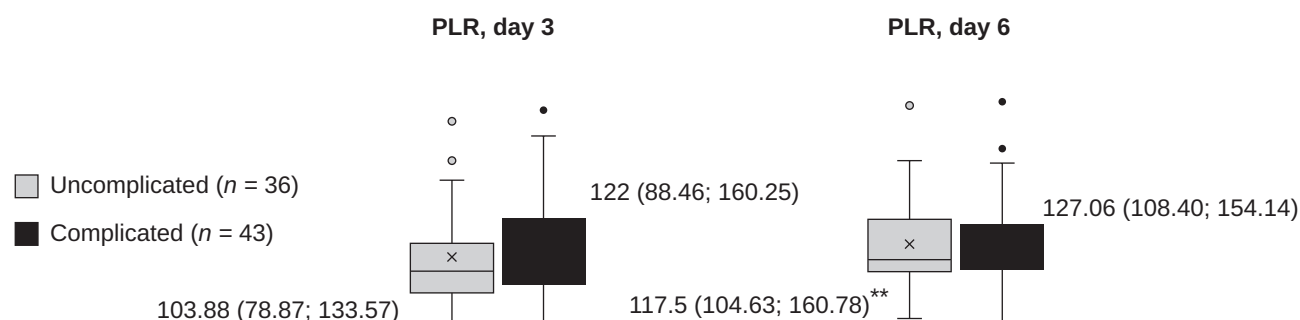
Table 2. Absolute values of neutrophils, lymphocytes and platelets on days 3 and 6 in patients of various age groups

Parameters	Young age (18–44 years old) <i>n</i> = 16	Middle age (45–59 years old) <i>n</i> = 29	Elderly age (60–74 years old) <i>n</i> = 33	<i>p</i> ⁴	General cohort of patients <i>n</i> = 79
Neutrophils, abs. ($\times 10^3/\mu\text{l}$) day 3	8.45 (7.03; 8.85)	8.40 (6.80; 10.60)	9.80 (7.30; 13.50)	0.072	8.7 (6.85; 11.95)
Neutrophils, abs. ($\times 10^3/\mu\text{l}$) day 6	7.50 (5.95; 8.63)	8.50 (6.30; 9.70)	7.50 (5.30; 9.00)	0.404	7.6 (5.75; 9.35)
Δ Neutrophils %	–0.58 (–15.01; 20.79)	1.00 (–35.16; 26.87)	–25.93 (–50.00; 2.74)	0.032	–9.76 (–37.71; 15.90)
<i>p</i> ¹	0.955	0.449	0.002		0.005
Lymphocytes, abs. ($\times 10^3/\mu\text{l}$) day 3	1.40 (0.98; 1.90)	1.10 (0.90; 1.70)	1.10 (0.80; 1.40)	0.245	1.1 (0.9; 1.6)
Lymphocytes, abs. ($\times 10^3/\mu\text{l}$) day 6	1.55 (1.18; 2.13)	1.60 (1.00; 2.00)	1.40 (1.00; 2.00)	0.682	1.5 (1.0; 2.0)
Δ Lymphocytes %	21.11 (–2.50; 35.79)	17.39 (0.00; 60.00)	28.57 (0.00; 100.00)	0.468	21.11 (0.00; 61.88)
<i>p</i> ²	0.047	0.001	0.001		< 0.001
Platelets ($\times 10^9/\text{l}$) day 3	132.00 (101.25; 138.75)	131.00 (98.00; 182.00)	146.50 (105.50; 178.50)	0.422	133.0 (103.25; 169.0)
Platelets ($\times 10^9/\text{l}$) day 6	193.00 (170.50; 224.50)	202.50 (138.00; 232.25)	187.00 (140.00; 242.00)	0.877	202.0 (143.0; 238.0)
Δ Platelets %	48.60 (33.82; 76.04)	29.63 (22.81; 59.48)	33.99 (9.38; 71.12)	0.317	37.09 (18.80; 69.11)
<i>p</i> ³	0.001	< 0.001	< 0.001		< 0.001

p — reliability of changes in the absolute values of neutrophils (1), lymphocytes (2), platelets (3) between days 3 and 6; *p*⁴ — reliability of changes in absolute values of parameters between age groups.

of complications: OR = 4.9 (95 % CI 1.9–12.7, *p* = 0.001), see Figure 4. As a result of ROC analysis, it was revealed that the level of NLR > 7.5 on day 3 as a predictor of complications has a sensitivity of 76.7 % and a specificity of 27.8 %, NLR > 5.0 on day 6 — a sensitivity of 62.8 % and specificity 27.8 %, see Figure 5. PLR did not demonstrate predictive ability regarding the development of complications.

The level of neutrophils on day 3 did not differ in patients with complications compared to the control group; the other studied parameters were statistically significantly different (Table 4). However, it was not possible to determine threshold values for any of the parameters, that is, individually they did not demonstrate predictive ability regarding the development of complications.

**Fig. 3.** Comparison of PLR in groups of patients with and without complications during the postoperative period

* *p* < 0.05 when compared with the control group;

** *p* < 0.05 when compared within the group with the previous measurement.

Table 3. Differences between groups of patients with uncomplicated and complicated course of the postoperative period

Parameters	Group I (n = 36)	Group II (n = 43)	p
Days in ICU	1 (1; 1)	3 (2; 5)	< 0.001
Days in hospital after surgery	7 (6; 8)	9,5 (7; 14)	0.001
Age	58 (45; 63)	54.5 (47.75; 64.2)	0.322
CCI, points	3 (2; 5)	4 (2; 5)	0.067
Duration CPB, minutes	112 (73; 141.5)	144 (116; 192)	0.001
Duration MI, minutes	84,50 (53.75; 104.50)	101 (80; 137)	0.019
Intraoperative blood loss, ml	800 (600; 900)	950 (700; 1500)	0.008
Blood loss through drains, ml	200 (140; 300)	300 (200; 500)	0.012
General blood loss, ml	950 (775; 1300)	1300 (957.50; 1875)	0.002

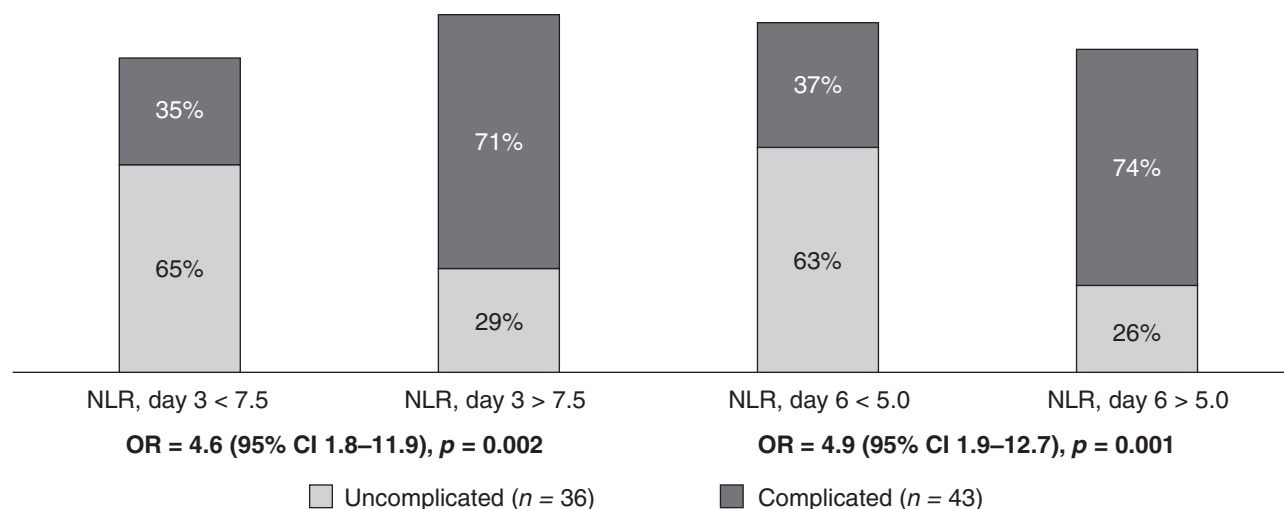
Correlation analysis in the overall cohort revealed positive correlations of NLR on postoperative day 6 with length of hospitalization, as well as with preoperative IL-6/IL-10 ratio, see Figure 6.

In the control group, NLR on day 6 after surgery correlated with the levels of IL-10 before and after surgery, as well as IL-6 before surgery, see Figure 7. The greatest number of correlations was identified in the group of patients with any complications: in this case, NLR on days 3 and 6 correlated with the duration of stay in the ICU, the total length of hospitalization and the ratio of IL-6 and IL-10 before surgery, see Figure 8.

Discussion

HI may reflect the inclusion of unobvious pathophysiological mechanisms that are not diagnosed during tradition-

al examination. This is especially important due to the fact that the population of patients requiring reconstructive interventions on the aorta is heterogeneous both in terms of initial pathology and the presence of concomitant diseases [21–23]. This study showed that age and CCI did not differ between patients with and without complications; levels of neutrophils, lymphocytes and platelets individually are not predictors of complications. This indicates the need to search for more accurate and reliable predictors of an unfavorable outcome than the patient's belonging to an older age group, the presence of a large number of concomitant diseases and changes in certain indicators of a general blood test. In addition to the initial chronic inflammation, the systemic inflammatory response provoked by CPB plays an important role in the postoperative period [24], and is also an integral part of the surgical stress response along with endocrine and metabolic reactions [25]. In a population of healthy non-geriatric people, NLR ranges from 0.78 to 3.53 [26]. In the postoperative period, NLR can

**Fig. 4.** The incidence of complications in groups of patients with different levels of NLR on the 3rd and 6th postoperative days

95 % CI — 95 % confidence interval; OR — odds ratio.

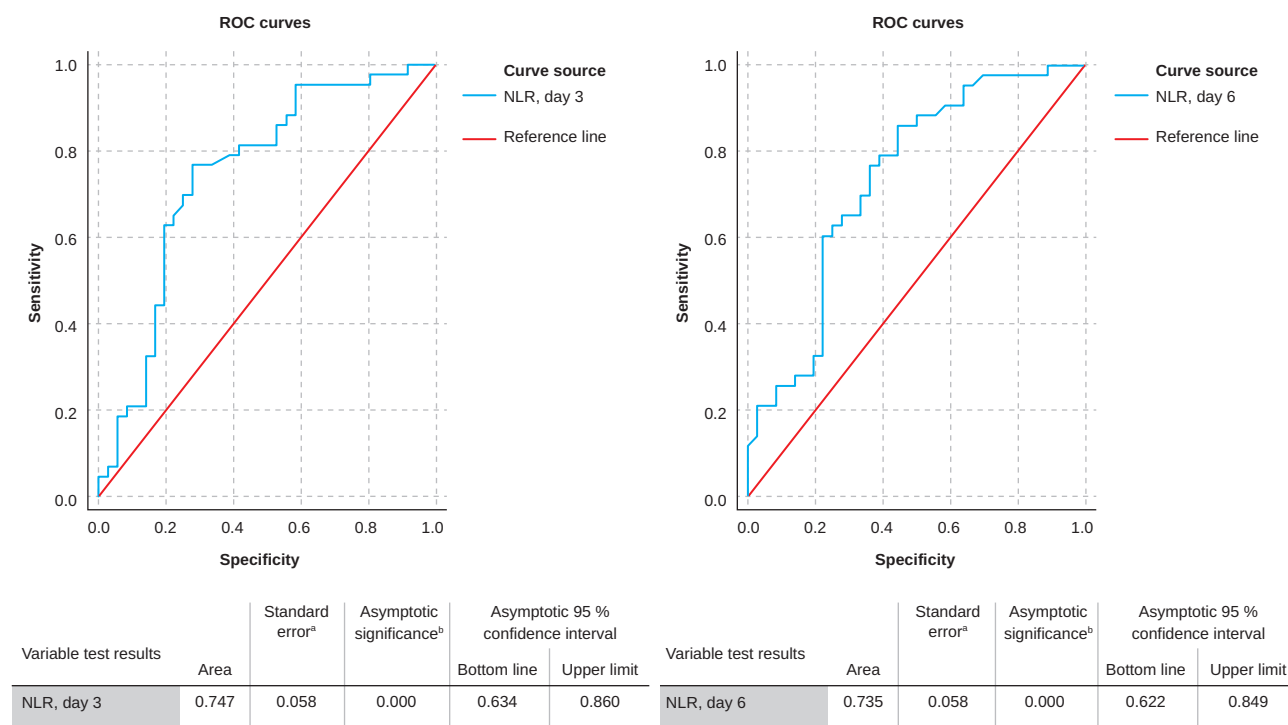
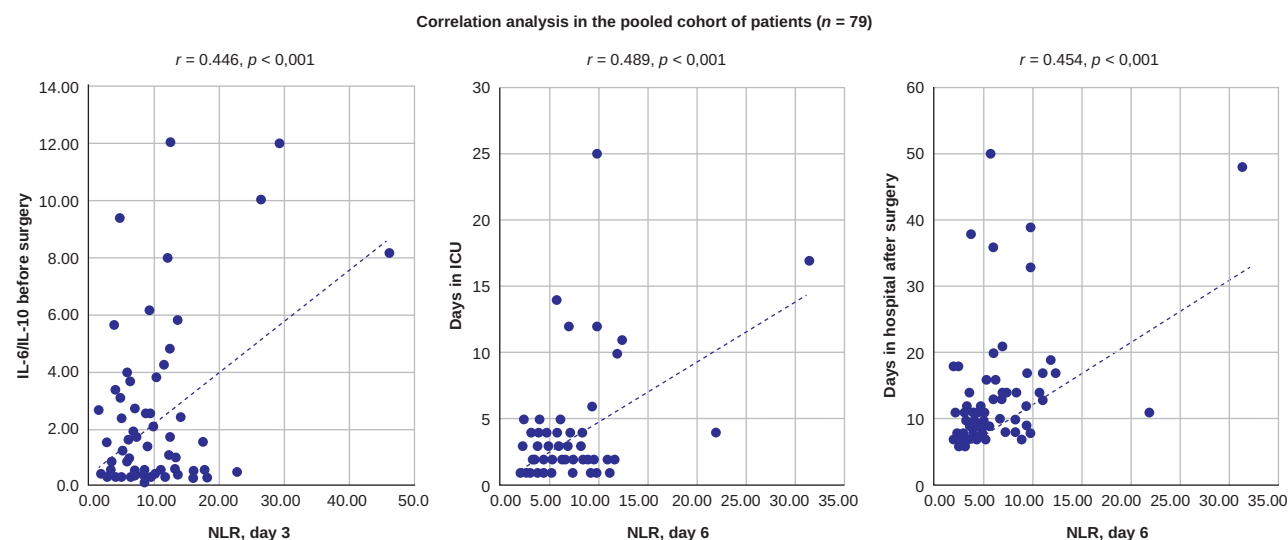
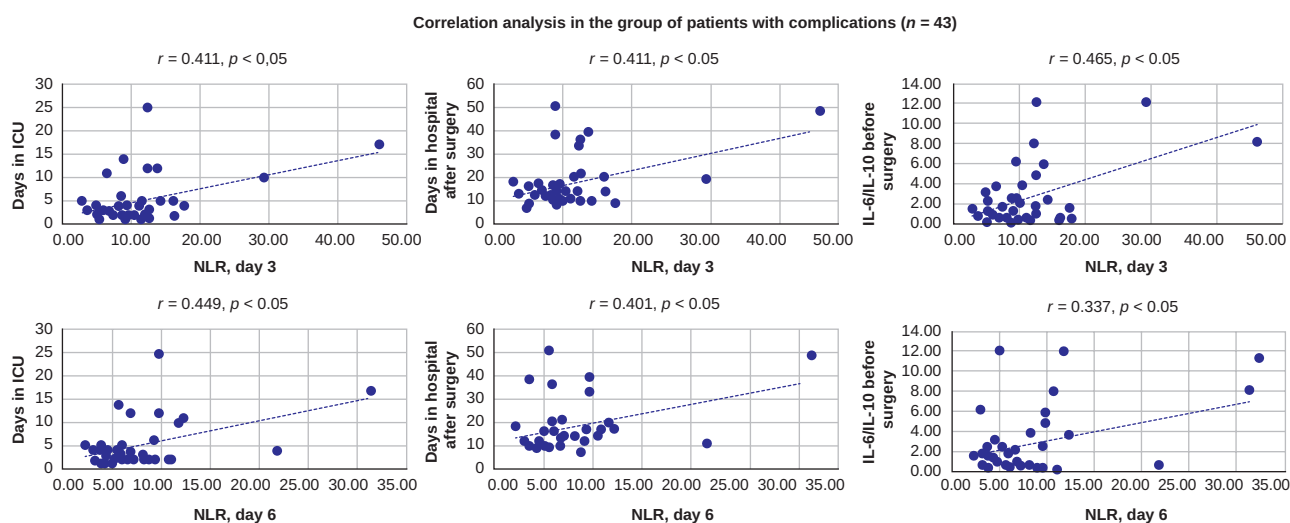
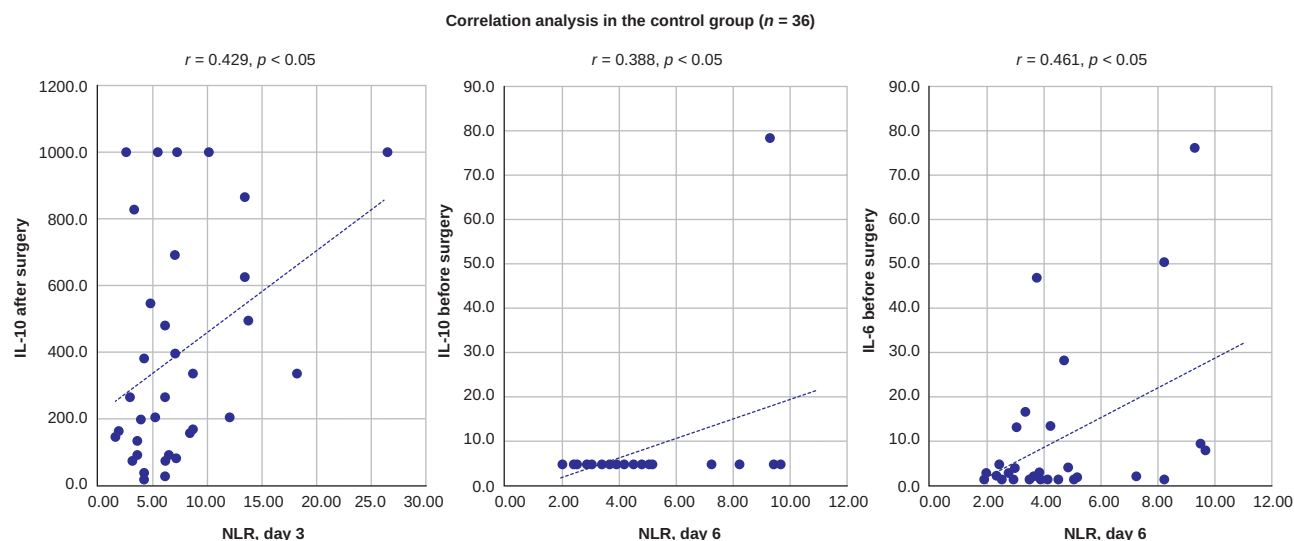


Fig. 5. The results of the ROC analysis

Fig. 6. Statistically significant results of correlation analysis in the pooled cohort of patients ($n = 79$)**Table 4.** Absolute values of neutrophils, lymphocytes and platelets in patients with uncomplicated and complicated course of the postoperative period

Parameters	Group I ($n = 35$)	Group II ($n = 43$)	p
Neutrophils, abs. ($\times 10^3/\mu\text{l}$) day 3	8.60 (6.50; 11.65)	8.85 (7.10; 12.03)	0.298
Neutrophils, abs. ($\times 10^3/\mu\text{l}$) day 6	6.50 (5.00; 8.35)	8.50 (6.78; 9.60)	0.006
Lymphocytes, abs. ($\times 10^3/\mu\text{l}$) day 3	1.40 (1.05; 1.85)	1.00 (0.80; 1.20)	0.001
Lymphocytes, abs. ($\times 10^3/\mu\text{l}$) day 6	1.80 (1.25; 2.05)	1.25 (1.00; 1.70)	0.022
Platelets ($\times 10^9/\text{l}$) day 3	153.00 (122.00; 181.00)	123.00 (80.50; 157.50)	0.032
Platelets ($\times 10^9/\text{l}$) day 6	208.00 (173.00; 257.00)	184.00 (130.25; 220.25)	0.035



be significantly higher than this level, while remaining within the adaptive response to surgical intervention. Elevated NLR level reflects changes in the complex interaction between regulators (helper T cells) and effectors (cytotoxic T cells and neutrophils) of the immune response, being a dynamic indicator influenced by both acute and chronic inflammation [27]. This makes it an interesting integral indicator that allows us to evaluate not only the response of the individual organism to surgical intervention, but also its initial inflammatory status, which affects the course of the perioperative period. In this study, this is indirectly confirmed by the fact that the NLR level after surgery positively correlated with the level of IL-6 and the IL-6/IL-10 ratio before surgery, and also in the postoperative period, unlike interleukin levels, did not correlate with the duration of cardiopulmonary bypass and the volume of blood loss. NLR is of great interest due to its ability to identify patients with a higher risk of postoperative complications not only

in the postoperative period, but also at the planning stage of surgical intervention. Moreover, in the postoperative period, the NLR level positively correlates with the length of stay in the ICU and the length of hospitalization in general. The results of the study demonstrate that HI, especially NLR, can serve as early predictive factors for the development of postoperative complications. According to ROC analysis, NLR has high sensitivity but low specificity, which is natural for an indicator that is a universal biomarker of inflammation. However, when the clinician must assess the risks of developing a wide range of complications in a highly heterogeneous group of patients, low specificity is not a significant disadvantage. Based on the NLR level, it is possible to stratify the risk of complications, focusing on a complete blood count, which is already used in routine clinical practice throughout the entire perioperative period. Patients with an NLR level > 7.5 on day 3 and > 5.0 on day 6, regardless of the presence of concomitant diseases and age,

may represent a previously unrecognized subgroup with an increased risk of postoperative complications. Patients from this group require increased attention to recognize complications at an early stage, especially those of an infectious nature. It may also be possible to consider performing additional diagnostic tests in these patients.

PLR, in turn, did not demonstrate prognostic significance for the development of complications or even significant differences in the group of patients with complications compared with the control group. According to the literature, PLR has shown good results as a predictor of complications after primary percutaneous intervention in patients with ACS [12], after TAVI [28], carotid endarterectomy [29] and CABG [30]. The volume of blood loss during aortic reconstructive surgery is higher than during the above-mentioned surgical procedures, which may reduce the predictive value of RLR in this cohort of patients. However, the absence of an increase in PLR over time may indicate a less favorable course of the postoperative period and the presence of hidden factors that impede the patient's recovery after surgery.

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Conclusion

Hematological indices can be used as predictors of complications in patients after surgery on the aorta and its branches.

Patients with an NLR level > 7.5 on day 3 and > 5.0 on day 6, regardless of the presence of concomitant diseases and age, may represent a previously unrecognized subgroup with an increased risk of postoperative complications.

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Author contribution. All authors according to the ICMJE criteria participated in the development of the concept of the article, obtaining and analyzing factual data, writing and editing the text of the article, checking and approving the text of the article.

Ethics approval. This study was approved by the local Ethical Committee of Petrovsky National Research Centre of Surgery (reference number: 7-15.04.2021).

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