Analysis of anamnestic and laboratory-instrumental indicators to determine the criteria for predicting complications during open surgical interventions using information techniques*

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Abstract
We conducted an in-depth analysis of the results of clinical observations, laboratory and instrumental studies of 44 patients with stenotic-occlusive lesions of the great arteries of the lower extremities, who underwent open surgical interventions. In order to identify the significance of combined changes in indicators for predicting complications, information techniques were applied. Average values, comparative analysis were first computed, and subsequently, correlation analysis was conducted. This research has proven the effective use of the above-mentioned techniques for identifying pairs of indicators, which suggests the possibility of using such changes as markers of the risk of complications. Thus, by knowing the indicators of complications, we can predict the occurrence of potential complications and, therefore, choose the safest and least invasive surgical technique.

Keywords
correlation analysis, information techniques, atherosclerosis, limb revascularization, surgical complications

1. Introduction

The frequency of complications in the early and late postoperative period is closely related not only to obliterating atherosclerosis as the main disease of the great arteries of the lower extremities, but also to comorbid pathology, which can increase this frequency [2, 18, 25].

Given the systemic nature of peripheral artery disease (PAD), patients always have concomitant chronic diseases. It has been proven that there is a 3-4 times higher risk of acute myocardial infarction (MI) and sudden death compared to patients without PAD. Lesions of several vascular segments are associated with worsening long-term treatment outcomes in patients with stenotic-occlusive lesions of the infrainguinal region [4, 15, 16, 21, 22].

Thus, it is important to determine the levels of risk and significance of a number of clinical and anamnestic indicators, both individually and in combination, to predict the risk of complications and select the optimal volume of surgical interventions.

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2. Materials and methods

Statistical analysis of clinical, instrumental, and laboratory data of 44 patients was conducted using methods of variational and analytical statistics [1, 6, 7, 8, 18]. Data processing was performed with Microsoft Excel (2016). For normally distributed variables, intergroup differences were assessed using the Student's (T-Test). In cases where the distribution deviated from normality, the non-parametric Mann–Whitney (U-Test) was employed. Statistical significance was considered at $p<0.05$.

To assess the strength and direction of linear relationships between variables, the Pearson correlation coefficient (r) was calculated:

$$r = \Sigma[(X_i - \bar{X})(Y_i - \bar{Y})] / \sqrt{([\Sigma(X_i - \bar{X})^2 \cdot \Sigma(Y_i - \bar{Y})^2])}$$

where:

X_i, Y_i — individual data points

$\bar{X}$, $\bar{Y}$ — means of X and Y

In case of nonparametric data, the Spearman rank correlation coefficient (ρ) was used:

$$\rho = 1 - [6 \cdot \Sigma d_i^2] / [n(n^2 - 1)]$$

where:

d_i — difference between the ranks of corresponding variables

n — number of observations

3. Main part

An analysis was conducted on indicators from 44 patients to assess combined changes in the parameters of the studied groups, with the aim of improving the prediction of postoperative complication risks for open surgery. For this purpose, comparative and correlation analyzes were applied.

To determine the character and extent of atherosclerotic lesions in the arterial system of the lower extremities, all patients underwent determination of the clinical manifestations, examination using the SonoScape S8 Exp. ultrasound system (China) and contrast-enhanced computed tomography with the Siemens Brilliance CT64 scanner (Germany), focused on the vascular area.

4. Results and Discussions

The results of laboratory and instrumental studies, as well as clinical observations, were analyzed using methods of variational and analytical statistic.

4.1. Evaluation of clinical symptoms and signs in patients

The following algorithm was used for the clinical examination of each patient. During medical history taking, the first complaints of the patient were identified, namely, “intermittent claudication”, which was noted by all patients (100%), the presence of pain at rest, which occurred in 25 (57.12%) patients, changes in skin temperature and color in 44 (100%) patients, the presence of hypotrichosis or hyperkeratosis in 44 (100%) patients, as well as trophic changes in the feet in 7 (16.6%) patients [2, 4] in Table 1.

During the examination of each patient, pulsation was determined symmetrically (on both lower limbs) on the femoral, popliteal, tibial arteries, and arteries of the feet.

Table 1
Clinical manifestations of pathology in patients with atherosclerotic stenotic-occlusive process of the infrainguinal arterial bed in conditions of stenotic-occlusive lesions of the arteries of the lower extremities

Clinical manifestations	**I group, (n=44)**	**1a group, (n=34)**	**1b group, (n=10)**	**%**
Intermittent claudication	44	34	10	100
Pain at rest	25	15	10	57,12
Necrosis of fingers	7	3	4	16,6

4.2. Anaysis of anamnestic and laboratory-instrumental indicators to determine criteria for predicting complications in open surgical interventions using information techniquesl

Patients with stenotic-occlusive processes in the infrainguinal arterial segment, whose indicators were analyzed using information techniques, were divided as follows. The first group consisted of 44 patients who underwent open surgery: 1a – 34 patients without complications; 1b – 10 patients with complications. The results of clinical observations, laboratory and instrumental studies of 44 patients (group 1) were analyzed. Reconstructive surgeries included: In 14 cases ((31.82±7.02) %), allografting was performed, in 14 cases ((31.82±7.02) %) deep profundoplasty was performed, and in 16 cases ((36.36±7.25) %) autovenous bypass was used.

An analysis of anamnestic and laboratory indicators was performed in 34 patients (77.3%) without complications (group 1a) and 10 patients (22.7%) with complications (group 1b). The average age of patients in the first group was (66.45±1.32) years. The body mass index (BMI) in patients in this group was (14.84±0.68) kg/m². Harmful habits were found in (54.55±7.51) % of patients. The proportions of other anamnestic indicators were as follows: extracranial artery lesions 26% – (54.55±7.51) %, diabetes mellitus – (18.18±5.82) %, history of stroke – (4.55±3.14) %, history of myocardial infarction – (11.36±4.78) %, gastrointestinal tract pathology – (13.64±5.17) %, respiratory failure – (13.64±5.17) %, cardiovascular disease – (95.45±3.14) %, history of cancer – (2.27±2.25) %, types of anesthesia: regional anesthesia – (15.91±5.51) %, epidural anesthesia – (84.1±5.51) %, mechanical ventilation + intravenous – (2.27±2.25) %.

In patients of group 1a, the average age was (66.56±1.63) years, and the BMI was (15.37±0.84) kg/m², which did not significantly (p>0.05) differ from the similar indicators of patients in group 1 of the study. The proportion of harmful habits ((52.94±8.56) %) was at the same level (p>0.05) as in patients in group 1. The proportions of other anamnestic indicators also did not differ significantly (p>0.05) and amounted to: extracranial artery lesions 26% – (52.94±8.56) %, diabetes mellitus – (17.65±6.54) %, history of stroke – (5.88±4.04) %, history of myocardial infarction – (8.82±4.86) %, gastrointestinal tract pathology – (11.76±5.53) %, respiratory failure – (14.71±6.07) %, cardiovascular disease – (94.12±4.04) % (Figure 1), type of anesthesia: regional anesthesia – (20.59±6.93) %, epidural anesthesia – (79.41±6.93) %, mechanical ventilation + intravenous – (2.94±2.90) %. At the same time, patients in group 1-a had no history of oncological diseases.

Among the complications observed in patients in group 1b were: thrombosis of the reconstruction segment ((80.0±13.33) %), myocardial infarction ((10.0±10.0) %) and conduit infection ((10.0±10.0) %).

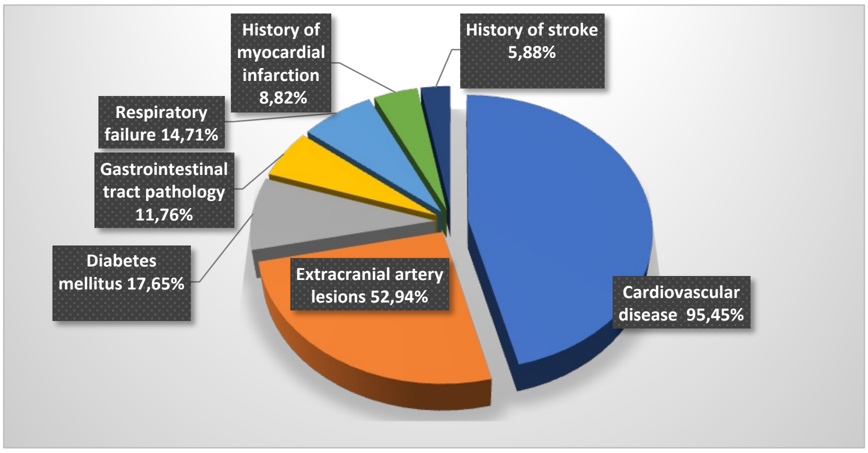

Figure 1: Proportions of anamnestic indicators in patients of group 1a with obliterating atherosclerosis of the main arteries of the lower extremities who underwent open surgical interventions.

The average age of patients in group 1b was (66.1±1.91) years, and the BMI index was (13.05±0.81), which did not significantly ($p>0.05$) differ from the similar indicators of patients in groups 1 and 1a of the study. The proportion of harmful habits ((60.0±16.33) %) was at the same level ($p>0.05$) as in patients in the aforementioned study groups. The proportions of other anamnestic indicators also did not differ significantly ($p>0.05$) and amounted to: extracranial artery lesions – (60.0±16.33) %, diabetes mellitus – (20.0±13.33) %, history of myocardial infarction – (20. 0±13.33)%, gastrointestinal tract pathology – (20.0±13.33)%, respiratory failure – (10.0±10.0)%), history of cancer – (10.0±10.0)%) (Figure 2). At the same time, all patients in this group had cardiovascular diseases and predominantly used epidural anesthesia. None of the patients had a history of stroke, regional anesthesia, or mechanical ventilation.

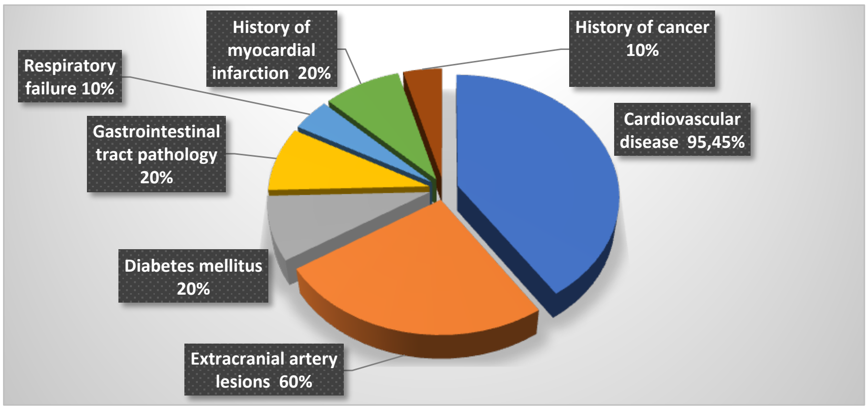

Figure 2: Proportions of anamnestic indicators in patients 1b with obliterating atherosclerosis of the main arteries of the lower extremities who underwent open surgical interventions.

A comparative analysis of complete blood count, biochemical parameters, and coagulogram parameters of patients in all groups was also performed, the results of which are presented in (Table 2).

In group 1b, there was a tendency toward a decrease in the average color index (CI) (0.90±0.00) and leukocyte level (7.09±0.74) *109/L compared to similar indicators in group 1 (CI – (0.91±0.00), leukocytes – (8.07±0.53)*109/L) without a statistically significant difference ($p>0.05$).

When analyzing biochemical indicators in the group of patients with complications (group 1b), a significant ($p<0.05$) increase in LDL levels was found (3.72±0.29) mmol/L compared to similar indicators in the group of patients without complications ((2.95±0.09) mmol/L). There was also a tendency toward an increase in creatinine ((76.80±4.61) µmol/L), AST ((31.20±10.89) U/L), ALT

((28.18±6.28) U/L) and cholesterol ((4.98±0.24) mmol/L) in the specified group compared to the corresponding indicators in group 1a (creatinine – (68.48±3.15) µmol/L, AST – (16.11±3.09) U/L, ALT – (16.94±0.27) U/L, cholesterol – (4.50±0.30) mmol/L), but no significant difference (p>0.05) was found. There was also a tendency toward increased levels of creatinine, AST, ALT, cholesterol, LDL, as well as K ((5.22±0.38) mmol/L) in group 1b compared to the corresponding indicators of the general (1st) group (creatinine – (70.37±2.64) µmol/L, AST – (19.54±2.65) U/L, ALT – (19.49±1.90) U/L, LDL cholesterol (3.12±0.24) mmol/L, K – (4.80±0.11) mmol/L, cholesterol – (4.61±0.20) mmol/L) without statistically significant differences (p>0.05).

Table 2
Complete blood count, biochemical parameters, and coagulation parameters in patients undergoing open surgery (M ± m)

Indicators	**1 group (n – 44)**	**1a group (n – 34)**	**1b group (n – 10)**
Erythrocytes, *1012/l	4,29±0,12	4,25±0,07	4,43±0,23
Hemoglobin, g/dl	124,89±3,03	125,09±0,03	124,20±5,66
Color index	0,907±0,004	0,909±0,134	0,900±0,001
Leukocytes, *109 /l	8,07±0,53	8,35±3,59	7,09±0,74
Eosinophils, %	2,50±0,38	2,44±0,001	2,70±0,78
Rod-shaped neutrophils, %	6,70±0,73	6,88±0,65	6,10±1,10
Segmented neutrophils, %	65,45±1,38	65,50±0,43	65,30±3,08
Lymphocytes, %	18,45±1,56	18,50±0,89	18,30±2,87
Monocytes, %	3,52±0,47	3,50±1,56	3,60±0,98
ESR, mm/hour	15,80±2,66	16,20±1,86	14,40±4,93
Glucose, mmol/l	5,78 ± 0,21	5,88 ± 0,55	5,43± 0,44
Creatinine, µmol/l	70,37±2,64	68,48±3,15	76,80±4,61
Urea, mmol/l	5,60±0,29	5,51±0,23	5,90±0,94
AST, u/l	19,54±2,65	16,11±3,09	31,20±10,89
ALT, u/l	19,49±1,90	16,94±0,27	28,18±6,28
Bilirubin, µmol/l	8,80±0,62	8,51±0,89	9,81±1,57
K, mmol/l	4,80±0,11	4,68±1,42	5,22±0,38
Na, mmol/l	138,32±0,79	138,15±0,67	138,90±1,03
LDL, mmol/l	3,12±0,24	2,95±0,09*	3,72±0,29
HDL, mmol/l	1,20±0,06	1,23±0,98	1,08±0,12
Cholesterol, mmol/l	4,61±0,20	4,50±0,30	4,98±0,24
Fibrinogen, g/l	4,17±0,27	4,17±0,03	4,17±0,61
Prothrombin time, sec.	11,51±0,22	11,57±0,06	11,34±0,27
Prothrombin according to Kwik, %	93,49±2,73	92,43±0,25	97,10±6,01
INR, index	0,99±0,03	1,00±0,27	0,95±0,04
Trombin time, sec.	11,08±0,17	11,14±3,09	10,87±0,54

According to the results of coagulogram analysis, patients without complications (group 1-a) tended to have lower INR values (0.95±0.04) compared to group 1 (0.99±0.03), but this difference was not statistically significant (p>0.05).

An analysis of the correlation [10] between outcomes of the complete blood count of patients in group 1-b of the study (Table 3) established a positive average correlation between the values of monocyte fractions and ESR levels (+0.57), a positive moderate correlation between erythrocyte and hemoglobin levels (+0.47), leukocyte and rod-shaped neutrophil counts (+0.30), and lymphocyte and monocyte counts (+0.32). There was a negative strong correlation between eosinophil and lymphocyte counts (-0.73), rod-shaped neutrophils and monocytes (-0.73), a negative moderate correlation between rod-shaped neutrophil counts and ESR levels (-0.56), segmented neutrophils and lymphocytes (-0.51), and a negative moderate correlation between the values of erythrocyte and leukocyte levels (-0.33) and erythrocytes and ESR (-0.40). The correlation between other indicators was weak, very weak, or absent.

A study of the correlation between similar indicators of general blood analysis in patients in groups 1-a and 1-b (Figure 3) revealed a positive moderate correlation between the values of erythrocyte levels (+0.41), hemoglobin (+0.46), ESR (+0.43), and segmented neutrophils (+0.37). The correlation between other indicators was weak to very weak.

Table 3

Correlation coefficients between complete blood count parameters in a group of patients with complications

Indicators	**Ery-thro-cytes**	**Hemo-globin**	**Leuko-cytes**	**Eosino-phils**	**Rod-shaped neutro-phils**	**Seg-ment-ed neutro-phils**	**Lym-pho-cytes**	**Mono-cytes**	**ESR**
Erythrocytes	–	+0,47	-0,33	-0,02	-0,21	+0,18	+0,11	-0,04	-0,40
Hemoglobin	+0,47	–	+0,04	+0,27	+0,24	-0,22	+0,22	-0,25	-0,19
Leukocytes	-0,33	+0,04	–	-0,22	+0,30	-0,09	+0,22	+0,06	+0,05
Eosinophils	-0,02	+0,27	-0,22	–	+0,28	+0,13	-0,73	-0,17	+0,29
Rod-shaped neutrophils	-0,21	+0,24	+0,30	+0,28	–	-0,22	-0,16	-0,73	-0,56
Segmented neutrophils	+0,18	-0,22	+0,22	-0,73	-0,16	–	-0,51	-0,25	+0,17
Lymphocytes	+0,11	+0,22	+0,22	-0,73	-0,16	-0,51	–	+0,32	-0,20
Monocytes	-0,04	-0,25	+0,06	-0,17	-0,73	-0,25	+0,32	–	+0,57
ESR	-0,40	-0,19	+0,05	+0,29	-0,56	+0,17	-0,20	+0,57	–

The analysis of the correlation between the biochemical blood parameters of patients in group 1-b of the study (Table 4) established a strong positive correlation between AST and ALT values (+0.86), a moderate positive correlation between LDL and cholesterol values (+0.69), creatinine and urea (+0.58), creatinine and cholesterol (+0.58), total bilirubin and cholesterol (+0.51), AST and Na (+0.58), ALT and Na (+0.61), K and HDL (+0.53), as well as a positive moderate correlation between urea and K (+0.35), bilirubin and LDL (+0.44), K and HDL (+0.35). There was a negative strong correlation between creatinine and AST (-0.72), a negative moderate correlation between urea and AST (-0.53), as well as a negative moderate correlation between ALT and total bilirubin (-0.48), ALT and creatinine (-0.47), urea and Na (-0.47), ALT and cholesterol (-0.34), AST and total bilirubin

(-0.30), and AST and cholesterol (-0.31). The correlation between other indicators was weak and very weak.

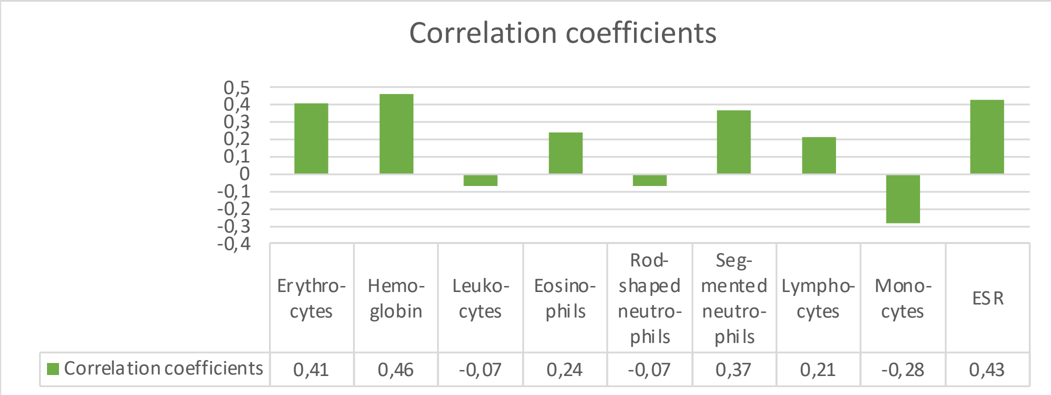

Figure 3: Correlation coefficients between similar indicators of general blood analysis in patients in groups 1-a and 1-b of the study.

Table 4
Correlation coefficients between biochemical blood test indicators in a group of patients with complications

Indicators	Glu-cose	Crea-tini-ne	Urea	AST	ALT	Bili-ru-bin	K	Na	LDL	HDL	Cho-leste-rol
Glucose	–	0,28	+,25	-0,24	-0,29	+0,06	-0,28	+0,21	-0,28	-0,01	-0,26
Creatinine	+0,28	–	+0,58	-0,72	-0,47	+0,10	-0,06	-0,19	+0,21	+0,21	+0,58
Urea	+0,25	+0,58	–	-0,53	-0,21	-0,24	+0,35	-0,36	+0,10	+0,02	+0,07
AST	-0,24	-0,72	-0,53	–	+0,86	-0,30	+0,24	+0,58	-0,13	-0,05	-0,31
ALT	-0,29	-0,47	-0,21	+0,86	–	-0,48	+0,27	+0,61	-0,22	-0,02	-0,34
Bilirubin	+0,06	+0,10	-0,24	-0,30	-0,48	–	-0,23	-0,26	+0,44	-0,17	+0,51
K	-0,28	-0,06	+0,35	+0,24	+0,27	-0,23	–	+0,07	+0,35	+0,53	+0,20
Na	+0,21	-0,19	-0,36	+0,58	+0,61	-0,26	+0,07	–	+0,09	+0,23	-0,21
LDL	-0,28	+0,21	+0,10	-0,13	-0,22	+0,44	+0,35	+0,09	–	-0,17	+0,69
HDL	-0,01	+0,21	+0,02	-0,05	-0,02	-0,17	+0,53	+0,23	-0,17	–	+0,17
Cholester-ol	-0,26	+0,58	+0,07	-0,31	-0,34	+0,51	+0,20	-0,21	+0,69	+0,17	–

A study of the correlation between similar indicators of general biochemical blood analysis in patients in groups 1-a and 1-b (Figure 4) established a positive average correlation between glucose levels (+0.53) and a positive moderate correlation between urea levels (+0.53). There was a negative average correlation between cholesterol (-0.67) and AST (-0.50) levels, as well as a negative moderate correlation between LDL (-0.36) and ALT (-0.45) levels. The correlation between other indicators was weak and very weak.

The analysis of the correlation between the coagulogram parameters of patients in group 1b of the study (Table 5) revealed a positive moderate correlation between INR values and fibrinogen levels (+0.30). There was a negative average correlation between the Protrombin time (PT) values and INR (-0.66). The correlation between other parameters was weak and very weak.

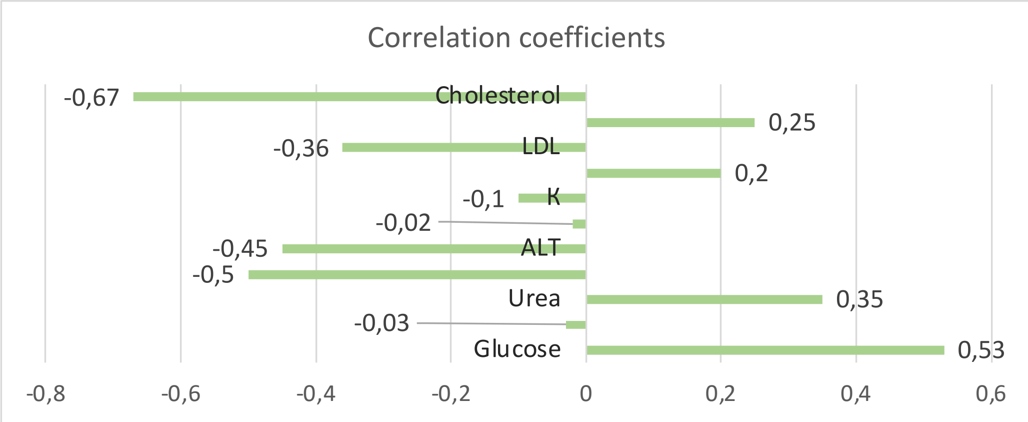

Figure 4: Correlation coefficients between similar indicators of general blood analysis in patients in groups 1-a and 1-b of the study.

Table 5
Correlation coefficients between coagulogram parameters of the group of patients with complications

Parameter	**Prothro-mbin time**	**Prothro-mbin acco-rding to Quik**	**INR**	**Thrombin time**	**Fibrinogen**
Prothrombin time	–	-0,24	-0,66	-0,16	+0,17
Prothrombin according to Quick	-0,24	–	+0,04	+0,02	-0,17
INR	-0,66	+0,04	–	+0,14	+0,30
Thrombin time	-0,16	+0,02	+0,14	–	+0,13
Fibrinogen	+0,17	-0,17	+0,30	+0,13	–

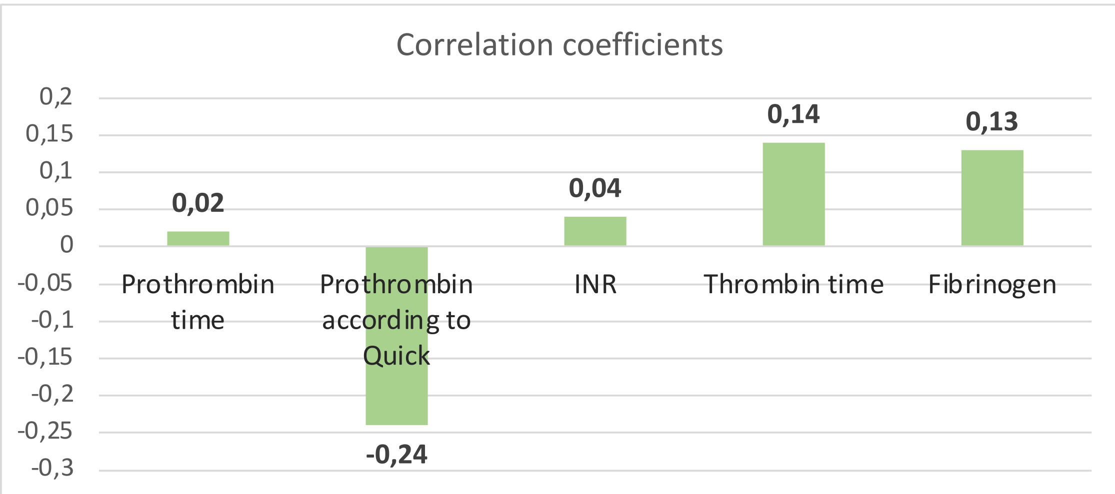

Figure 5: Correlation coefficients between similar coagulogram indicators in patients in groups 1-a and 1-b of the study.

A study of the correlation between similar coagulogram indicators in patients in groups 1-a and 1-b revealed only a weak correlation between prothrombin levels according to Quick (-0.24) (Figure 4). The correlation between other indicators was weak to very weak.

5. Conclusions

An analysis of the anamnestic and clinical-laboratory indicators of patients with obliterating atherosclerosis of the great arteries of the lower extremities who underwent open surgical interventions revealed that among the complications in 8 patients of the first group, thrombosis of the reconstruction segment was observed (18.2%), one patient had myocardial infarction (2.3%), and one had conduit infection (2.3%).

In patients with complications, the average age was (66.1±1.91) years, and the BMI was (13.05±0.81) kg/m², which did not significantly ($p>0.05$) differ from the similar indicators of patients in groups 1 and 1a of the study. The proportion of harmful habits ((60.0±16.33) %) was at the same level ($p>0.05$) as in patients in the aforementioned study groups. The proportions of other anamnestic indicators also did not differ significantly ($p>0.05$).

During the analysis of biochemical parameters in the patient group with complications (group 1b), a significant ($p<0.05$) increase in LDL levels was found (3.72±0.29) mmol/L compared to the same indicator in the group of patients without complications ((2.95±0.09) mmol/L). According to the results of the coagulogram analysis of patients in group 1-a, there was a tendency toward a lower INR index (0.95±0.04) compared to the corresponding indicator in group 1 (0.99±0.03), but this difference was not statistically significant ($p>0.05$).

A study of the correlation between the indicators of the general blood test of patients with complications established a positive average correlation between the values of monocyte fractions and ESR levels (+0.57) mm/h, a positive moderate correlation between the values of erythrocyte and hemoglobin levels (+0.47), leukocyte levels and the percentage of rod-shaped neutrophils (+0.30) and the percentage of lymphocytes and monocytes (+0.32), which indicates the significance of the combined changes of the indicated pairs of indicators for predicting the development of complications.

The analysis of the correlation between the biochemical blood parameters of patients in the study group with complications revealed a strong positive correlation between AST and ALT values (+0.86), a moderate positive correlation between LDL and cholesterol values (+0.69), creatinine and urea (+0.58) , creatinine and cholesterol (+0.58), total bilirubin and cholesterol (+0.51) AST and Na (+0.58), ALT and Na (+0.61), K and HDL (+0.53), AST and ALT (+0.86), a positive moderate correlation between creatinine and urea (+0.58), AST and Na (+0.58), ALT and Na (+0.61), K and HDL (+0.53), a positive moderate correlation between urea and K (+0.35), bilirubin and LDL (+0.44), K and LDL (+0.35), as well as a positive moderate correlation between INR values and fibrinogen levels (+0.30), indicating the significance of combined changes in these pairs of biochemical indicators for predicting the development of complications.

Correlation assessment of similar variables of general, biochemical blood analysis in patients with and without complications in the study groups established a negative average correlation between cholesterol levels (-0.67), AST (-0.50), indicating the possibility of using such changes as markers of the risk of complications [17].

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Declaration on Generative AI

During the preparation of this work, the authors used generative tools in order to: grammar and spelling check; DeepL Translate in order to: some phrases translation into English. After using these tools/services, the authors reviewed and edited the content as needed and take full responsibility for the publication’s content.

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