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DYNAMICS OF CLINICAL AND LABORATORY PARAMETERS OF PATIENTS WITH COVID-19 ON THE BACKGROUND OF TREATMENT

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The article presents the results of the analysis of the dynamics of the main indicators of the blood coagulation system and cytokines (IL-6, D-dimers, C-reactive protein and procalcitonin) on the background of thromboprophylaxis in patients with COVID-19. The aim of our study was to determine the dynamics of the main indicators of the blood coagulation system and cytokines in the setting of thromboprophylaxis. The study was conducted at the Department of Infectious and Pediatric Infectious Diseases, Parasitology, Phthisiology and Pulmonology of the Kharkiv National Medical University and at the Municipal Non-Profit Enterprise "Kharkiv Regional Infectious Diseases Hospital" of the Kharkiv Regional Council, in 2020–2024 with compliance of the existing recommendations of bioethical norms and rules. All patients singed informed consent. We examined 179 patients aged 20–88 years (average age of [58.75±13.82] years) with COVID-19. The diagnosis of COVID-19 was confirmed by enzyme-linked immunosorbent assay and polymerase chain reaction. Medical and statistical calculations were performed using the SPSS 25.0 software package. The mean value and standard square deviation were calculated. The probability of differences was determined using the Mann-Whitney U-test with a threshold value of statistical significance of $p=0.05$. According to the results of the study, a significant ($p<0.001$) dynamic of restoration of D-Dimers' levels was noted against the background of the applied therapy (on days 9–10, a decrease of 166.3 Fibrinogen Equivalent Unit (FEU), ng/ml, and on days 12–15 – of 376.7 FEU, ng/ml) and procalcitonin (on days 6–7 the content was by 0.04 ng/ml, $p=0.006$; on days 10–11 – 0.01 ng/ml, $p<0.001$; on days 12–15 – also 0.01 ng/ml, $p=0.027$).

Keywords: *D-dimers, C-reactive protein, procalcitonin.*

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Introduction

Since the end of 2019, COVID-19 has reached the levels of a large-scale pandemic in a rather short period of time, with quite threatening levels of morbidity and mortality [1–9], which, according to many studies, reach more than 10.0% [4].

The World Health Organization defines COVID-19 as a severe acute respiratory syndrome caused by coronavirus type 2 (SARS-CoV-2) [6; 7; 9; 10], which has infected more than 100 million people worldwide and caused more than 2.5 million deaths.

The overwhelming majority of COVID-19 infected patients report predominantly respiratory system involvement, but a certain cohort of patients also indicates the development of systemic involvement with resistant fever, acute lung injury, and severe acute respiratory syndrome with shock and the development of multiple organ failure [2; 4; 11–14]. In addition, in most cases, there is also a disorder of the blood coagulation system with the development of diffuse intravascular coagulation and large-caliber vascular thrombosis [3].

Given this situation, the diagnosis of clinical and laboratory criteria for thrombotic risk stratification is a priority for clinical trials to optimize thromboprophylaxis [15].

Thus, according to Coomes E.A. et al. [12], it is extremely promising to study the dysregulation of the humoral immune response in patients with COVID-19, which manifests itself as a cytokine response syndrome with a predominance of InterLeukin-6 (IL-6) production and activity, in view of optimizing immunostabilizing therapeutic tactics, especially in patients with severe and extremely severe infection. The immune response in this case can manifest itself in the form of a cytokine storm: in the vast majority of patients, there is a significant increase in the levels of IL-6, IL-17A, and tumor necrosis factor-α [4].

In addition to these cytokines, increased levels of D-dimers [1] and other indicators of the blood coagulation system are determined: C-Reactive Protein (CRP), ProCalciTonin (PCT). These changes determine the high risk of developing thrombosis, which requires appropriate thromboprophylaxis [6; 15–18] under close monitoring of the dynamics of blood coagulation system parameters.

Therefore, given the significant risks of blood coagulation disorders with the development of thrombotic complications and cytokine response syndrome, determining the dynamics of the main indicators of the blood coagulation system and cytokines is of clinical relevance in the treatment of COVID-19.

The aim of the study is to determine the dynamics of the main indicators of the blood coagulation system and cytokines in the context of thromboprophylaxis.

Materials and Methods

The study was conducted at the Department of Infectious and Pediatric Infectious Diseases, Parasitology, Phthisiology and Pulmonology of Kharkiv National Medical University and at the Municipal Non-Profit Enterprise "Kharkiv Regional Infectious Diseases Hospital" of the Kharkiv Regional Council, in 2020–2024, in accordance with existing international and national bioethical standards and regulations. All patients signed the informed consent.

179 patients with COVID-19 (53.63% women and 46.37% men) aged 20–88 years (average age was [58.75±13.82] years) were examined.

The diagnosis of COVID-19 was confirmed by Enzyme-Linked ImmunoSorbent Assay (ELISA) and Polymerase Chain Reaction (PCR). The patient's examination program included biochemical blood test of IL-6, D-Dimer, ProCalciTonin (PCT) and C-Reactive Protein (CRP).

The medical and statistical calculation of the results was performed using IBM SPSS 25.0 for Windows (USA).

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The distribution of the obtained quantitative features was assessed visually by the graphical method and using the Kolmogorov-Smirnov and Lillifors and Shapiro-Wilk criteria. The evaluation of the data revealed significant differences from the normal distribution, so nonparametric statistics were used for further calculations.

To characterize the central tendency and variability of quantitative features (continuous or interval), the mean value (M) and standard square deviation (SD) were determined.

The probability of differences in the obtained features was determined using the Mann-Whitney U-test. The threshold value of the statistical significance of the calculated traits was taken as 0.05 (p=0.05).

Results and Discussion

First of all, we studied the dynamics of IL-6 levels in the examined patients with COVID-19 coronavirus infection on the 5^{th}–7^{th} days after hospitalization compared to the values obtained on admission to the clinic (*Table 1*).

Good dynamics and a decrease in IL-6 levels by 0.56 pg/ml (from [24.56±22.9] pg/ml to [24.00±26.2] pg/ml) were noted, but the difference in the obtained values was not significant (*Table 1*). Positive dynamics of IL-6 levels on the background of the treatment confirmed the effectiveness of the therapy of the examined patients and indicated a decrease in the risk of cytokine storm and the development of disseminated intravascular coagulation syndrome and significant respiratory failure.

At the same time, the levels of D-Dimer initially indicated a probable increase in their quantitative values, and then had a significant tendency to their active decrease (*Tables 2–6*).

Table 1. Dynamics levels of IL-6 of the examined patients with acute respiratory disease, obtained on admission to the clinic and on the 5^{th}–7^{th} days of hospitalization (M±SD)

Indices	Admissions to the clinic	5–7 days	p
IL-6, pg/ml	24.56±22.9	24.00±26.2	0.712
	dynamics	-0.56	

Notes: p – significance of the difference between the levels obtained on admission to the clinic and on the 5^{th}–7^{th} days of hospitalization.

Table 2. Dynamics of D-Dimer levels in the examined patients with acute kidney injury, obtained on admission to the clinic and on the 2^{nd}–3^{rd} days of hospitalization (M±SD)

Indices	Admissions to the clinic	2–3 days	p
D-Dimer, FEU, ng/ml	873.3±1776.4	1120.86±2167.0	0.040
	dynamics	+247.56	

Notes: FEU (here and further) – Fibrinogen Equivalent Unit, reference values of D-dimer;
p – significance of the difference between the levels obtained on admission to the clinic and on the 2^{nd}–3^{rd} days of hospitalization.

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Table 3. Dynamics of D-Dimer levels in the examined patients with acute kidney injury, obtained on days 2nd–3rd days and 5th–6th days of hospitalization (M±SD)

Indices	2–3 days	5–6 days	p
D-Dimer, FEU, ng/ml	1120.86±2167.0	1056.9±1685.3	0.444
	dynamics	-63.96	

Notes: significance of the difference between the levels obtained on days 2–3 and 5–6 of hospitalization.

Table 4. Dynamics of D-Dimer levels in the examined patients with acute respiratory failure, obtained on the 5th–6th days and 7th–8th days of hospitalization (M±SD)

Indices	5–6 days	7–8 days	p
D-Dimer, FEU, ng/ml	1056.9±1685.3	998.9±1324.1	0.113
	dynamics	-58.0	

Notes: p – significance of the difference between the levels obtained on days 5–6 and 7–8 of hospitalization.

Table 5. Dynamics of D-Dimer levels in the examined patients with acute respiratory failure, obtained on the 7th–8th days and 9th–10th days of hospitalization (M±SD)

Indices	7–8 days	9–10 days	p
D-Dimer, FEU, ng/ml	998.9±1324.1	832.6±1048.4	<0.001
	dynamics	-166.3	

Notes: p – significance of the difference between the levels obtained on days 7–8 and 9–10 of hospitalization.

Table 6. Dynamics of D-Dimer levels in the examined patients with acute care received on 9th–10th days and 12th–15th days of hospitalization (M±SD)

Indices	9–10 days	12–15 days	p
D-Dimer, FEU, ng/ml	832.6±1048.4	455.9±530.6	<0.001
	dynamics	-376.7	

Notes: p – significance of the difference between the levels obtained on days 9–10 and 12–15 of hospitalization.

Thus, the obtained levels of D-Dimer in patients with COVID-19 on the 2nd–3rd days of hospitalization compared with the values obtained on admission to the clinic showed a significant (p=0.040) tendency to increase (most likely in response to COVID-19 infection) from [1120.86± ±2167.0] FEU to [873.3±1776.4] FEU, ng/ml, indicating a dynamics of +247.56 FEU, ng/ml (*Table 2*).

Subsequently (on days 5–6 from the start of hospitalization), the levels of D-Di-

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mer in patients with COVID-19 compared with day 2–3 of hospitalization tended to decrease significantly (p=0.444) in response to the treatment (from [1120.86±2167.0] FEU to [1056.9±1685.3] FEU, ng/ml), indicating a decrease of -63.96 FEU, ng/ml (*Table 3*).

Subsequently (7–8 days after hospitalization), compared with 5-6 days after hospitalization, the levels of D-Dimer in patients with coronavirus infection COVID-19 significantly (p=0.113) determined a tendency to decrease against the background of the treatment (from [1056.9±1685.3] to [998.9±1324.1] FEU, ng/ml), indicating a decrease of 58.0 FEU, ng/ml (*Table 4*).

Subsequently (on days 9–10 of hospitalization), the levels of D-Dimer in patients with COVID-19 compared with days 7–8 from the beginning of hospitalization showed an even greater significant trend toward a decrease in response to treatment (from [998.9±1324.1] FEU to [832.6± ±1048.4] FEU, ng/ml; p<0.001), indicating a decrease of 166.3 FEU, ng/ml (*Table 5*).

Subsequently (on days 12–15 from the beginning of hospitalization), significant decreases in the quantitative levels of D-Dimer of the examined patients with coronavirus infection COVID-19 on the background of the applied treatment were noted compared with days 9–10 of hospitalization from [832.6±1048.4] FEU to [455.9± ±530.6] FEU, ng/ml (p<0.001) with a decrease of 376.7 FEU, ng/ml (*Table 6*).

Thus, against the background of the applied treatment, there was a gradual decrease in one of the markers of the severity of lung tissue damage, indicating its effectiveness and feasibility and reducing the risk of developing severe viral pneumonia and activation of the blood coagulation system.

A similar tendency to a gradual decrease in elevated levels in response to the treatment was noted in relation to acute-phase Indices in the subjects, determining a decrease in the risk of sepsis and septic shock.

Such positive dynamics was noted in relation to the obtained PCT values of patients' blood, which initially reached a rather significant excess of reference levels (*Tables 7–13*).

Table 7. Dynamics of PCT levels in the examined patients with acute respiratory failure, obtained on admission to the clinic and on the 2nd–3rd days of hospitalization (M±SD)

Indices	Admissions to the clinic	2–3 days	p
PCT, ng/ml	0.53±2.40	0.9±1.54	0.699
	dynamics	-0.04	

Notes: p – significance of the difference between the levels obtained on admission to the clinic and on the 2nd–3rd days of hospitalization.

Table 8. Dynamics of PCT levels in the examined patients with acute respiratory failure, obtained on the 2nd–3rd days and 4th–5th days of hospitalization (M±SD)

Indices	2–3 days	4–5 days	p
PCT, ng/ml	0.49±1.54	0.17±0.95	0.699
	dynamics	-0.32	

Notes: p – significance of the difference between the levels obtained on days 2–3 and 4–5 of hospitalization.

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Table 9. Dynamics of PCT levels in the examined patients with acute respiratory failure, obtained on the 4th–5th days and 6th–7th days of hospitalization (M±SD)

Indices	4–5 days	6–7 days	p
PCT, ng/ml	0.17±0.95	0.13±0.94	0.006
	dynamics	-0.04	

Notes: p – significance of the difference between the levels obtained on days 4–5 and 6–7 of hospitalization.

Table 10. Dynamics of PCT levels in the examined patients with acute respiratory failure, obtained on the 6th–7th days and 8th–9th days of hospitalization (M±SD)

Indices	6–7 days	8–9 days	p
PCT, ng/ml	0.13±0.94	0.05±0.07	0.236
	dynamics	-0.08	

Notes: p – significance of the difference between the levels obtained on days 6–7 and 8–9 of hospitalization.

Table 11. Dynamics of PCT levels in the examined patients with acute respiratory failure, obtained on the 8th–9th days and 10th–11th days of hospitalization (M±SD)

Indices	8–9 days	10–11 days	p
PCT, ng/ml	0.05±0.07	0.04±0.06	<0.001
	dynamics	-0.01	

Notes: significance of the difference between the levels obtained on days 8–9 and 10–11 of hospitalization.

Table 12. Dynamics of PCT levels in the examined patients with acute respiratory failure, obtained on the 10th–11th days and 12th–15th days of hospitalization (M±SD)

Indices	10–11 days	12–15 days	p
PCT, ng/ml	0.04±0.06	0.03±0.04	0.027
	dynamics	-0.01	

Notes: significance of the difference between the levels obtained on days 10–11 and 12–15 of hospitalization.

Table 13. Dynamics of PCT levels in the examined patients with acute respiratory failure, obtained on the 12th–15th and 17th–18th day of hospitalization (M±SD)

Indices	12–15 days	17–18 days	p
PCT, ng/ml	0.03±0.04	0.09±0.93	0.359
	dynamics	+0.06	

Notes: p – significance of the difference between the levels obtained on days 12–15 and 17–18 of hospitalization.

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Thus, against the background of the treatment used among the subjects on the 2nd–3rd days of hospitalization compared with the indicators noted on admission to the clinic, a decrease in PCT levels from [0.53±2.40] ng/ml to [0.49±1.54] ng/ml was noted, indicating an unlikely (p= =0.699) dynamics of -0.04 ng/ml (*Table 7*).

Subsequently (on days 4–5 from the moment of hospitalization), compared with the indicators of days 2–3, an even greater decrease in PCT levels was recorded among patients under treatment (from [0.49±1.54] ng/ml to [0.17±0.95] ng/ml), but the difference was not significant (p= =0.699) and determined the dynamics of -0.32 ng/ml (*Table 8*).

On the 6^{th}–7^{th} days of hospitalization, compared with the levels of the 4^{th}–5^{th} days, a significant decrease in PCT levels was determined among the subjects undergoing therapy (from [0.17±0.95] ng/ml to [0.13±0.94] ng/ml; p=0.006) with a dynamics of -0.04 ng/ml (*Table 9*).

On days 8–9 of hospitalization, compared with days 4–5, patients noted an unreliable decrease in PCT levels (from [0.13±0.94] ng/ml to [0.05±0.07] ng/ml; p=0.236) with a dynamics of -0.08 ng/ml (*Table 10*).

This trend was determined further (on days 10–11 from the moment of hospitalization) and compared with day 8–9 indicated a significant decrease in PCT among patients (from [0.05±0.07] ng/ml to [0.04± ±0.06] ng/ml; p<0.001) with a dynamics of -0.01 ng/ml (*Table 11*).

On days 12–15 after hospitalization, compared with days 10–11, patients noted an even more significant decrease in PCT levels (from [0.04±0.06] ng/ml to [0.03± ±0.04] ng/ml; p=0.027) by 0.01 ng/ml (*Table 12*).

Subsequently, this trend towards a decrease in PCT levels in patients with infection on the background of prescribed therapy did not persist and on days 17–18 after hospitalization compared with days 12–15 indicated an unlikely (p=0.359) increase in these values from [0.03±0.04] ng/ml to [0.09±0.93] ng/ml with a dynamics of +0.06 ng/ml (*Table 13*).

Another acute-phase indicator (CRP) in response to treatment among COVID-19 infected patients initially showed a trend towards an increase in quantitative levels (*Table 14*), and then to a decrease (*Table 15*). However, the difference in the values obtained was not significant.

Table 14. Dynamics of CRP levels in the examined patients with acute kidney disease, obtained on admission to the clinic and on the 2^{nd}–3^{rd} days of hospitalization (M±SD)

Indices	Admissions to the clinic	2–3 day	*p*
CRP, mg/l	54.6±72.4	58.9±69.9	0.411
	dynamics	+4.3	

Notes: p – significance of the difference between the levels obtained on admission to the clinic and on days 2–3 of hospitalization.

Table 15. Dynamics of CRP levels in the examined patients with acute respiratory failure, obtained on the 2^{nd}–3^{rd} days and 5^{th}–6^{th} days of hospitalization (M±SD)

Indices	2–3 days	5–6 days	p
CRP, mg/l	58.9±69.9	50.9±71.9	0.11
	dynamics	-8.0	

Notes: p – significance of the difference between the levels obtained on days 2–3 and 5–6 of hospitalization.

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Thus, CRP levels on the 2nd–3rd days after hospitalization compared with the values obtained on admission to the clinic indicated an unlikely dynamic to increase by 4.3 mg/l (from [54.6±72.4] mg/l to [58.9± ±69.9] mg/l; p=0.411) (*Table 14*).

On days 5–6 of hospitalization, compared with the values of days 2–3 from admissions to the clinic, CRP levels showed an unlikely dynamic to a decrease of 8.0 mg/l (from [58.9±69.9] mg/l to [50.9±71.9] mg/l; p=0.11) (Table 15).

Our results on changes in the main indices of the state of the blood coagulation system and cytokines in patients with COVID-19 and their positive dynamics on the background of thromboprophylaxis were confirmed by the results of other world studies. For example, a meta-analysis [19] found that elevated PCT values were associated with an almost 5-fold higher risk of severe SARS-CoV-2 infection [OR=4.76; 95% CI 2.74–8.29].

Other studies have found [20] that PCT increases in patients with severe COVID-19 infection. Thus, they indicated that the odds of a more severe course of COVID-19 disease were higher in individuals with higher PCT levels (≥0.05 ng/ml) compared to those with low levels (<0.05 ng/ml) [OR=2.91; 95% CI 1.14–7.42, p=0.025]. After estimating the mean and standard deviation based on the sample size, the analysis of the median and interquartile range of the pooled effects showed a higher serum PCT concentration in patients with severe disease compared to less severe disease [SMD=0.64; 95% CI 0.02–1.26, p=0.042].

In turn, Liu Z.M. et al. [21] proved that patients with elevated PCT have a higher incidence of severe and critical conditions (p<0.001) and higher mortality. An association between elevated PCT levels and mortality was found in univariate [OR=3.377; 95% CI 1.012–10.344; p=0.033] and multivariate Cox regression analysis [OR= =4.933; 95% CI 1.170–20.788; p=0.030]. Similarly, patients with elevated PCT were more likely to have critically ill disease in univariate analysis [OR=7.247; 95% CI 3.559–14.757; p<0.001] and multivariate logistic regression analysis [OR=10.679; 95% CI 4.562–25.000], and Kaplan-Meier curves showed the worst prognosis for patients with elevated PCT (p=0.024). At the same time, PCT peaked on the 40th day after the onset of symptoms and then gradually decreased.

In addition, an increase in D-Dimer levels above 1.0 ng/ml during hospitalization, increased prothrombin and IL-6, and troponin were identified as the main factors associated with mortality [1]. This increase in D-Dimer (more than 1.0 mg/l) was significantly associated with increased odds of mortality [HR=18.42; 95% CI 2.64–128.55; p=0.003] [1; 2].

At the same time, it was shown that in patients who died, the mean concentrations of D-Dimer were 2.12 (0.77–5.27) mg/l, compared with 0.61 (0.35–1.29) mg/l in survivors [2; 17].

Conclusions

When analyzing the dynamics of clinical and laboratory characteristics of patients with coronavirus infection COVID-19 against the background of the applied therapy, a significant (p<0.001) dynamics of recovery of D-Dimer levels (on days 9–10, a decrease of 166.3 FEU, ng/ml, and on days 12–15, a decrease of 376.7 FEU, ng/ml) and PCT (on days 6–7, a decrease of 0.04 ng/ml, p=0.006 ng/ml, on days 10–11 and 12–15, a decrease of 0.01 ng/ml, p<0.001 and p=0.027).

Conflict of interest is absent.

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ДИНАМІКА КЛІНІКО-ЛАБОРАТОРНИХ ПОКАЗНИКІВ ХВОРИХ ІЗ COVID-19 НА ФОНІ ПРОВЕДЕНОГО ЛІКУВАННЯ

В статті надано результати аналізу динаміки основних показників стану згортальної системи крові й цитокінів (інтерлейкіну-6, Д-Дімерів, С-реактивного білку та прокальцитоніну) на фоні застосованої тромбопрофілактики у хворих на COVID-19. Метою нашого дослідження було визначення динаміки основних показників стану згортальної системи крові й цитокінів на фоні тромбопрофілактики. Дослідження було проведено на кафедрі інфекційних і дитячих інфекційних хвороб, паразитології, фтизіатрії та пульмонології Харківського національного медичного університету й на базі Комунального некомерційного підприємства «Харківська обласна інфекційна лікарні» Харківської обласної ради протягом 2020–2024 рр. згідно з існуючими біоетичними нормами та правилами. Усі пацієнти підписали інформовану згоду на участь у науковому дослідженні. Було обстежено 179 хворих на COVID-19 віком 20–88 років (середній вік склав [58,75±13,82] років). Діагноз COVID-19 визначали шляхом імуноферментного аналізу та полімеразної ланцюгової реакції. Медико-статистичний розрахунок був виконаний за допомогою пакета програм IBM SPSS 25.0. Було вирахувано середнє значення (M) та стандартне квадратичне відхилення (SD). Результати представлені у вигляді: M±SD. Вірогідність відмінностей визначали за допомогою U-тесту Мана-Уітні з пороговою величиною статистичної значущості p=0,05. За результатами дослідження на фоні застосованої терапії було констатовано вірогідну (p<0,001) динаміку відновлення рівнів Д-Дімеру (на 9–10 добу зниження на 166,3 Фібриноген-Еквівалентні Одиниці (ФЕО), нг/мл, на 12–15 – на 376,7 ФЕО, нг/мл) і прокальцитоніну (на 6–7 добу – на 0,04 нг/мл, p=0,006; на 10–11 добу – на 0,01 нг/мл, p<0,001; на 12–15 добу – також на 0,01 нг/мл, p=0,027).

Ключові слова: *Д-Дімери, С-реактивний білок, прокальцитонін.*

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