ASSESSMENT OF THE HEMOSTASIS SYSTEM IN ADOLESCENTS WITH IDIOPATHIC SCOLIOSIS

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Objective. To assess the hemostasis system status in adolescents with idiopathic scoliosis before surgical correction of spinal deformity and at the peak of intraoperative blood loss.

Material and Methods. The study is based on an analysis of hemostasis system functional parameters in 80 adolescents with idiopathic scoliosis who underwent primary surgical correction of spinal deformity. Hemostasis system parameters were assessed before elective surgery and at the peak of intraoperative blood loss. Standard laboratory diagnostic methods and low-frequency piezoelectric thromboelastography (LPTEG) were used.

Results. No abnormal preoperative laboratory parameters were recorded. Analysis of preoperative LPTEG parameters revealed a decrease in the total coagulation index (TCI) against the background of structural and chronometric hypocoagulation, as well as increased clot retraction and lysis. Comparison of initial LPTEG parameters with those measured at the peak of blood loss revealed an adequate hemostasis system response to surgical trauma: a normalization of the TCI was observed, while deviations in other LPTEG parameters became less pronounced as compared to reference values. The observed dynamics of LPTEG parameters led to the conclusion that the hemostasis system in the vast majority of patients with idiopathic scoliosis is effectively self-regulated. This is confirmed by the fact that in 90% of patients, blood loss did not exceed 30% of the total blood volume and did not require the use of donor blood components.

Conclusion. The established background abnormality in the coagulation profile in adolescents with idiopathic scoliosis is the presence of structural and chronometric hypocoagulation. Low-frequency piezoelectric thromboelastography can be used to assess the functional state of the hemostasis system, though only from the standpoint of personalized recording and analysis.

Key Words: idiopathic scoliosis; scoliosis surgery; hemostasis system; hypocoagulation; piezoelectric thromboelastography; global hemostasis tests.

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The hemostasis system is one of the most important systems of the body, ensuring its vital activity, simultaneously maintaining the fluidity of circulating blood and preventing blood loss upon damage to the vascular wall through blood coagulation [1–3]. Currently, it is recognized that standard laboratory tests used to diagnose the hemostasis system have a number of limitations, the main ones being insufficient informativeness and the inability to track the dynamics of various phases of hemostasis in real time [4–6]. Taking this circumstance into account, global tests for investigating the hemostasis system are finding increasingly widespread application, allowing the assessment of the temporal and qualitative characteristics of the process of clot formation and lysis, determination of the contribution of blood components to clot formation, identification of risks for the development of venous thromboembolic complications, and also more accurate selection of doses of anticoagulant drugs when their use is necessary [7–9].

One of the global methods for assessing the hemostasis system is low-frequency piezothromboelastography (LPTEG), based on recording changes in the aggregate state of blood at a specific moment in time [10, 11]. Currently, the LPTEG has found application and proven its effectiveness in cardiology, cardiac surgery, in obstetric practice, in orthopedic pathology, as well as for evaluating therapy with the use of antiplatelet agents and anticoagulants [4, 12, 13]. A number of studies [14–16] confirm the high informativeness of global diagnostic methods, including the LPTEG, in the issue of early detection of hypercoagulable disorders, which is extremely relevant in connection with the increase in the frequency of thromboembolic complications in various pathological conditions.

A previously conducted study by us using the LPTEG showed the presence of specific features of the hemostasis system prior to forthcoming elective surgical intervention in patients with idiopathic scoliosis. However, its limitation was the small number of participants [13].

Considering this circumstance, it seems interesting at the preoperative stage to clarify previously obtained information and compare it with the results of laboratory investigation of the hemostasis system in this category of patients. Furthermore, information is needed on the intraoperative state of the hemostasis system at the background of blood loss and ongoing infusion therapy, since these factors can exert a significant impact on blood coagulation [17–19]. Of note, the number of studies devoted to the investigation of the functional state of the hemostasis system in patients with idiopathic scoliosis using global diagnostic methods is extremely limited, and available data are often contradictory.

Objective of the study was to determine the state of the hemostasis system in adolescents with idiopathic scoliosis prior to surgical correction of the spinal deformity and at the height of intraoperative blood loss.

Material and Methods

The study is single-center prospective. Period – 2022–2024. Indicators of the hemostasis system were studied in 80 adolescents with idiopathic scoliosis before elective surgical correction of the spinal deformity. Inclusion criteria for patients in the study: idiopathic adolescent scoliosis, primary correction of spinal deformity. Exclusion criteria: deviations in preoperative hemostasiological tests, hemorrhagic syndrome in the medical history, blood diseases.

The number of female patients was 67, male – 13. The main characteristics of the patients: age – 14.7 [11.5; 16.9] years, body weight – 51.0 [44.0; 58.2] kg, height – 162.5 [156.00; 168.25] cm, magnitude of spinal deformity – 58.5 degrees [51.0 degrees; 73.0 degrees]. All patients underwent elective surgical correction of the spinal deformity with the use of transpedicular fixation (TPF) under conditions of general anesthesia with artificial lung ventilation: sevoflurane (0.7–1.2 MAC under the control of the depth of anesthesia level, measured using the Bispectral Index (BIS) monitor, in the range of 40–60), fentanyl (0.002 mg/kg for induction; 0.002–0.005 mg/kg – prolonged infusion via infusion pump), ketamine (bolus administration of 0.25 mg/kg followed by prolonged infusion of 0.25 mg/kg/h), rocuronium (1.0 mg/kg for induction followed by bolus administration of 0.3 mg/kg upon the necessity to deepen the degree of myorelaxation). The average duration of the operation was 270.0 [245.0; 291.2] minutes, the number of TPF levels – 9.0 [9.0; 10.0], intraoperative blood loss – 17.0 [13.0; 21.0] % of the circulating blood volume (CBV). The volume of infusion therapy amounted to 3000.0 [2600.0; 3100.0] mL, diuresis – 200.0 [150.0; 300.0] mL. In 8 (10%) patients with intraoperative blood loss of over 30% of the CBV, donor blood components were used. Data of LPTEG obtained in these patients were excluded from the statistical analysis of LPTEG indicators at the height of blood loss and were analyzed on an individual basis. The study design is presented in Fig. 1.

At the preoperative stage, standard laboratory indicators of the hemostasis system were evaluated: platelet count, prothrombin time, activated partial thromboplastin time, international normalized ratio, fibrinogen level (grams/liter). Also, hemostasis indicators were evaluated by the LPTEG using the “LPTEG MEDNORD” device, Russia (registration certificate of the Federal Service for Surveillance in Healthcare No. Medical Device Registration 2020/12855). Measured and calculated parameters of the LPTEG curve were investigated and analyzed (Fig. 2).

Measured indicators included the following: A_1 – maximum decrease in amplitude for the reaction period T_1 (relative units); T_1 – reaction period (time from the start of the study until achieving minimum amplitude, minutes); A_2 – increase in amplitude of LPTEG by 100 relative units; T_2 – time to achieve amplitude A_2 (minutes); A_3 – magnitude of LPTEG amplitude at the gelation point (relative units); T_3 – time to achieve the gelation point (minutes); A_4 – magnitude of LPTEG amplitude 10 minutes after achieving the gelation point (relative units); T_4 – time 10 minutes after achieving the gelation point (minutes); A_5 – maximum LPTEG amplitude recorded over 10 minutes (relative units); T_5 – time to achieve maximum LPTEG amplitude (minutes); A_6 – value of LPTEG amplitude 10 minutes after achieving maximum amplitude (relative units); T_6 – time 10 minutes after achieving A_5 (minutes).

Calculated indicators: ICC – intensity of contact coagulation, reflecting the aggregational activity of platelets and other formed elements of the blood; CTA – constant of thrombin activity; ICD – intensity of coagulation drive; ICP – intensity of clot polymerization; ITC – intensity of total coagulation; ICRL – intensity of clot retraction and lysis (%); MA – maximum clot amplitude (relative units), which is the difference (A_5–A_1, relative units), characterizing the maximum density of the clot.

Sampling of venous blood for investigation of the hemostasis system in the institute’s laboratory was performed during the preparation of patients for the elective operation. Investigation of the hemostasis system by the LPTEG method was carried out twice: on the eve of the operation and in the operating room at the height of blood loss (stage of mounting the metal construct after the installation of pedicle screws). Blood for the study was aspirated from a peripheral vein using an insulin syringe in a volume of 1 mL without applying a tourniquet.

To all patients, prior to skin incision, for the purpose of inhibiting fibrinolysis processes, tranexamic acid was administered at a dose of 15 mg/kg. Patients who underwent hemo- and/or plasma transfusion were excluded from the statistical analysis of low-frequency piezothromboelastography indicators at the height of blood loss due to the possible impact of blood components on blood coagulation indicators. Infusion therapy was conducted with balanced solutions of crystalloids in a volume corresponding to physiological requirements and the volume of intraoperative blood loss. Intraoperative blood loss was calculated by weighing the surgical material and measuring the volume of blood collected from the wound by an electric aspirator.

The study protocol was reviewed at a meeting of the local ethics committee of the Novosibirsk Research Institute of Traumatology and Orthopaedics n.a. Ya.L. Tsivyan and received a positive conclusion (extract No. 001/22-1 from protocol 001/22 dated January 17, 2022).

All patients or their legal representatives gave consent to use the obtained results in the format of scientific reports and publications by signing voluntary informed consent.

Statistical calculations were performed in the RStudio program (version 2025.05.0 Build 496, URL: https://www.rstudio.com, R language version 4.4.2 (2024-10-31 ucrt), URL: https://

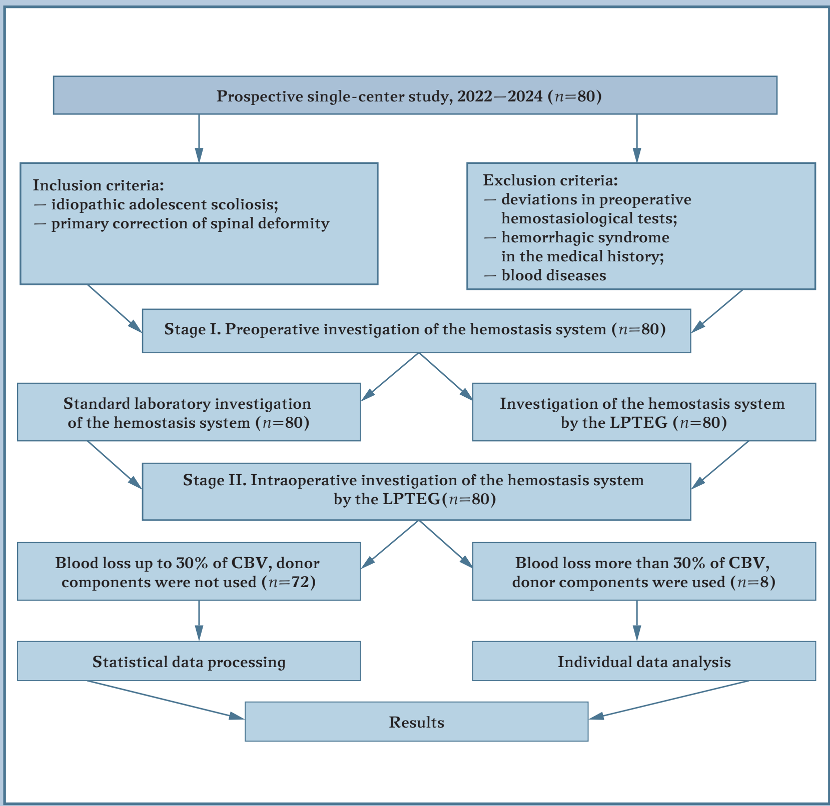

Fig. 1
Study design: low-frequency piezothromboelastography

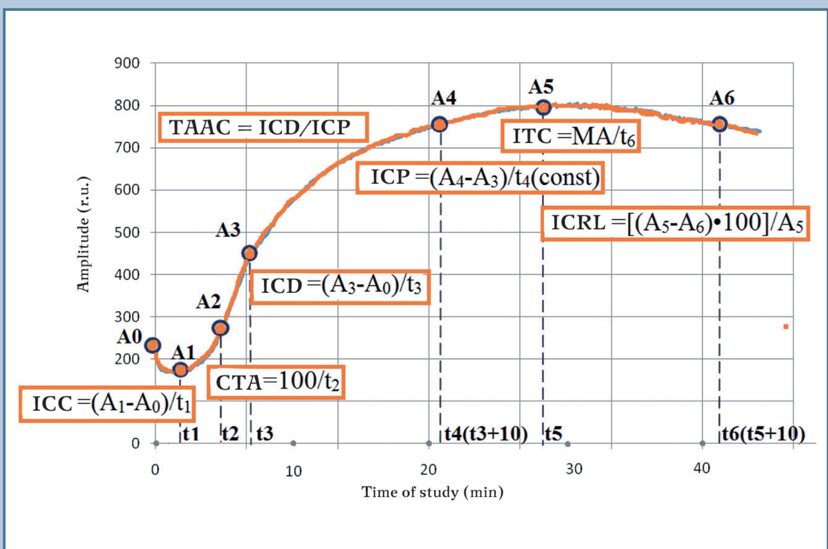

Fig. 2
Curve of low-frequency piezothromboelastography

www.R-project.org/). The significance of changes in continuous parameters of the hemostasis system was evaluated by the Wilcoxon rank-sum test due to the non-compliance of distributions with the normal law according to the Shapiro-Wilk test. Descriptive characteristics are presented by the median indicating the first and third quartiles (Median [Q1; Q3]). The magnitude of differences between the baseline state and at the height of blood loss was evaluated absolutely by means of pseudomedians of differences with the construction of a 95% CI (95% CI), as well as relatively – by the standardized difference of means with a 95% CI. Numerical associations between parameters of the hemostasis system and data on intraoperative blood loss with infusion were evaluated by calculating Spearman's correlation coefficients. Differences were considered statistically significant upon reaching a level of $p < 0.05$.

Results

Preoperative indicators of the hemostasis system are presented in Table 1, from which it can be seen that preoperative deviations of laboratory indicators from reference values were not registered. The decrease in the medians of the indicators of ICD, ICP, MA in comparison with reference values shows the presence of structural hypocoagulation.

The prolongation of blood clot formation time (T_1, T_2, T_3, T_4) indicates the presence of chronometric hypocoagulation. The result of these changes was a decrease in the ITC. However, the corresponding reference indicators of the median T_5 indicate the normalization of the rate of clot formation by the stage of forming its maximum density. Also, a trend towards increased retraction and lysis of the clot was registered.

An example of a LPTEG curve of a patient with adolescent idiopathic scoliosis is presented in Fig. 3.

Data of the correlation analysis aimed at identifying associations of preoperative LPTEG indicators with laboratory hemostasis indicators are presented in Table 2.

As can be seen from the data in Table 2, significant correlation links between the studied indicators were not established. Only a moderate link between the ITC and the level of fibrinogen can be noted.

Table 3 presents a comparison of preoperative LPTEG values with data obtained at the height of blood loss.

When comparing baseline LPTEG data with indicators at the height of blood loss, a normalization of the indicators ICC, CTA and ITC is noted, and statistically significant differences of a number of temporal and amplitude indicators became less pronounced, which, in our opinion, ensured an adequate reaction of the hemostasis system to surgical trauma.

The correlation dependence of baseline LPTEG indicators and the difference (Δ) between baseline indicators and LPTEG indicators at the height of blood loss with the volume of intraoperative blood loss and the volume of infusion therapy is presented in Table 4.

The data in Table 4 indicate the presence of a moderate correlation link of the intensity of contact coagulation with the volume of intraoperative blood loss (in % of the CBV). Links indicating the influence of infusion therapy on LPTEG indicators were not revealed.

Eight clinical observations were analyzed separately, which amounted to 10% of the total patient sample, when intraoperative blood loss exceeded 30% of the CBV and required the use of donor blood components. The results of the analysis showed that in all these cases, the general trend towards hypocoagulation was preserved, while the values of a number of indicators had more pronounced deviations from the reference values in comparison with the low-frequency piezothromboelastography indicators of those patients for whom blood components were not used: prolongation of T_1, decrease in the ICD, ICP, CTA, MA, a significant increase in the ICRL. In one case, significant changes in the indicators of preoperative LPTEG were registered in the form of pronounced activation of formed blood elements ($t_1 \rightarrow 0$; ICC $\rightarrow 0$; increase in A_1), an increase in thrombin activity up to 45.5 and an enhancement of fibrinolytic activity up to 9.8%. The result of these disorders was massive intraoperative blood loss, reaching 62% of the CBV. No abnormalities in standard laboratory tests were registered in all these observations.

The preoperative LPTEG curve of the patient with massive intraoperative blood loss is presented in Fig. 4.

Discussion

Global diagnostic methods of the state of the hemostasis system, based on the investigation of the viscoelastic properties of whole blood, are currently gaining wider prevalence due to the possibility of the most accurate determination of the hemostasiological profile of patients [20–22]. The method of LPTEG envisions the start of whole blood analysis immediately after its sampling and allows tracking the dynamics of changes in clot properties directly during the coagulation process [23]. Despite the prevalence of global diagnostic methods, standard laboratory investigations of the hemostasis system remain relevant.

In the presented study, preoperative deviations of laboratory indicators from reference values were not registered. The absence of deviations from the norm in preoperative standard hemostasiological tests in patients with idiopathic scoliosis is also reported by other authors. In their opinion, this very circumstance does not allow identifying any specific

Table 1

Preoperative indicators of the hemostasis system

Indicator	Median [Q1; Q3]	Reference values
Laboratory indicators		
Platelets	216 [186; 262]	150–400 × 10^9 cells/L
Prothrombin time	13.40 [12.70; 14.17]	10–14 sec
International Normalized Ratio	1.22 [1.15; 1.29]	0.8–1.2
Activated Partial Thromboplastin Time	32.00 [30.10; 34.70]	24.3–35.0 sec
Fibrinogen	3.32 [2.98; 3.69]	1.56–4.00 g/L
Indicators of low-frequency piezothromboelastography		
A_1	172.00 [163.75; 182.25]	85–105 p.u.
T_1	2.10 [1.40; 2.95]	0.8–1.6 min
ICC	−11.82 [−16.89 ; −7.19]	From −37 to −14
A_2	270.50 [263.00; 281.25]	183–203 p.u.
T_2	7.70 [6.27; 9.62]	3.5–4.8 min
CTA	19.24 [15.57; 25.00]	22.2–38.5
A_3	445.50 [395.75; 482.50]	505–525 p.u.
T_3	12.40 [10.80; 16.70]	5.7–10.0 min
ICD	20.54 [16.31; 24.87]	31.9–36.0 p.u.
A_4	555.50 [505.75; 581.00]	646–666 p.u.
T_4	22.40 [20.80; 26.63]	15.7–20.0 min
ICP	10.15 [7.38; 12.33]	15.6–20.0
A_5	579.50 [535.75; 603.00]	681–701 p.u.
T_5	30.15 [27.07; 35.50]	28–42 min
MA	408.50 [362.50; 435.00]	472–655 p.u.
ITC	12.98 [11.24; 14.87]	14.68–20.12
A_6	575.00 [524.50; 602.00]	672–692 p.u.
T_6	40.20 [37.65; 45.50]	51–57 min
ICRL	1.48 [0.53; 3.00]	0–1 %

Expansion of LPTEG indicators is given in the text.

deviation that could predict future blood loss, which is a significant limitation in practical activity [18]. At the same time, the use of global diagnostic tests provides essential information, allowing the identification of disorders in the hemostasis system that are possibly responsible for the resulting volume of intraoperative blood loss.

Thus, in the study conducted by us, when analyzing the medians of LPTEG indicators, it became obvious that the examined patients have structural and chronometric hypocoagulation. The result of these violations was a decrease in the intensity of total blood coagulation. Also, a tendency towards an increase in clot retraction and lysis was registered. Taking this circumstance into account, the administration of an antifibrinolytic drug before the start of the operation was completely justified. The fact that fibrinolysis is an area where efforts should be focused to improve hemostasis in patients during surgical intervention for scoliosis is also indicated

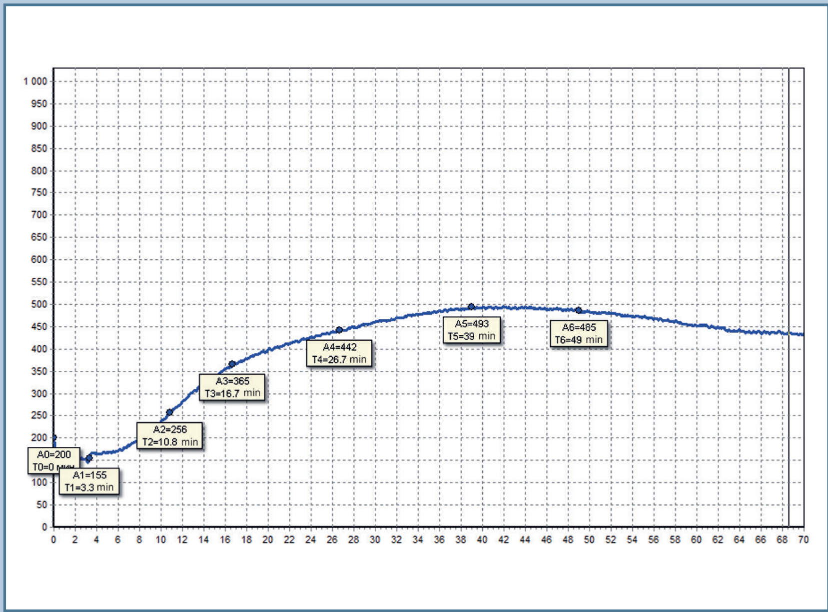

Fig. 3
Curve of low-frequency piezothromboelastography of an adolescent with idiopathic scoliosis

Table 2
Correlation links between preoperative indicators of low-frequency piezothromboelastography and laboratory indicators of hemostasis

Indicator	Prothrombin time r (p)	International Normalized Ratio r (p)	Activated Partial Thromboplastin Time r (p)	Fibrinogen r (p)
A_1	−0.01 (0.950)	0.00 (0.984)	−0.01 (0.915)	0.05 (0.648)
T_1	−0.14 (0.218)	−0.13 (0.236)	0.09 (0.434)	−0.05 (0.692)
ICC	−0.14 (0.210)	−0.13 (0.242)	−0.03 (0.771)	0.04 (0.716)
A_2	−0.02 (0.888)	−0.01 (0.952)	−0.02 (0.878)	0.05 (0.695)
T_2	−0.07 (0.520)	−0.07 (0.554)	0.25 (0.024*)	−0.23 (0.045*)
CTA	0.00 (0.970)	0.00 (0.996)	−0.18 (0.115)	0.23 (0.045*)
A_3	−0.12 (0.274)	−0.12 (0.285)	−0.02 (0.852)	0.16 (0.154)
T_3	−0.06 (0.585)	−0.06 (0.609)	0.25 (0.023*)	−0.15 (0.196)
ICD	−0.01 (0.938)	−0.01 (0.894)	−0.24 (0.036*)	0.28 (0.013*)
A_4	−0.11 (0.336)	−0.11 (0.334)	−0.05 (0.674)	0.20 (0.081)
T_4	−0.05 (0.667)	−0.04 (0.690)	0.24 (0.033*)	−0.16 (0.154)
ICP	−0.04 (0.741)	−0.05 (0.676)	−0.07 (0.545)	0.08 (0.465)
A_5	−0.06 (0.609)	−0.06 (0.590)	−0.02 (0.859)	0.12 (0.311)
T_5	0.13 (0.248)	0.13 (0.266)	0.32 (0.004*)	−0.36 (0.001*)
MA	−0.06 (0.598)	−0.06 (0.578)	−0.03 (0.823)	0.11 (0.347)
ITC	−0.12 (0.304)	−0.12 (0.294)	−0.28 (0.011*)	0.38 (<0.001*)
A_6	−0.04 (0.727)	−0.04 (0.713)	−0.06 (0.625)	0.05 (0.678)
T_6	0.15 (0.187)	0.14 (0.204)	0.30 (0.007*)	−0.29 (<0.001*)
ICRL	−0.13 (0.265)	−0.13 (0.264)	0.03 (0.785)	0.25 (0.031*)

* $p < 0.05$; expansion of LPTEG indicators is given in the text.

Table 3

Comparison of baseline indicators of low-frequency piezothromboelastography with indicators at the height of blood loss

Indicator	Baseline Median [Q1; Q3]	At the height of blood los Median [Q1; Q3]	Effect size PSEUDOMEDIAN [95% CI]	Wilcoxon test *p*-level
A_1	172.0 [164.25; 181.75]	181.0 [172.00; 187.00]	−5.5 [−6.00; −5.00]	0.006*
T_1	2.1 [1.40; 2.90]	1.3 [0.90; 1.78]	0.9 [0.85; 0.95]	<0.001*
ICC	−11.825 [−16.560; −7.020]	−14.645 [−18.610; −9.600]	2.500 [2.230; 2.850]	0.044*
A_2	271.5 [264.00; 280.75]	280.0 [272.00; 286.75]	−5.5 [−6.00; −5.00]	0.007*
T_2	7.70 [6.35; 9.78]	5.45 [4.12; 7.18]	2.15 [2.05; 2.20]	<0.001*
CTA	18.18 [15.63; 25.00]	24.39 [17.94; 35.71]	−5.83 [−6.18; −5.45]	<0.001*
A_3	450.5 [396.50; 492.75]	468.5 [419.00; 496.75]	−5.0 [−7.50; −2.50]	0.613
T_3	12.70 [10.90; 16.92]	11.05 [7.90; 14.30]	2.52 [2.25; 2.70]	0.006*
ICD	20.535 [15.59; 25.01]	26.165 [21.72; 31.95]	−5.630 [−5.83; −5.38]	<0.001*
A_4	557.0 [505.50; 581.75]	576.5 [543.50; 598.00]	−17.0 [−19.00; −15.50]	0.040*
T_4	22.70 [20.09; 26.70]	21.05 [17.90; 24.30]	2.40 [2.20; 2.60]	0.004*
ICP	10.1 [6.60; 12.10]	10.4 [7.65; 13.80]	1.2 [−1.35; −1.05]	0.121
A_5	581.5 [535.25; 610.00]	601.0 [569.00; 631.50]	−20.0 [−21.50; −18.00]	0.041*
T_5	30.30 [28.15; 35.50]	28.55 [23.55; 32.18]	3.25 [3.05; 3.45]	0.008*
MA	412.0 [361.75; 435.75]	422.0 [395.25; 449.50]	−14.5 [−16.00; −12.50]	0.109
ITC	12.88 [11.17; 14.77]	14.69 [12.97; 17.03]	−2.51 [−2.58; −2.38]	<0.001*
A_6	577.0 [526.00; 603.00]	591.0 [551.00; 626.00]	−13.0 [−15.00; −10.05]	0.228
T_6	40.40 [38.30; 45.50]	38.20 [33.50; 42.10]	3.45 [3.25; 3.75]	0.003*
ICRL	1.28 [0.41; 2.80]	1.81 [0.46; 4.83]	−0.93 [−1.04; −0.84]	0.086

* $p < 0.05$; expansion of LPTEG indicators is given in the text.

by other researchers [18]. The presented features of the preoperative state of the hemostasis system in patients with idiopathic scoliosis confirm the data previously obtained by us [13]. The presence of a background state of hypocoagulation in a number of patients with severe forms of scoliosis is also reported by other authors [24].

The analysis of LPTEG indicators obtained at the height of blood loss showed that the state of structural and chronometric hypocoagulation persisted, however, the changes in a number of temporal and amplitude indicators became less pronounced, which, in our opinion, ensured an adequate reaction of the hemostasis system to surgical trauma. Confirmation of this is the fact that, despite the presence of hypocoagulable shifts, intraoperative blood loss in 36 (45%) patients did not exceed 15% of the CBV, another 36 (45%) – did not exceed 30% of the CBV and did not require the use of donor blood components. This, in turn, allowed confirming the conclusion made by us earlier that the hemostasis system in the overwhelming majority of patients with idiopathic scoliosis is in a state of adequate and effective self-regulation [13]. At the same time, the analysis of LPTEG data of patients with blood loss exceeding 30% of the CBV showed that registration at the initial stage of the study of pronounced activation of formed blood elements, as well as a significant increase in thrombin activity and enhancement of fibrinolytic activity can be considered as prognostic factors of massive blood loss. Confirmation of this is the established moderate correlation link of the intensity of contact coagulation with the volume of intraoperative blood loss.

The results obtained by us in some judgments echo the data of other researchers who studied the perioperative dynamics of changes in the hemostasis system in children operated on for spinal deformities using the thromboelastography method. Thus, the study by K.V. Pshenisnov et al. [17], which included 20 patients, established that the most pronounced changes in hemostasis indicators were observed at the end of the operation, while having a hypocoagulation nature. However, the registered state of hypocoagulation is associated by the authors of the study with a deficiency of coagulation factors against the background of acute blood loss, in particular fibrinogen, the level of which statistically significantly decreased towards the end of the operation. At the same time, no statistically significant difference between baseline values and data upon completion of the operation was revealed in the indicators of fibrinolysis. The obtained results allowed the authors to conclude that the main factor determining the state of hypocoagulation in children operated on for the spine is the volume of intraoperative blood loss. Considering the results of the study conducted and the data obtained earlier, we incline towards a different point of view: adolescent patients with idiopathic scoliosis have initial features of the hemostasis system in the form of structural and chronometric hypocoagulation, the degree of severity of which ultimately

Table 4

Correlation dependence of baseline indicators of low-frequency piezothromboelastography and Δ of indicators of low-frequency piezothromboelastography with the volume of Intraoperative Blood Loss (IBL) and the volume of infusion therapy

Baseline Indicator	IBL, mL r (p)	IBL, % CBL r (p)	Δ of indicator	Infusion, mL r (p)	IBL, mL r (p)	IBL, % CBL r (p)
A_1	0.02 (0.888)	−0.07 (0.518)	Δ A_1	−0.08 (0.513)	−0.14 (0.237)	−0.37 (0.002*)
T_1	−0.05 (0.665)	0.08 (0.446)	Δ T_1	0.04 (0.739)	−0.03 (0.832)	0.17 (0.165)
ICC	0.04 (0.717)	0.02 (0.824)	Δ ICC	−0.05 (0.652)	−0.11 (0.367)	−0.12 (0.336)
A_2	0.01 (0.943)	−0.07 (0.531)	Δ A_2	−0.10 (0.408)	−0.17 (0.172)	−0.38 (0.001*)
T_2	0.02 (0.846)	0.09 (0.418)	Δ T_2	−0.13 (0.285)	−0.06 (0.639)	0.02 (0.852)
CTA	−0.06 (0.603)	−0.07 (0.510)	Δ CTA	0.13 (0.279)	0.07 (0.589)	0.06 (0.625)
A_3	−0.07 (0.515)	−0.16 (0.144)	Δ A_3	−0.04 (0.744)	−0.15 (0.228)	−0.29 (0.013*)
T_3	0.05 (0.671)	0.07 (0.526)	Δ T_3	−0.09 (0.477)	−0.07 (0.589)	−0.10 (0.414)
ICD	−0.04 (0.734)	−0.10 (0.346)	Δ ICD	0.10 (0.406)	0.07 (0.568)	0.06 (0.598)
A_4	−0.11 (0.299)	−0.24 (0.024*)	Δ A_4	−0.08 (0.526)	−0.13 (0.281)	−0.27 (0.023*)
T_4	0.06 (0.601)	0.08 (0.478)	Δ T_4	−0.07 (0.588)	−0.07 (0.540)	−0.10 (0.407)
ICP	−0.07 (0.521)	−0.09 (0.411)	Δ ICP	−0.08 (0.516)	0.03 (0.788)	0.13 (0.275)
A_5	−0.13 (0.237)	−0.26 (0.016*)	Δ A_5	−0.08 (0.528)	−0.07 (0.583)	−0.19 (0.115)
T_5	−0.01 (0.952)	0.04 (0.729)	Δ T_5	−0.12 (0.328)	−0.07 (0.579)	−0.10 (0.417)
MA	−0.12 (0.260)	−0.24 (0.023*)	Δ MA	−0.04 (0.717)	−0.03 (0.832)	−0.12 (0.329)
ITC	0.00 (0.964)	−0.07 (0.507)	Δ ITC	0.09 (0.468)	0.07 (0.556)	0.10 (0.392)
A_6	−0.11 (0.310)	−0.25 (0.020*)	Δ A_6	−0.01 (0.963)	−0.02 (0.841)	−0.16 (0.181)
T_6	0.00 (0.967)	0.05 (0.652)	Δ T_6	−0.10 (0.428)	−0.04 (0.715)	−0.08 (0.518)
ICRL	−0.09 (0.391)	−0.03 (0.784)	Δ ICRL	−0.16 (0.201)	−0.07 (0.561)	0.03 (0.817)

* $p < 0.05$; expansion of indicators of low-frequency piezothromboelastography is given in the text.

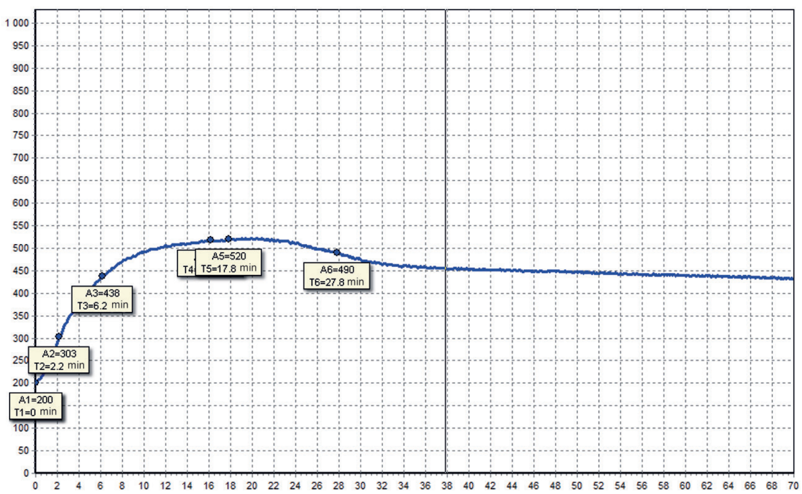

Fig. 4
Curve of low-frequency piezothromboelastography of a patient with massive intraoperative blood loss

determines the volume of intraoperative blood loss. We also assume that it is precisely the state of structural and chronometric hypocoagulation that makes the main contribution to the frequency of development of thromboembolic complications in scoliosis surgery, which is extremely low in comparison with other orthopedic interventions [25].

However, there is also opposing information based on thromboelastography data and laboratory tests: stress arising during posterior spinal fusion operations in patients with adolescent idiopathic scoliosis causes a state of hypercoagulation, platelets and blood coagulation factors are not depleted against the background of blood loss, and fibrinolysis of varying severity develops during the first two hours after the operation [18]. The presence of hypercoagulable shifts in the first six hours after the correction of scoliosis according to laboratory diagnostic methods is also reported by other authors [26].

In the present study, a correlation analysis was conducted aimed at identifying links between LPTEG indicators, results of standard laboratory tests, the volume of blood loss, and the volume of infusion therapy. Significant correlation links were not established.

We understand that the presented results provide averaged information on the functional state of the hemostasis system in adolescents with idiopathic scoliosis and cannot be extrapolated to the entire patient cohort and to each specific case. This fact confirms the importance and validity of personalized preoperative assessment of the hemostasis system in adolescents with idiopathic scoliosis using global diagnostic methods.

As far as we know, the completed study is the largest domestic study in which the LPTEG method is applied to assess the hemostasis system in adolescents with idiopathic scoliosis. At the same time, the study has a number of limitations, the main ones being the absence of postoperative monitoring, the lack of dynamics of standard laboratory indicators, and the absence of regression analysis to establish predictors of expected intraoperative blood loss. Eliminating these limitations will be the area of our future studies.

Conclusion

The established background deviation in the coagulation profile in adolescents with idiopathic scoliosis is the presence of structural and chronometric hypocoagulation at all stages of the hemostasis process – from the initiation of blood coagulation to clot lysis. The provision of intraoperative infusion support with the use of balanced crystalloid solutions does not have a significant impact on hemostasis indicators. The application of the LPTEG method can be used to assess the functional state of the hemostasis system, but only from the standpoint of personalized recording and analysis.

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Дополнительная информация

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Ethical review. The conduct of the study was approved by the local ethics committee of the Ya.L. Tsiv'yan Novosibirsk Research Institute of Traumatology and Orthopedics (extract No. 001/22-1 from protocol 001/22 dated January 17, 2022).

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