Original article

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MONITORING OF HEMOSTASIS DISORDERS IN CARDIAC SURGERY

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Bleeding during and after cardiopulmonary bypass is a multifactorial and potentially lethal complication. That is why one of the most difficult tasks in cardiac surgery is the establishment of a timely, physiological hemostasis. The aim of this study was to diagnose the most common coagulation disorders in patients who underwent surgical revascularization of the myocardium (their frequency, follow-up complications) and therapeutic care of them. The prospective survey included 100 respondents (22 female females-22.0% and 78 male respondents -78.0%), who were subjected to single, double and triple surgical revascularization of the myocardium. Preoperative as well as 3 hours and 24 hours postoperatively determined the following parameters: blood count, coagulation status, platelet function parameters, rotational thromboelastometric parameters, blood and blood product use, use of synthetic hemostatic agents. The most commonly diagnosed hemostasis disorders are preoperative and postoperatively disrupted platelet function (up to 31% of patients), postoperative extrinsic coagulation factor concentration depletion (postoperatively) (21% of patients), intrinsic factor coagulation activity disorder (23% of patients after surgery) and disturbed concentration of functional fibrinogen and impaired fibrin clot polymerization in 17% of patients following surgery. During the study, 13% of patients received a cryoprecipitate transfusion after surgery, 10% of patients received frozen fresh plasma, 22% were transfunded with platelet concentrates, 20% of patients received desmopressin acetate, while 3 patients received a prothrombin complex concentrate in the postoperative course.

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Introduction

The aortocoronary bypass is usually performed under conditions of extracorporeal circulation (ECC). Cardiopulmonary bypass (CPB) is a method that replaces cardiac arrest and pulmonary circulation during cardiac surgery. The primary role of this technique is to provide tissue oxygenation and thermoregulation during surgery. The extracorporeal circulation machine is used for this purpose (1, 2).

Bleeding during and after cardiopulmonary bypass is multifactorial. Namely, prolonged contact of platelets with the intestinal surfaces of the extracellular bloodstream interferes with their function, leads to activation of platelets and coagulation cascade, which in the final outcome has a thrombocytopenia in more than 30%, as well as consumable coagulopathy. Contact activation of the coagulation cascade occurs upon contact of the artificial surface with blood, primarily through the activation of factor XII. Platelets of patients undergoing cardiac surgery are very sensitive, as patients are generally preoperatively receiving mono or dual antiplatelet therapy, which inhibits their function and further disrupts perioperative and postoperative hemostasis. Dilution within the primer, hypothermia during the intervention, prolonged duration of the extracorporeal blood flow procedure, also disrupt systemic hemostasis. A number of patients have used oral or parenteral anticoagulation therapy, prior to the surgery which inhibits successful hemostasis by inhibiting the activation of factors II, VII, IX, X, XI. Increased perioperative blood loss, combined administration of heparin and protamine, preoperative anemia, renal failure, liver disease, age over 70 years, female gender, congenital or acquired coagulopathies are all risk factors that disrupt the coagulation cascade and hemostasis.

One of the most difficult tasks in cardiac surgery is the establishment of timely, physiological hemostasis. Bleeding usually occurs during and after cardiac surgery. During this emergency, routine laboratory testing of coagulation using PT, APTT, platelet counts is usually slow and insufficient. The point of care (POC) devices for monitoring the hemostatic system play a real role in these acute conditions: rotational thromboelastometry, impedance aggregation, activated coagulation time, functional fibrinogen and percentage of clot lysis (3).

Systemic hemostatic therapy is crucial for the timely management of bleeding complications.

The aim of the study

The aim of this study was to diagnose the most common coagulation disorders in patients undergoing surgical myocardial revascularization (their frequency, associated complications) and their therapeutic management, as well as the selection of adequate hemostatic therapy in the management of coagulation disorders in cardiac surgery patients.

Materials and methods

This prospective study included 100 patients who underwent single, double and triple surgical myocardial revascularization at the Clinic of Cardiac Surgery, Clinical Center Niš, from 15.06.2018. to 15.12.2018. One hundred patients were included in the research (22 female 22.0% and 78 male 78.0%). The mean age of the study population was 64.6 ± 7.5 years (min 43, max 80 years).

All patients enrolled in the study underwent preoperative mono or dual antiplatelet therapy (acetylsalicylic acid ± clopidogrel/ticagrelor), which was discontinued 5 days before surgery.

Following standard cardiac surgery preoperative patient preparation, patients were operated on according to standard cardiac surgery protocols.

The following parameters were determined preoperatively as well as 3 hours and 24 hours postoperatively:

1. blood count (erythrocyte-Rbc count, hemoglobin-Hgb, hematocrit-Hct, leukocyte count-Wbc, platelet count-Plt) on a Horiba CRP 200 automatic counter, from 4ml whole blood sampled in a EDTA anticoagulant tube.

2. coagulation status (prothrombin time-PT, International Normalized Ratio-INR, activated partial thromboplastin time-aPTT, fibrinogen-F I, antithrombin III-AT III, D dimer, on ACL Elite Procoagulome ter), from the whole blood sampled using Na-citrate anticoagulated tube, centrifuged immediately after sampling for 15 min at 3500 rpm and then pipetted 250 microlitre samples from the serum were released for coagulometer testing.

3. parameters of platelet function (platelet activation by adenosine diphosphate (ADP test)–registers residual effect of clopidogrel/ticagrelor on platelet function; platelet activation by arachidonic acid (ASPI test)-registers residual effect of acetylsalicylic acid and TRAP test-represents the natural potential of platelet-independent therapy, performed on a MULTIPLATE Roch Germany impedance aggregator). Blood was sampled in 4ml lithium-heparin anticoagulant tubes and within 30 min of sampling, analyzes were performed.

4. basic parameters of rotational thrombelastometry (parameters of internal-INTEM test and external coagulation pathway-EXTEM test, namely: (coagulation time-CT which depends on the concentration and activity of plasma coagulation factors, maximum clot strength-MCF whose value is conditioned by number and platelet function as well as fibrinogen concentration, the amplitude clots after 10 minutes-A10 also depends on platelet count/ function and fibrinogen concentration, alpha angle, maximal lysis-ML registering pathological lysis of the clot), functional fibrinogen-FIBTEM test, A10 depending on the persistence and polymerization of fibrin clot), on a ROTEM rotational platelet device Roche Germany, whole blood 4ml in sodium citrate tube as anticoagulant, and blood was also analyzed within 30 min of sampling.

5. The use of blood and blood products, perioperatively and postoperatively, was recorded in the medical records kept in the operating room (operating list), as well as in the intensive care unit (shock list).

6. The use of synthetic hemostatic agents (prothrombin complex concentrate-PCC complex, desmopressin acetate-DDAVP, tranexamic acid) was recorded in the medical records kept in the operating room (operating list) as well as in the intensive care unit (shock list).

Multiplate test parameter values indicating an increased risk of increased perioperative and postoperative bleeding, which may result from impaired platelet function, are based on recommendations and guidelines as follows: ADP test ≤ 310 (reference value 570-1130) aggregation units per minute (AU/ min), ASPI test ≤ 400 AU/min (ref. values 710-1490 AU/min) and TRAP test ≤ 500 AU/min. (ref. values 923-1509 AU/min).

The basic parameters of ROTEM tests that are related to various disorders of hemostasis (accompanied by increased bleeding) and the consequent use of hemostatic therapy are:

- Coagulation time-CT Extem ≥ 100 s (ref. value 38-79s), indicates disturbance of the coagulation factor of the external coagulation pathway (II, V, VII, IX factor).
- Coagulation time-CT Intem ≥ 300 s (ref. value 100-240s), refers to disruption of the coagulation factor of the intrinsic pathway (all factors except VII and XIII) or the presence of residual effect of high molecular weight heparin.
- Maximum clot strength-MCF Extem/Intem ≤ 45mm (ref. Value 50-72mm), occurs with impaired function and platelet count or fibrinogen deficiency.
- Clot amplitude after 10 minutes-A10 Fibtem ≤ 8 mm (ref. Value 9-23mm) registers at low concentration and poor polymerization of fibrin clot, which depends on the concentration of functional fibrinogen.
- Maximum clot lysis-ML ≥ 15% (ref. Value

< 15%) indicates pathological hyperfibrinolysis, which also results in increased bleeding in patients.

Statistical data processing

Data were presented in the form of arithmetic mean and standard deviation, minimum and maximum values, as well as absolute and relative numbers.

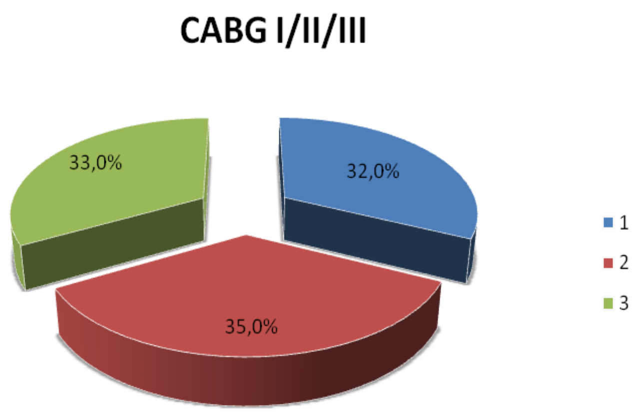
The normality of continuous variables was tested by the Kolmogorov-Smirnov test. If the data distribution was a normal comparison of values preoperatively and postoperatively at two moments (3 h and 24 h after surgery), an ANOVA was performed for repeated measurements. If data distribution was not normal, Friedman's test was used for this comparison. If the data distribution was a normal comparison between the two groups, the t-test was performed, if the data distribution was not normal this comparison was performed by the Mann-Whitney test.

The hypothesis was tested with a significance threshold of $p < 0.05$. Data analysis was performed in SPSS 16.0 software package.

Results

The number of surgical revascularization types (single, double, triple cardiopulmonary bypass-CABG I, II/III) was uniform in the study population. Double cardiopulmonary bypass (35.0%) was the most common; it was followed by triple (33.0) and single (32.0%) (Graph 1).

The number of erythrocytes monitored in the three measurements decreased significantly ($p < 0.001$). Also, hemoglobin and hematocrit values declined statistically significantly over the follow-up period ($p < 0.001$ and $p < 0.001$, respectively). The number of leukocytes 3 h after surgery increased, compared to the period before surgery and then up to 24 h after surgery. There was a statistically significant difference in the number of leukocytes during the follow-up period ($p < 0.001$). Platelets dropped abruptly up to 3 hours after surgery, then we had a slight increase in the 24-hour period after surgery. Platelet counts changed statistically significantly during the follow-up period ($p < 0.001$) (Table 1).

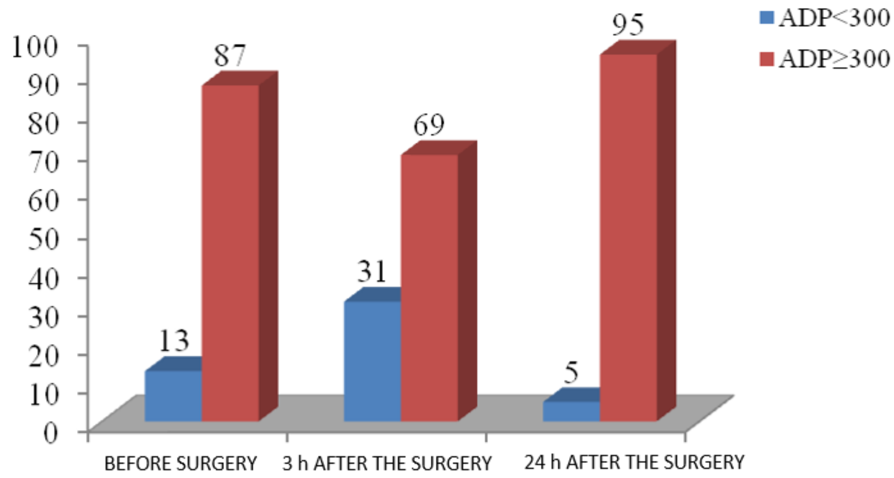


Graph 1. CABG I/II/III distribution

Table 1. Red blood cells number (RBC), hemoglobin values (HGB), hematocrit (Hct), white blood cells (Wbc) and platelet number (PLT) before and 3 h and 24 h after surgery

Parameter	Preoperatively	3 h postoperatively	24 h postoperatively	p-value[1]
RBC	4.46 ± 0.47	3.86 ± 0.55	3.76 ± 0.49	< 0.001
Hgb	137.74 ± 10.93	114.98 ± 11.32	109.96 ± 8.87	< 0.001
Hct	39.18 ± 4.17	32.99 ± 3.95	31.86 ± 3.10	< 0.001
WBC	7.11 ± 1.28	10.07 ± 3.07	9.14 ± 3.34	< 0.001[2]
PLT	236.22 ± 63.88	148.13 ± 56.65	167.01 ± 50.96	< 0.001[2]

ⁱAritmetic mean ± standard deviation, [1]ANOVA for repeated measurements, [2]Friedman test

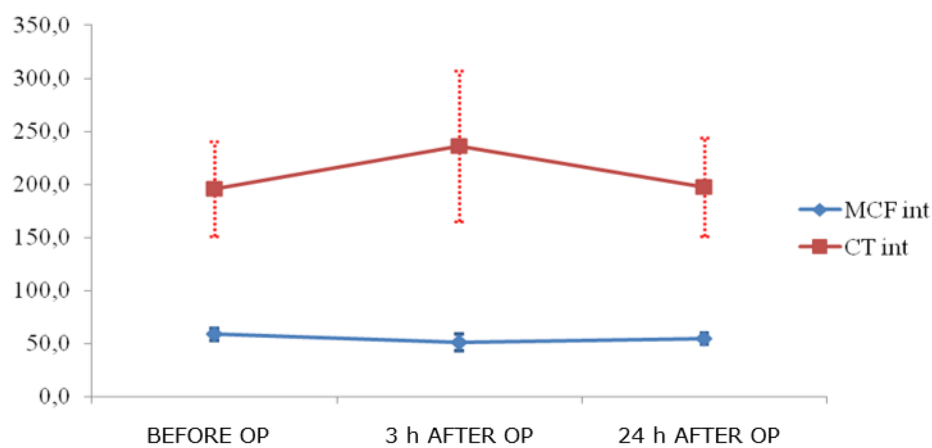


Graph 2. Distribution of patients with low ADP before surgery and 3 h and 24 h after surgery

Table 2. Values of CT int and MCF int at follow-up in the study population

Parameter	Preoperatively	3 h postoperatively	24 h postoperatively	p-value[1]
CT INTEM	195.96 ± 44.63	236.11 ± 70.65	197.43 ± 46.83	< 0.001
MCF INTEM	58.89 ± 5.70	50.91 ± 7.87	54.70 ± 7.87	< 0.001

†Aritmetic mean ± standard deviation, [1]Friedman test



Graph 3. Values of CT int and MCF int during the monitoring period in the study population

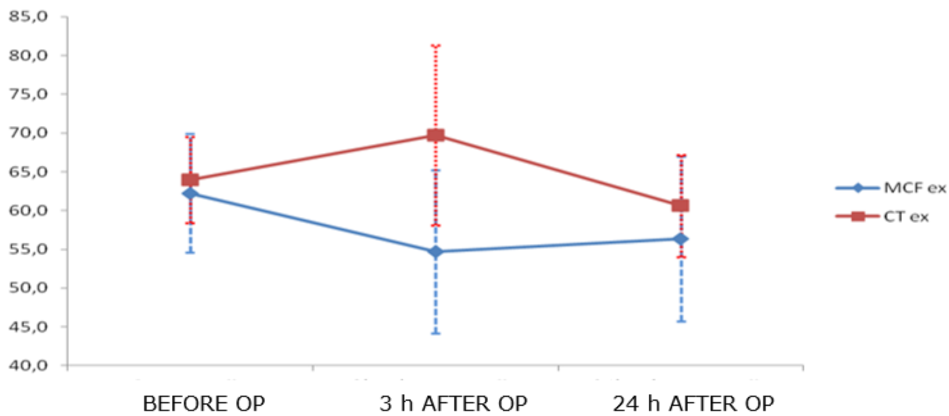
Preoperatively, 13 persons had ADP < 300 aggregation units per minute-AU/min (13.0%), after 3 hours of surgery 31 persons had ADP < 300 (31.0%), and after 24 hours of surgery 5 persons had ADP < 300 (5.0%) (Graph 2). CT intem values increased in the first 3 h of surgery compared to the preoperative period and then returned to the preoperative values in the period up to 24 h. It was found that there was a statistically significant difference in CT intem values between the three measurements (p < 0.001) (Table 2). MCF intem values declined in the first 3 hours after surgery compared to the preoperative period, and then began to increase slightly up to 24 hours after surgery. It was found that there was a statistically significant difference in the values of this parameter between the three measurements (p < 0.001) (Table 2, Graph 3).

CT extem values increased in the first 3 hours after the surgery compared to the preoperative period, and then fall to lower values compared to the preoperative period up to 24 hours. It was found that there was a statistically significant difference in CT extem values between the three measurements (p <0.001) (Table 3). MCF extem values decline in the first 3 hours after surgery relative to the preoperative period, and then begin to increase slightly within 24 hours of surgery. It was found that there was a statistically significant difference in the values of this parameter between the three measurements (p < 0.001) (Table 3, Graph 4).

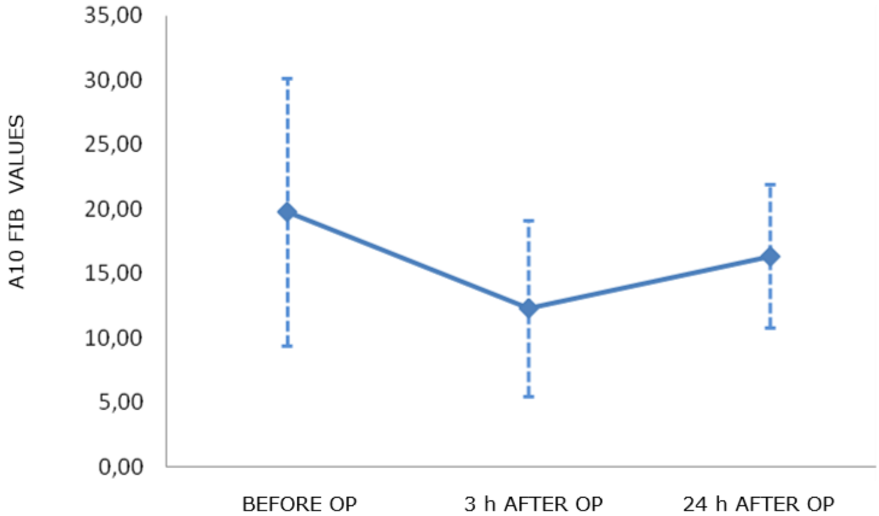
Table 3. Values of CT ex and MCF ex in the monitoring period in the study population

Parameter	Preoperatively	3h postoperatively	24h postoperatively	p-value[1]
CT extem	63.96 ± 7.67	69.71 ± 10.56	60.62 ± 10.61	< 0.001
MCF extem	62.25 ± 5.58	54.73 ± 11.63	56.38 ± 6.59	< 0.001

[1]Aritmetic mean ±standard deviation, [1]ANOVA for repeated measurements



Graph 4. Values of CT ex and MCF ex during the monitoring period in the study population



Graph 5. Values of A10 fibtem during the follow-up period in the total population

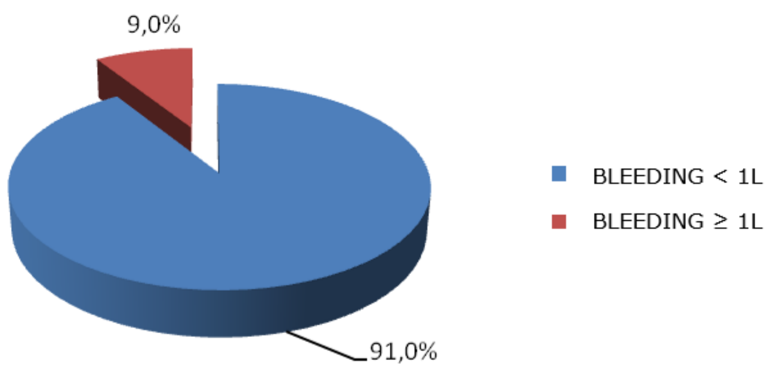
A10 fibtem values decreased within 3 hours after surgery (12.31 ± 6.82) in comparison to preoperative values (19.79 ± 10.35) and that was followed by a slight increase (16.36 ± 5.89) (Graph 5). It was found that there was a statistically significant difference in the values of this parameter between the three measurements ($p < 0.001$).

MCF extem of less than 45mm was measured in 21 patients (21.0%) 3 hours after surgery and in 3 patients (3.0%) 24 hours after surgery. CT intem greater than 300 was measured in 23 patients 3 hours after surgery and there were no such measurements after 24 hours. MCF intem of less than 45 was measured in 17 patients (17.0%) 3 hours after surgery and in 5 patients (5.0%) 24 hours after surgery. A10 fibtem ≤ 8 was measured in 8% of patients before surgery, in 15% of patients 3 h after surgery, and in 2% of patients 24 h after surgery (Table 4).

In the study population, 9 patients (9.0%) had bleeding of over 1L in the drain (Graph 6).

Table 4. Parameters indicating increased peri and postoperative bleeding

	Before operation	3 h after operation	24 h after operation
CT ex > 100	0 (0.0%)	4 (4.0%)	0 (0.0%)
MCF ex < 45	0 (0.0%)	21 (21.0%)	3 (3.0%)
CT int > 300	0 (0.0%)	23 (23.0)	0 (0.0%)
MCF int < 45	0 (0.0%)	17 (17.0)	5 (5.0%)
A10 fib ≤ 8	8 (8.0%)	15 (15.0%)	2 (2.0%)
INR > 2	0 (0.0%)	6 (6.0%)	0 (0.0%)
APTT > 50	0 (0.0%)	8 (8.0%)	5 (5.0%)
ML > 15	0 (0.0%)	0 (0.0%)	0 (0.0%)



Graph 6. Frequency of bleeding in the drain ≥1L after 24 h after surgery in the study population

Blood and blood products (plasma, cryoprecipitate, platelets), as well as systemic hemostatic agents (desmopressin acetate, prothrombin complex concentrate) were not received by any patient prior to surgery.

Three hours after surgery, 12 patients (12%) received allogeneic resuspended erythrocytes, while 24 hours postoperatively 8 patients received one unit (350ml) of resuspended donor erythrocytes.

Three hours after the operation, 13 patients (13.0%) received cryoprecipitate. Five patients (5%) received 10 doses of cryoprecipitate, 6 patients (6%) received 15, and 2 patients (2%) received 20 doses (A10 fibtem </ = 8). After 24 hours of surgery, no one received cryoprecipitate.

After 3 hours, 10 patients (10.0%) received fresh frozen plasma-CT Extem/Intem ≥ 100/240s. One patient received 3 doses and nine patients 4 doses of plasma. Within 24 hours of myocardial revascularization, fresh frozen plasma was not received by any of the patients.

Platelet transfusion after 3 hours from surgery was received by 22 patients (22.0%)-MCF Ext / Int ≤ 45mm, A10 Fibtem ≥ 10mm, ADP test ≤ 300 AU /min, ASPI ≤ 400 AU/min, TRAP ≤ 500 AU/min. An average of 11.14 ± 4.45 doses was administered. After 24 h of intervention, there were no patients requiring platelet concentrate transfusion.

With regard to systemic hemostatic agents, desmopressin acetate (DDAVP) and prothrombin concentrate complex (PCC), 3 hours after surgery, 13 patients received one ampoule of DDAVP (20mcg)-ASPI test ≤ 300 AU/min, while 24 hours after surgery another 7 patients received the same medication.

Each of 3 patients received PCC of 1000 IU postoperatively, and all patients' INR level was 5 or greater before therapy, as well as CT Extem ≥ 100s.

Discussion

According to the National Blood Collection & Utilization Survey (NBCUS), blood transfusions and blood derivatives, with the exception of platelet transfusions, declined between 2008 and 2011 in the United States of America. A reduction of 8.2% in red blood cell (RBC) transfusions and a decrease in plasma transfusion by 13.4% were observed.

In the United States, contrary to the general trend, there was an increase in blood and blood transfusions during cardiac surgery during 2010, when a total of 34% of operated patients received transfusions of erythrocytes or other blood derivatives (4). Moreover, cardiac surgery was the branch of surgery that consumed the largest amounts of blood flow, while orthopedic surgery was in the second position (5, 6). Transfusion is often necessary during cardiac surgery to correct coagulopathy, blood loss, and hemodilution due to priming. Very often, patients undergoing cardiac surgery have numerous comorbidities, such as anemia or previous myocardial infarctions, which increase the risk of complications and therefore the need for blood transfusions is greater (7).

It is important to note that in most patients who underwent cardiac surgery and who had an increased rate of morbidity and mortality, an average of one to two units of blood were compensated (1, 7, 8). These patients are generally treated for anemia but have generally been hemodynamically stable (8, 9).

The study we performed included 100 cardiac surgery patients, of whom 20 patients received 24 h postoperatively an average of one unit-350ml of resuspended erythrocytes, exclusively at Hgb ≤ 85 g/l, with the aim of correcting postoperative anemia to avoid hypoxia, what is consistent with the results described previously.

The authors performed rigorous statistical analysis for their data and were able to show, using multiple logistic regression, that decreased activity due to ADP activation, predicted increased bleeding. In platelet mapping, the percentage of platelet inhibition, which subtracts the contribution of fibrin to the curve, but also the maximum amplitude due to platelet activator (MAADP), can be examined. The authors showed that both parameters were equally predictive in this data group. In addition to the predictive effect with respect to blood loss, platelet activation due to ADP predicts the need for platelet transfusion. It appears that the value of MAADP may have the ability to determine which patients on clopidogrel are likely to require platelet transfusion (10, 11). The results in this study also indicate the importance of preoperative and early postoperative testing of ADP as an independent predictor of increased bleeding in cardiac surgery.

Regarding frozen fresh plasma transfusions, as well as platelet concentrate transfusions, this study was performed solely on the basis of hemostasis therapy algorithms guided by ROTEM and Multiplote (12, 13). A total of 10 patients received an average of 3.5 units within 3 hours of surgery, with an average of 3.5 units of 220ml per patient, exclusively after detection of coagulation factor deficiency by ROTEM assay parameters (Extem and Intem). Donor platelet concentrate was obtained by 22% of patients early after surgery, also based on analysis of point-of-care (POC) hemostasis tests, both on ROTEM parameters and on Multiplate analyzer (ADP, ASPI, TRAP test). The use of the synthetic hemostatic agent desmopressin acetate to correct platelet function was performed on the basis of ASPI test values and on the comparison of ROTEM values related to blood clot strength (a total of 20 subjects received the drug after surgery).

In order to reduce the amount of blood loss and blood transfusions required during and after cardiac surgery, it is important that antiplatelet drugs such as acetylsalicylic acid and clopidogrel, routinely prescribed for patients before cardiac surgery, especially those undergoing surgical myocardial revascularization, are suspended before surgery. There is no precise information when to and on what day antiplatelet medication should be discontinued in order to obtain the most optimal results in terms of reducing postoperative drainage and the need for reimbursement of blood and blood derivatives (14). However, the literature data show that discontinuation of antiplatelet medication 2 days before cardiac surgery results in a significant reduction in the need for reimbursement of platelets (15).

The connection between discontinuation of antiplatelet drugs, and preoperative Multiplate and ROTEM values and major adverse cardiovascular and cerebral prothrombotic events could not be demonstrated, which is in agreement with the results obtained in our study.

Thromboelastography is a dynamic qualitative and quantitative assessment of clot formation that consists of three stages: clot initiation, clot strength, and clot stability (fibrinolysis). Performing thromboelastography using ROTEM is very useful, but it does not eliminate the need for other POC techniques that allow the evaluation of platelet function (e.g., Aggregometry-Multiplate), all of which are incorporated into numerous algorithms that are constantly being modified and developed (16, 17).

Despite the improvements made with existing new techniques, most surgeons are still inclined to accept a significant amount of blood loss as a characteristic of cardiac surgery. The research conducted at our institution also indicates that only 9% of patients had an average postoperative drainage loss of more than 1000ml, primarily due to the timely administration of so-called hemostatic agents. Targeted hemostasis therapies are guided by point of care devices for testing hemostasis.

It is very important to ensure adequate drainage and removal of blood from the pericardium and pleura cavity (it has high fibrinolytic activity and tissue coagulation factor). Removing this blood and clot probably not only reduces the chance of excessive blood loss by preventing systemic coagulopathy, but also has beneficial effects on several other factors associated with surgery, such as inflammation, atrial fibrillation, pericardial effusions (tamponade), and development of adjuncts (18). Our results indicate that no patients with pathological hyperfibrinolysis were registered as a result of early administration of anti-fibrinolytic-tranexamic acid at a dose of 1000mg immediately after the sternotomy.

After careful evaluation, hemodilution appears to be the most prominent factor associated with the development of coagulopathy after cardiac surgery, and probably plays an important role in the onset of blood loss after cardiac surgery (19). Prothrombin Complex Concentrate (PCC) is a hemostasis agent used for vitamin K dependent coagulation factor deficiency (II, VII, IX, X), which occurs especially in dilution coagulopathy during and after cardiac surgery. The advantage is on the PCC side compared to the plasma. There is currently no consensus on the dosage and timing of PCC administration, and the increased risk of thromboembolic complication must always be balanced for PCC administration. Three patients in this study received an average PCC dose of 1000 IU postoperatively because of the deficiency of these factors, which was registered by the CT extem parameter 100 ≥ s on ROTEM, as well as the values of prothrombin time or INR over 5.

Fibrinogen is one of the most important coagulation factors and it is possible for the clotting process to fall below a critical level during hemodilution, so care should be taken when it is necessary to administer fibrinogen concentrate (20). Since we did not possess fibrinogen concentrate following the FIBTEM test on ROTEM, and especially the clot amplitude after 10 min (A10), each of 13 patients received an average of 15 doses of cryoprecipitate early postoperatively (3 h after intervention).

Fibrinogen is an acute-phase protein whose level gradually increases during and after surgery in response to surgical trauma and the use of extracorporeal circulation. Increased concentrations of D-dimer and prothrombin fragment 1 + 2, together with increased thrombin production, indicate that the hypercoagulable state develops up to 5 days after cardiac surgery. The interaction of these two factors (hypercoagulable state and administration of fibrinogen concentrate) may increase the risk of thromboembolic complications in the postoperative period. Therefore, adequate anticoagulant and/or antiaggregation therapy to prevent the occurrence of thromboembolic complications in the postoperative course is required, especially in patients not receiving vitamin K antagonists, even in patients without prior bleeding. The delicate balance between bleeding tendency and hypercoagulable state must be maintained.

Point of care coagulation management with ROTEM and impedance aggregometry is now often used to determine first-line therapy with specific coagulation factor concentrates such as fibrinogen concentrates and prothrombin complex concentrates (PCC).

Roberts HR and colleagues published the results of a prospective randomized trial aimed at studying the effects of hemostatic therapy, guided by either conventional coagulation analysis or POC testing, in cardiac surgery patients (21). Patients diagnosed with diffuse bleeding after heparin reversal or increased blood loss for the first 24 hours were included and randomized to the POC group. The hemostatic therapy algorithms in combination with POC testing reduced the number of erythrocyte transfusion units compared with conventional laboratory coagulation testing. Moreover, POC-guided therapy was associated with decreased use of fresh frozen plasma (FFP) and platelet concentration and cost, as well as improved clinical outcome.

The use of POC evaluation can provide a faster and more complete insight into this delicate balance, creating a more individualized, patient-centered treatment. The wide variation in the patient's sensitivity to the use of clopidogrel, often produces very different individual results before surgery, necessitating the continued use and determination of POC before, during and after cardiac surgery. A patient-centered, individual approach can help reduce perioperative and postoperative blood loss and minimize the need for transfusion.

Conclusion

Due to the complexity and duration of cardiac surgery procedure, hemostatic changes occur in patients undergoing CABG. Moreover, other hemostatic abnormalities may already be detected in patients preoperatively due to their type of disease and/or their pharmacological treatments (oral anticoagulants, antiplatelet aggregation drugs).

Because of all of the above, it is a priority to diagnose the most common coagulation disorders in patients undergoing surgical myocardial revascularization and to choose appropriate hemostatic therapy to timely manage coagulation disorders in cardiac patients.

In this context, the most common disorders of the hemostatic system in this study were diagnosed with preoperatively and postoperatively impaired platelet function (up to 31% of patients), impaired activity and concentrations of extrinsic coagulation factors postoperatively (21% of patients), impaired activity and concentrations of intrinsic coagulation factors (23% of patients after surgery) and impaired concentration of functional fibrinogen and impaired polymerization of fibrin clot in 17% of patients after surgery. Described disorders resulted in bleeding which, in an extreme case, can cause a lethal outcome.

Of particular clinical importance are the devices for POC testing of the hemostatic system, which allow for the correct and timely diagnosis of these disorders of coagulation, the prediction of possible bleeding that has not yet manifested clinically, and the choice of targeted hemostatic therapy that will prevent or stop the bleeding. Due to laboratory and clinical detection of hemostatic disorders recorded during the study, 13% of patients received cryoprecipitate transfusion after surgery, 10% of patients received frozen fresh plasma, 22% were transfused with platelet concentrates, 20% of patients received desmopressin acetate, while 3 patients received prothrombin complex concentrate in postoperative flow. It should be noted that 20% of patients received transfusion of resuspended erythrocytes (an average of 1 unit) after cardiac surgery, and all operated patients received autologous transfusion of their own blood through the intraoperative blood salvage device during the intervention.

Because of all this, only 9% of surgery patients had drainage greater than 1L within the first 24 hours of surgery, with no consequent complications regarding surgical reintervention.

Thanks to the described protocols of the POC application of coagulation system testing, the speed of the tests themselves, and rapid clinical decisions regarding hemostatic therapy, the mortality rate of operated patients included in the study was about 1% (not due to hemostatic disorders), which ranks among the world's eminent institutions that deal with cardiac surgery.

Modern methods combined with proven clinical protocols, extensive clinical experience of staff, respecting the principle "time is life", enables the best possible care for patients with detected hemostatic disorder in cardiac surgery.

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MONITORING POREMEĆAJA HEMOSTAZE U KARDIOHIRURGIJI

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Krvarenje tokom i posle ugradnje kardiopulmonalnog bajpasa je multifaktorijalna i potencijalno letalna komplikacija. Zato je jedan od najtežih zadataka u kardiohirurgiji uspostavljanje pravovremene, fiziološke hemostaze.

Cilj ovog istraživanja bio je dijagnostikovati najčešće poremećaje koagulacije kod bolesnika koji su podvrgnuti hirurškoj revaskularizaciji miokarda (njihovu učestalost, prateće komplikacije) i terapijsko zbrinjavanje istih. U prospektivno istraživanje uključeno je 100 ispitanika (22 osobe ženskog pola - 22% i 78 muških ispitanika – 78%), koji su bili podvrgnuti jednostrukoj, dvostrukoj i trostrukoj hirurškoj revaskularizaciji miokarda. Preoperativno, kao i tri sata i 24 sata postoperativno, određivani su sledeći parametri: krvna slika, koagulacioni status, parametri funkcije trombocita, parametri rotacione trombolastometrije, upotreba krvi i produkata krvi, upotreba sintetskih hemostaznih agenasa. Najčešći dijagnostifikovani poremećaji hemostaznog sistema su preoperativno i postoperativno poremećena funkcija trombocita (do 31% bolesnika), poremećaj aktivnosti i koncentracije faktora spoljašnjeg puta koagulacije postoperativno (21% bolesnika), poremećaj aktivnosti i koncentracije faktora unutrašnjeg puta koagulacije (23% bolesnika posle operacije) i poremećena koncentracija funkcionalnog fibrinogena i poremećena polimerizacija fibrinskog ugruška kod 17% bolesnika posle hirurške intervencije. Tokom istraživanja, 13% bolesnika je primilo transfuziju krioprecipitata posle operacije, 10% bolesnika je primilo zamrznutu svežu plazmu, 22% je transfundovano koncentratima trombocita, 20% bolesnika je dobijalo dezmopresin-acetat, dok su tri bolesnika primila koncentrat protrombinskog kompleksa u postoperativnom toku.

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Ključne reči: *kardiohirurgija, hemostaza, krvarenje*