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Klinik Çalışma

Coagulation Effects of Hydroxyethylstarch Versus Modified Fluid Gelatin When Used as Normovolemic Hemodilution Solutions During Cardiac Surgery

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SUMMARY

Objective: *The aim of this study to examine the effects of hydroxyethyl starch and gelatin solutions used for acute normovolemic hemodilution on coagulation during coronary artery bypass surgery.*

Material and Method: *Seventy-two patients undergoing elective coronary artery bypass graft surgery randomly received no hemodilution (control), or 6% HES 200/0.5 (n=24) or 4% gelatin solution (n=24) for acute normovolemic hemodilution before cardiopulmonary bypass. Thromboelastography parameters were measured before (T0) and after (T1) acute normovolemic hemodilution, and one (T2) and four (T3) hours after separation from CPB.*

Results: *The R (reaction) time in HES was significantly longer than in controls at T(2) (p=0.03). The K (coagulation) values in group HES and GEL were significantly longer than in controls at T(2) and T(3) (p=0.02 and 0.03, respectively). Rapidity of clot formation (alpha angle) was significantly smaller in HES and GEL compared to controls (p=0.01 and p=0.02, respectively). Maximum amplitudes in HES and GEL were not significantly different than controls at T(2) (p=0.3 and 0.9, respectively). At T2, three patients in GEL (but none in HES) showed clotlysis at 30 min (p=0.1). GEL and HES received fewer units of erythrocyts compared to controls(p<0.001); however, use of fresh frozen plasma was not significantly different than in controls. Mediastinal blood loss was greater in group HES than in controls (p<0.05).*

Conclusion: *Performing acute normovolemic hemodilution with HES and GEL solutions caused significant change in coagulation state by thromboelastography, reduced the need for errytrocyt. Regarding the increase in mediastinal chest drainage, we concluded that HES may not be safety in patients undergoing coronary surgery.*

Key words: *hydroxyethyl starch, gelatin, thromboelastography, coronary surgery*

ÖZET

Koroner Arter Baypas Cerrahisi Sırasında Akut Normovolemik Hemodilüsyon Sıvısı Olarak Kullanılan Hidroksietil Starch ve Modifiye Sıvı Jelatinin Koagulasyon Etkileri

Amaç: *Bu çalışmanın amacı, koroner arter baypas cerrahisi sırasında akut normovolemik hemodilüsyon için kullanılan hidroksietil starch ve gelofusin sıvılarının koagulasyon üzerine etkilerini araştırmaktır.*

Gereç ve Yöntem: *Elektif koroner arter baypas greft cerrahisi geçiren 72 hasta, randomize olarak, hemodilüsyonsuz (kontrol) veya kardiyopulmoner baypas öncesi akut normovolemik hemodilüsyon için; 6% HES 200/0.5 (n=24) veya 4% jelatin solüsyonu (n=24) sıvılarını aldılar. Thromboelastografi parametreleri, akut normovolemik hemodilüsyon öncesi (T0) ve sonrası (T1) ve kardiyopulmoner baypastan ayrıldıktan sonra bir (T2) ve 4. (T3) saatlerde ölçüldü.*

Bulgular: *HES grubunda R (reaksiyon) zamanı T(2)'de, kontrol grubundakinden anlamlı olarak daha uzundu (p=0.03). HES ve GEL grubunda K (koagulasyon) değeri T(2) ve T(3)'de, kontrollerdekinden anlamlı olarak daha uzun idi (sırası ile p=0.02 ve 0.03). Pıhtı oluşum hızı (alfa açısı), HES ve GEL grubunda, kontrollerdekinden anlamlı olarak daha küçüktü (sırası ile p=0.01 ve p=0.02). HES ve GEL grubunda maximum amplitude T(2)'de, kontrollerdekinden olarak farklı değildi (sırası ile, p=0.3 and 0.9). GEL grubunda 3 hasta (HES de hiçbiri) T(2)'de, 30. dakikada pıhtı lizisi gösterdi (p=0.1). GEL ve HES, kontrolle karşılaştırıldığında daha az ünite eritrosit aldı (p<0.001). Mediyastinal kan kayıpları, HES grubunda kontrollerdekinden daha fazlaydı (p<0.05).*

Sonuç: *HES ve GEL ile akut normovolemik hemodilüsyon uygulaması, tromboelastogram ile koagulasyonda anlamlı değişikliklere neden oldu, eritrosit gereksinimini azalttı. Mediyastinal göğüs direnajını artırması ile HES 200/0.5 in koroner cerrahisi geçiren hastalarda, güvenli olmayabileceği sonucuna vardık.*

Anahtar kelimeler: *hidroksietil starch, gelatin, tromboelastografi, koroner cerrahi*

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INTRODUCTION

Dilutional coagulation dysfunction during cardiopulmonary bypass (CPB) due to priming of the CPB system is of major concern in cardiopulmonary bypass

surgery with resultant decreased levels of platelets, fibrinogen and clotting factors like antithrombin and plasminogen [1,2]. Acute normovolemic hemodilution (ANH) is related to self-donation, and develops at the beginning of the operation and re-transfusion of the donated blood at the end of the surgery, with the Intention of volume replacement to maintain normovolemia. ANH avoids exposure to allogenic blood products and ensures transfusion of whole blood back to the patient, without using fractionational blood [3-5]. During ANH, colloidal fluids given to expand plasma volume may alter coagulation through their effect on specific factors and platelets, and/or through a dilutional effect [6-9].

The aim of the study was to examine the effects on different replacement fluids used for acute normovolemic hemodilution in patients undergoing coronary artery surgery on coagulation using thromboelastographic (TEG) tests.

MATERIAL and METHODS

This prospective randomized study was approved by our university's clinical research ethics committee (0209/6.2009). Patients scheduled for elective primary CABG with CPB were enrolled in the study. Patients who gave their written informed consents were included in the study.Those with any of the following were excluded from the study:haemoglobin <13.0 g. dL-1, abnormal coagulation profile, preoperative left ventricular ejection fraction <40%, creatinine >1.5 mg. dL-1, abnormal liver function, allergy to study fluids, continued use of anticoagulation medications or ε-aminocaproic acid, or hemodynamic instability.

Aspirin and clopidogrel were discontinued one week before the surgery. The patient's usual medications were administered on the morning of the procedure. On the morning of the surgery, patients were randomly allocated to one of three groups: a colloid group (HES or gelatin) for acute normovolemic hemodilution, or a control group (ANH was not performed in these patients). Group HES received 6% HES 200/0.5 (HES Steril®, 6%,average molecule weight of 200,000 daltons, molar substitution ratio of 0.5; Fresenius Kabi, Bad Homburg, Germany) and Group GEL received 4% modified gelatin solution (Gelofusine®, MW 30,000 daltons, B.Braun, Melsungen, Germany). Controls (CON) did not undergo acute normovolemic hemodilution, but were given only a balanced electrolyte solution (Isolyte S®, Eczacıbaşı-Baxter,Istanbul, Turkey) as a maintenance fluid.

All patients were induced with etomidate (0.2 mg. kg^{-1}), fentanyl (3 μg kg^{-1}), and rocuronium (0.6 mg. kg^{-1}), followed by maintenance with sevoflurane and continuous fentanyl infusion (3-5 μg kg^{-1} hr^{-1}) for general anesthesia. The priming solution included Ringer´s lactate and mannitol without colloids. Non-heparin-coated circuits were utilized for CPB. Moderate hypothermia (28–32°C) and non-pulsatile flow were maintained throughout CPB. The rest of the operation was completed in a standard fashion. Perioperative anticoagulation was performed with 300 units kg^{-1} IV standard heparin and was monitored with repeated analyses of activated clotting time, which were kept over 450 seconds during CPB. Anticoagulation was reversed with protamine sulfate (1 mg per 100 units of heparin administered).

In the perioperative period, crystalloid (Isolyte S®) solution was infused (8 mL kg^{-1} h^{-1} during surgery and 2 mL kg^{-1} h^{-1} after surgery) to all patients. Postoperatively, upon arrival to the cardiac surgical ICU, all patients were routinely given an additional 500 mL of their study fluid (HES or GEL) over 30 minutes.

At this point, controls were randomly given gelofusine or HES. Volume replacement was performed according to routine intra- and postoperative care guidelines aimed at maintaining adequate filling pressures (CVP near baseline values) and diuresis of >0.5 m L kg^{-1} h^{-1}.

In the HES and GEL groups, blood for ANH was withdrawn through a central venous line after induction of anesthesia [10]. Target hematocrit level was 35% after withdrawal of blood. The same volume was simultaneously replaced by HES or GEL. The withdrawn blood was preserved at room temperature and re-transfused immediately after weaning from CPB and heparin neutralization.

Erythrocyte (PRBC) transfusion was performed during CPB if the hemotocrit level decreased to less than 18%, and perioperatively and postoperatively if the hemotocrit level decreased to less than 25 percent.

In patients who might not tolerate significant anemia (eg. elderly), higher hemotocrit levels were targeted (30-35%). Blood products (fresh frozen plasma and platelets) were given based on a modified version of the TEG-based transfusion algorithm proposed by Royston and Kier [11]. TEG analyses in all groups were studied at the following time points:before induction of anaesthesia (T0), after acute normovolemic hemodilution (T1) (or, in controls, about one hour after induction, before CPB), 1 hour post-CPB (just before leaving the operating room, T2), and 4 hours post-CPB (T3).

TEG was performed with a thromboelastograph (Model 5000®, Haemoscope Corp., Los Angeles, USA) using 1% celite activation. All blood samples were tested by TEG within 3 minutes of patient sampling [12]. Automatic TEG variables were: time of the initial clot formation (reaction time = R, normal value 1-4 min), fibrin formation kinetics (clot formation time = K, normal value 4-8 min), rapidity of clotting formation (α angle, normal value 54-67°), clot strength of the thrombin-generated clot (maximum amplitude = MA, normal value 59-68 mm), and fibrinolysis 30 minutes after clot formation (clot lysis= CL30, normal value <7.5%). R reflects the function of intrinsic and extrinsic coagulation factors. K is influenced not only by coagulation factors but also by fibrinogen and the number and function of platelets. The K and α angle parameters give an indication of clot strength and firmness, and depend mainly on clotting factors. MA reflects clot stability and represents the degree of platelet contribution to clot strength through platelet-fibrin bonding.

Excessive postoperative blood loss was defined as blood loss from mediastinal chest drains of over 400 mL in the first hour after surgery or over 100 mL/hour for 4 consecutive hours. Durations of CPB and aortic cross-clamping, amount of mediastinal chest drainage, and amounts of homologous blood and blood products transfused intraoperatively and in the first 4 hours postoperatively were recorded.

Statistical analysis

Data analysis was performed using Statistics for Windows® v6.0 (Stat Soft Inc., Tulsa, USA). A pre-hoc power analysis (two-way ANOVA test) revealed that a power of 0.84 would be achieved at an α level of 0.05 with 24 patients in each group, in order to demonstrate a 20% difference in mean R values between the groups. Student t test was used for intergroup comparisons of descriptive statistics. Since the data were normally distributed (Kolmogorov–Smirnov test), between- and within-group analysis of TEG® parameters were performed with repeated measurements of ANOVA test. Post-hoc comparisons were performed by Tukey's HSD test. Fisher exact or chi-square tests were utilized for comparisons of categorical variables. A p value of less than 0.05 was considered statistically significant. The statistician responsible for data management and statistical analysis was blinded to the study group assignment.

RESULTS

Seventy-two patients (24 patients in each group) were enrolled and all completed the study according to the protocol. Demographic and clinical characteristics of study population, all TEG parameters are given in Tables 1, and 2, respectively. Compared to controls, R time was not affected by haemodilution in Group GEL (p=0.4) but it was increased in Group HES(p=0.03). Compared to controls, K time was higher in both HES and GEL groups (p=0.02 and, p=0.03, respectively). Compared to controls, the α angle was significantly smaller in HES and GEL groups (p=0.01 and p=0.02, respectively). Compared to controls, MA values were not significantly different in HES and GEL groups (p=0.3 and p=0.9, respectively). Besides the difference in R mentioned above, no other TEG parameter was significantly different between the HES and GEL groups.

Regarding within-group comparisons, in none of the groups a difference in TEG parameters was found between baseline (T0) and after acute normovolemic hemodilution (T1). However, in Group HES, R time was significantly longer at one hour after weaning from CPB (T2) and four hours after weaning from CPB (T3) compared to baseline (T0). K time at T(2) in Group HES and Group GEL was significantly longer than in controls. The α angle (clot formation rate) in all groups was lower after weaning from CPB (T2) compared to baseline, but this decrease was only significant in Group HES and Group GEL at T2.

Table 1. Demographic and peri-operative details.

	Controls n=24	Group HES n=24	Group GEL n=24
Age (years)	60.3±11.5	64.3±13.2	60.1±8.9
Gender (M/F)	16/4	18/6	20/4
BSA (m^2)	1.8±0.2	1.8±0.2	1.8±0.1
Euro Score	5.1±0.1	5.1±1.5	4.9±1.5
Ejection fraction (%)	47±5.7	51±6.3	55±5.6
AoX (min)	38±12	42±17	42±14
CPB time (min)	62±18	69±21	70±18
Operation time (min)	211±33	219±42.8	211.5±35.4
Comorbid diseases			
Hypertension (n)	17	18	18
COPD (n)	5	6	4
Diabetes mellitus (n)	5	4	6
Preoperative platelet count (x109 $litre^{-1}$)	243±58	239±55	223±61
Preoperative PTT (seconds)	12.6±1.3	12.1±0.9	12.5±1.2
Preoperative APTT (seconds)	34.5±2.8	32.5±2.4	33.5±2.1
Intraoperative inotrope usage (n)	19	18	19
Postoperative inotrope usage (n)	14	14	12

In contrast, MA was not significantly different from baseline in all groups at any time point in the study period. Increased CL30, compared to baseline, occurred in 3 GEL patients at T2. Excessive hemorrhage was experienced in only one patient who was given 1.5 g of tranexamic acid. The others required no treatment.

The intraoperative course in all patients was uneventful. Significantly fewer patients in Groups GEL and HES received intra- and/or post-operative erythrocyte transfusions compared to controls ($p<0.001$). The number of patients requiring FFP in the postoperative period was not significantly different between groups (Table 3). Excessive hemorrhage was experienced by two GEL, and four HES patients, but none required surgical re-exploration. In Group HES one

Table 2. Thrombelastograph values.

	Groups	Baseline (T0)	After ANH (T1)	1 hr after CPB (T2)	4 hrs after CPB (T3)	p
R time (min.)	CON (n=24)	8.4±4.0	8.8 ±3.3	9.2±3.4	7.3±2.0	&<0.001
	HES (n=24)	9.0±3.8	10.7±7.4	14.7±5.2*	10.3±3.7	&<0.001 Ω0.03
	GEL (n=24)	9.5±3.3	11.6±3.2	12.7±2.8	11.0±7.3	&<0.001 Ω0.4 £0.1
K (min.)	CON (n=24)	3.9±2.0	3.9±1.7	3.6±1.4	3.1±1.3	&<0.001
	HES (n=24)	4.0±1.2	4.4±1.9	5.9±0.2*$€	4.4±2.1	&<0.001 Ω0.02
	GEL (n=24)	3.8±2.0	4.3±2.6	5.1±2.9*	5.0±2.1	&<0.01 Ω0.03 £0.6
α angle (degrees)	CON (n=24)	52.8±13.2	54.7±14.7	44.5±13.4	55.3 ±8.5	&<0.001
	HES (n=24)	54.1±13.6	44.1±11.8	32.8±14.1*$€	45.3±6.8	&<0.001 Ω0.01
	GEL (n=24)	51.9±11.5	46.1 ±14.3	39.9± 10.1*	43.6±9.7	&<0.001 Ω0.02 £0.7
MA (mm)	CON (n=24)	65.1±11.3	64.2±10.9	66.9±6.5	69.1±9.6	&<0.001
	HES (n=24)	65.9±11.7	59.8±10.1	59.6±8.9	58.9±7.1	&<0.001 Ω0.3
	GEL (n=24)	65.5±10.3	60.6±9.3	61.2±6.8	60.9±9.2	&<0.001 Ω0.1 £0.9

Data are mean±SD. CON: control group (no hemodilution was used); HES: acute normovolemic hemodilution with 6% hydroxyethylstarch 200/0.4; GEL acute normovolemic hemodilution with 4% gelatin. Repeated measures of ANOVA test: &Within group comparison, ΩCompared to controls; £Compared to Group HES.

*Post-hoc comparisons by Tukey's HSD test: *P<0.05 compared with baseline values; $P<0.05 compared with T3, at 4 hrs after CPB; €p<0.01 compared to controls. R = reaction time; K=coagulation time; MA=maximum amplitude; min = minutes;*

Table 3. Perioperative fluid requirements, urine output, and use of blood and blood products.

	Controls n=24	Group HES n=24	Group GEL n=24
Intraoperative crystalloid (mL)	2635±498	2535±670	2362±460
Intraoperative colloid (mL)	N/A	595±72.6	642±63.4
Postoperative crystalloid in the first 4 hrs. (mL)	1390±128	1140±330	1172±158
Postoperative colloid in the first 4 hrs. (mL)	574±69.1	525±71.6	610±92.8
Intraoperative urine output (mL)	1274±305	1540±610	1371±420
Postoperative urine output in the first 4 hrs. (mL)	1322±316	1600±221	1465±242
Post-CPB pRBC (in first 4 hrs)			
none (n)	6	14*	16Ω
1 unit (n)	14	6*	6Ω
>1 unit (n)	16	4	3
Perioperative FFP (in first 4 hrs)			
none (n)	5	4	4
1 unit (n)	16	16	18
>1 unit (n)	2	4	1
Intraoperative blood loss (mL)	560±229	582±161	603±111
Mediastinal drainage in the first 4 hours (mL)	191±84	293±143*	226±78£

Data are mean±SD. CON: control group (no hemodilution was used); HES: acute normovolemic haemodilution with %6 hydroxyethylstarch 200/0.4; GEL acute normovolemic haemodilution with 4% gelatin. pRBC: packed red blood cells. FFP: fresh frozen plasma.
*Significant p<0.05 by student's t test for perioperative fluid in and output. *Controls vs Group HES, ΩControls vs Group GEL, £Group HES vs Group GEL.*
*Significant p<0.05 by Fischer exact two-tailed test for blood and blood products. *Controls vs Group HES, ΩControls vs Group GEL, £Group HES vs Group GEL.*

Table 4. Hemoglobin levels, platelet counts and coagulation parameters.

	Groups	Baseline (T0)	After ANH (T1)	1 hr after CPB (T2)	4 hrs after CPB (T3)	p
Hemoglobin (g dL-1)	CON (n=24)	13.7±0.8	11.2±0.3	8.2±0.1*	8.7±0.2$	&<0.01
	HES (n=24)	13.8±0.7	10.1±0.5	8.7±0.3*	9.0±0.1$	&<0.001 Ω 0.1
	GEL (n=24)	13.7±0.5	10.5±0.2	8.7±0.1*	9.2±0.1$	&<0.001 Ω 0.3 £0.1
Platelets (103 μL–1)	CON (n=24)	243±58	208±52	162±30*	198±65$	&<0.001
	HES (n=24)	239±55	209±50	185±39*	211±61$	&<0.01 Ω 0.4 * 0.3
	GEL (n=24)	223±61	209±52	162±32*	199±65$	&<0.001 Ω 0.4 £0.6
Protrombin time (seconds)	CON (n=24)	12.6±1.3	13.2±1.5	14.3±1.1	14.2±2.3	&<0.01
	HES (n=24)	12.9± 0.9	13.9±1.5	15.5±1.5*	14.6±1.0	&<0.01 Ω 0.02
	GEL (n=24)	12.5±1.2	13.2±2.4	15.1±1.0*	14.4±1.1	&<0.01 Ω 0.04 £0.5
Activated partial thromboplastin time (seconds)	CON (n=24)	34.5±2.8	30.8±3.4	32.5±1.1	33.7±5.3	&<0.001
	HES (n=24)	32.5±2.4	33.4±1.9	37.8±1.0*	35.5±5.0$	&<0.001 Ω 0.03
	GEL (n=24)	33.5±2.1	32.8±1.5	35.3±2.1*	34.6±1.3	&<0.001 Ω0.04 £ 0.2

Data are mean±SD. CON: control group (no hemodilution was used); HES: acute normovolemic hemodilution with 6% hydroxyethyl starch 200/0.4; GEL acute normovolemic hemodilution with 4% gelatin.
Repeated measures of ANOVA test: &Within group comparison, ΩCompared to controls; £Compared to Group HES.
*Post-hoc comparisons by Tukey's HSD test: *P<0.05 compared with baseline values; $P<0.05 compared with T3, at 4 hrs after CPB; €p<0.01 compared to controls.*

patient with a normal TEG had active bleeding that stopped spontaneously. In Group HES one patient had increased CL30 (as mentioned above). The other four patients (two GEL and three HES patients) had prolonged R (>14 minutes) and K times; decreased α angles (compared to baseline). Therefore three units of FFP were given to each patient. No patients received platelet or fibrinogen suspensions. Volumes of mediastinal chest drainage within four hours after CPB were higher in Group HES than Group GEL and controls (Table 3). Hemoglobin and platelet concentrations fell similarly after hemodilution and after CPB in groups (Table 4).

DISCUSSION

The objective of this investigation was to determine whether replacement fluids used for acute normovolemic hemodilution had any influence on post-CPB coagulation disturbances involving the pathway fibrin formation to clot lysis as evaluated by TEG. TEG parameters measured after hemodilution with HES and GEL (T1) were not significantly different from baseline. In-vitro studies have found that as hemodilution with colloids increases, blood changes from hypercoagulable (decreased R time, decreased K time, increased alpha angle compared to normal values) to hypocoagulable state, as measured by TEG parameters [10-16]. When blood was diluted to 20 or 30% by volume with either GEL or HES 200/0.5, coagulation (K) time increased, and rapidity of clot formation (α angle) and clot strength (MA) decreased [10-16]. Although some studies found that HES decreased clot strength more than GEL [14,16], we did not find such a difference. Our difference in results may have been due to our smaller percentage of hemodilution (10%), or to the fact that our patients were also receiving routine maintenance crystalloid fluid intraoperatively (in addition to HES or GEL), or to the fact that our patients were undergoing cardiac surgery (vs. in-vitro studies, or studies in healthy volunteers).

In our study, we examined whether coagulation effects may have been the result of hemodilution with colloid (HES or GEL) solution in comparison with a control group which did not undergo hemodilution. Hemodilution with HES and GEL resulted in similar coagulation parameters, as measured by TEG: both increased coagulation time (K time) and decreased rapidity of clot formation (α angle), and did not affect clot firmness (maximum amplitude) compared to controls. Thus, we found that hemodilution with HES and GEL during CPB for CABG had its most negative effect on clot formation kinetics (K time and α angle). In addition, reaction time (R) was effected more in Group HES than in controls.

Several studies using modified thromboelastometry coagulation analysis (ROTEM) after cardiac surgery found that HES and gelatin solutions given perioperatively in a dose-dependent fashion, prolonged clot formation times (intrinsic and extrinsic), and fibrin formation [6-8]. Decreased maximum clot firmness. Similarly, in-vitro and ex-vivo studies demostrated that colloid administration may critically impair fibrinogen polymerization and reduce fibrinogen concentrations [13-19]. Although administration method of colloids (acute normovolemic hemodilution with colloids instead of colloids being given only in the post-CABG period), and the tool for measuring coagulation parameters were different (TEG vs. ROTEM), our results were similar to theirs (some, but not all parameters were affected by colloid administration).

Fibrinolysis 30 minutes after clot formation occurred only in a small percentage of GEL patients, but in no others. Hemodilution with HES and gelofusine colloids negatively effects coagulation through compromising thrombin-fibrinogen and factor XIII-fibrin polymer interactions [8,20]. Schramko and colleagues emphasized that even when gelatin-induced whole-blood coagulation abnormalities (in-vitro, impairment of fibrin clot firmness) were corrected by fibrinogen, clot strength remains decreased when coagulation is triggered by an activator of the extrinsic coagulation pathway. Thus, administration of fibrinogen alone is not enough to reverse gelatin-related coagulopathy. FFP, which contains fibrinogen as well as other factors, must be given [20].

In contrast to Zisman et al., we found that ANH with either colloid (HES or GEL) resulted in need for transfusion of fewer units of erythrocytes, but similar amounts of FFP, being transfused compared to controls [3]. In prior studies, when HES and gelatin solutions were infused during induction of anesthesia without AHN (as priming fluids) [21,22] and after cardiac surgery [6,7], any intergroup differences regarding

amounts of blood or blood products transfused was not found. On the other hand, some studies found that mediastinal blood loss was higher in HES 200 than GEL patients when these fluids were used for priming and postoperative volume management (maximum total dose was 30±3 mL $kg^{-1}day^{-1}$) [1,6,21,22] . We found that the amounts of postoperative mediastinal chest drainage fluid were higher in HES and GEL groups (used during ANH and beyond) when compared with controls.

At baseline in our patients, R times were higher than values considered normal by the manufacturer in nearly 40% of each group. This finding is similar to that of previous TEG studies, which found that factor deficiency is much more common than platelet-related abnormalities in patients before CPB [23-,24]. On the other hand, Rafiq and colleagues found that all of their CABG patients had an increased maximum amplitude (>69 mm) pre-operatively [25]. Thus, variation in preoperative coagulability of CABG patients may affect the results of studies similar to ours.

CONCLUSIONS

Performing ANH with hydroxyethyl starch and gelofusine solutions in patients undergoing CABG surgery causes significant change in coagulation state as detected by by thromboelastography. ANH with colloid solutions reduced the need for PRBC, but did not change the need for FFP. Regarding the increase in mediastinal chest drainage, we concluded that acute normovolemic hemodilution with HES 200/0.4 may not be a safe procedure in CABG patients.

Declaration of conflicting interests

The authors declared no conflicts of interest with respect to the authorship and/or publication of this article.

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