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Evaluation of perioperative coagulation in patients undergoing brain and spine surgery

Beyin ve omurga cerrahisi geçiren hastalarda perioperatif koagülasyonun değerlendirilmesi

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ABSTRACT

Aim: Conditions during brain and spine surgery, such as trauma, surgery, general anesthesia, fluid infusions, hypothermia, and patient inactivity, may lead to coagulation disorders, increasing the risk of bleeding or thrombosis. This study aimed to evaluate the relationship between thromboelastography (TEG), coagulation, and perioperative transfusion.

Materials and Methods: In 2012, 58 adult ASA I–III patients undergoing brain and spine surgery were prospectively included after obtaining ethics committee approval and patient consent. Patients with coagulopathy or anticoagulants were excluded. Fluid requirements were managed with balanced crystalloids, and selected patients were randomly administered 6% hydroxyethyl starch or 4% gelatin solutions. Coagulation was monitored preoperatively, at the end of surgery, and 24 hours postoperatively using TEG and standard coagulation parameters.

Results: The mean age of the patients was 46.7 years, the mean BMI was 27.7, and 62.1% were female. Eleven patients (18.9%) required an average of 6.1 (±4.1) mL/kg erythrocyte transfusion. Transfused patients had longer operative times (p=0.022), anesthesia durations (p=0.014), total fluid requirements (p<0.001), and crystalloid infusions (p=0.039). TEG data revealed no coagulation abnormalities causing clinical bleeding. However, postoperative Maximum Amplitude (MA) significantly increased in both groups. MA showed a positive correlation with age (r=0.27, p=0.039) and crystalloid volume (r=0.29, p=0.027), and a negative correlation with the lowest temperature (r=-0.28, p=0.029). Coagulation Index (CI) was positively correlated with preoperative fibrinogen levels (r=0.28, p=0.045).

Conclusion: TEG analysis showed similar coagulation profiles in transfused and non-transfused patients. Before drawing general conclusions about perioperative coagulation, these findings should be compared with studies using restrictive transfusion protocols.

Keywords: Coagulation, thromboelastography, neurosurgery, transfusion

ÖZ

Amaç: *Beyin ve omurga cerrahisi sırasında travma, cerrahi, genel anestezi, sıvı infüzyonları, hipotermi ve hastanın hareketsizliği koagülasyon bozukluklarına yol açarak kanama veya tromboz riski oluşturabilir. Bu çalışmada, tromboelastografi (TEG) kullanılarak koagülasyon, perioperatif kanama ve transfüzyon arasındaki ilişki değerlendirildi.*

Gereç ve Yöntem: *Etik kurul onayı ve hasta onamı alındıktan sonra, 2012 yılında beyin ve omurga cerrahisi geçiren 58 yetişkin ASA I–III hasta prospektif olarak çalışmaya dahil edildi. Koagülopatisi veya antikoagülan kullanan hastalar dışlandı. Sıvı ihtiyacı dengeli kristalloidlerle karşılandı; rastgele seçilen hastalarda %6 hidroksietil-starch veya %4 jelatin solüsyonları kullanıldı.*

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Koagülasyon, cerrahi öncesinde, sonunda ve 24 saat sonrasında TEG ve standart koagülasyon parametreleri ile takip edildi.

Bulgular: *Hastaların yaş ortalaması 46,7, BMI ortalaması 27,7 olup %62,1'i kadındı. Transfüzyon gerektiren 11 hastaya ortalama 6,1 (±4,1) mL/kg eritrosit verildi. Bu hastalarda operasyon süresi (p=0,022), anestezi süresi (p=0,014), toplam sıvı (p<0,001) ve kristaloit infüzyon miktarı (p=0,039) daha fazlaydı. TEG verilerine göre klinik kanamaya yol açacak koagülasyon anormalliği saptanmadı. Ancak, her iki grupta da postoperatif Maksimum Amplitüd (MA) anlamlı şekilde arttı. MA, yaş (r=0,27, p=0,039) ve kristaloit miktarı (r=0,29, p=0,027) ile pozitif; en düşük sıcaklık değeri ile negatif (r=-0,28, p=0,029) korelasyon gösterdi. Ayrıca Koagülasyon İndeksi (CI) preoperatif fibrinojen seviyesi ile pozitif korelasyon gösterdi (r=0,28, p=0,045).*

Sonuç *TEG analizleri, transfüzyon yapılan ve yapılmayan hastalarda koagülasyon profillerinin benzer olduğunu ortaya koydu. Perioperatif koagülasyon sürecine ilişkin genel kararlar vermeden önce, sonuçlarımızın restriktif transfüzyon rejimleri uygulanan çalışmalarla karşılaştırılması gerekmektedir.*

Anahtar Sözcükler: *Koagülasyon, nöroşirurji, transfüzyon, tromboelastografi*

INTRODUCTION

Blood transfusion is a common occurrence during spinal surgery—prior studies have shown that anywhere from 6% to 32% of patients undergoing spine surgery require perioperative transfusion. Transfusion requirements for spine surgery patients vary depending on preoperative patient characteristics and surgical parameters (1). The decision to perform a transfusion is primarily influenced by factors such as the patient's age, preoperative hemoglobin levels, the length of surgery, and the surgeon's experience and preferences or factors like hypothermia and fluid infusions (2–6). Blood transfusion during neurosurgery is a typical procedure used to restore blood loss and maintain proper blood pressure and oxygenation of the patient. However, there is a strong relationship between perioperative blood transfusion and worsened outcomes following spine surgery. The authors reviewed that the main indicators for blood transfusions during intracranial meningioma surgery were blood loss and preoperative anemia. Perioperative hemostatic abnormalities can lead to either hemorrhagic or thrombotic complications. Neurosurgical patients are known to be particularly exposed to thromboembolic events, infection and longer hospital stays (1,7). Therefore, distinguishing bleeding due to surgery or coagulation disorders in the perioperative period and recognizing dynamic changes in hemostasis are necessary for safe patient management (4).

Nowadays, thromboelastography (TEG) has become widespread as a very useful and important method in understanding whether perioperative bleeding is caused by coagulation disorder (8,9). In this study, we aimed to evaluate coagulation using TEG in patients undergoing brain and spine surgery with and without transfusion.

MATERIALS AND METHODS

Patient Selection

After the approval of the ethics committee (decision number 11-12/3 dated 18.01.2012) in our prospective, double-blind study, it was decided to include patients between the ages of 18 and 65 who underwent elective brain or spine surgery in the operating room of the Department of Brain and Nerve Surgery within 6 months, who were ASA (The American Society of Anesthesiologists) score I-III, did not have heart, kidney or liver failure, did not have hemorrhagic diathesis, did not have coagulation disorders and were not receiving anticoagulant treatment. During this period, 75 patients were reached. Twelve patients were excluded from the study due to exclusion criteria and 5 patients were not included in the study due to incomplete data. Fifty-eight volunteer patients who met the criteria were accepted into the study. Written consent was obtained from patients (or their legal guardians) stating that their medical data could be published.

Anesthesia Management

In the preoperative period, demographic data of patients (age, gender, weight, height, ASA score, preoperative laboratory data [hemoglobin, hematocrit (Hct), platelet count, fibrinogen level,

prothrombin time, INR and activated partial thromboplastin level]) were recorded.

All patients received inhalation based general anesthesia in combination with opioid and non-depolarizing neuromuscular blockers, with standard ASA monitoring and tracheal intubation. Blood pressure drops were occasionally intervened by titrating ephedrine or noradrenaline to keep the MAP at 65 mmHg and above. Total fluid replacement was performed according to the 4:2:1 rule. Intravenous fluids were determined as balanced crystalloids (Isolyte S®, Eczacıbaşı, İstanbul, Türkiye), 6% hydroxyethyl starch *130/0.4 (Voluven®, Fresenius Co, Bad, Hamburg, Germany)* and 4% succinylated gelatin (Gelofusin®*, B.Braun Co, Melsungen, Germany*). Anesthetic drug dose changes according to the depth of anesthesia and the type and dose selection of intravenous fluids were left to the experience and interpretation of the experienced anesthesiologist. Red Blood Cell (RBC) transfusion was aimed at patients with a hematocrit level below 30% or with 1000 mL or more bleeding during intraoperative period. The Gross Formula was used to calculate the amount of intraoperative bleeding (10).

V_{loss}= BV x (H_o – H_f) H_{AV}

V_{loss} (mL) represents the patient's calculated blood loss, while the patient's total blood volume BV (mL) is determined using the Nadler formula. H_o refers to the patient's preoperative hematocrit value, H_f denotes the postoperative Hct value, and H_{AV} is the average of the preoperative and postoperative Hct values.

All patients were extubated in the operating room at the end of the operation. Intraoperative data including surgical site (brain, spine]) lowest body temperature, lowest hematocrit, total bleeding amount, total fluid volume administered, total crystalloid and colloid volumes, colloid type, blood product transfusion, anesthesia and operation duration were recorded at the end of the operation. Below 36ºC was considered hypothermia.

The patient's coagulation course was evaluated with TEG-Haemoscope 5000 (Thromboelastograph® 5000 coagulation analyser “Haemoscope”, Niles, Illinois, USA) by a physician who was unaware of the simultaneous patients’ clinical course and applications. Blood samples were taken in three periods (preoperative, postoperative 1st and 24th hours) to determine for TEG variables as R (reaction time), K (coagulation time), α (α angle), MA (maximum amplitude), Ly30 (lysis rate) and CI (coagulation index).

In this study, we aimed to evaluate coagulation changes and their relationship with transfusion using thromboelastography (TEG) in patients undergoing cranial and spinal surgery.

Statistical Analysis

Data was evaluated with the SPSS 21.0 program. Mean, standard deviation, ratio, frequency values were used in descriptive statistics of the data. The distribution of variables was checked with the Kolmogorov-Simirnov test. Independent sample t-test and Mann-Whitney U test were used in quantitative data analysis. Paired sample t-test and Wilcoxon test were used in repeated measurements. Pearson and Spearman’s correlation analysis identified the associations between the variables.

RESULTS

Demographic and intraoperative characteristics of patients are shown in (Table-1). The mean age of the patients in the study was 46.8, BMI was 28, the female ratio was 62.1%, and the operation time was 128 minutes. Intraoperative hypothermia (minimum 34.5 ºC) was observed in 77.6% of the patients (45 patients). Eleven (19%) patients required a mean of 6.1 (± 4.1) mL/kg erythrocyte transfusion. Comparing the characteristics of patients with and without transfusion (Table-2). Preoperative Hb (p=0.002), Htc (p=0.003) were lower in the transfused group. Total bleeding was 4.7 ± 3.6 mL/kg in those who were not transfused and 10.4 ± 6.2 mL/kg in those who were transfused (p<0.001). The lowest hematocrit was 27.4 ± 1.9 % in patients with transfusion and 39.8 ± 4 % in those without (p<0.001). The duration of operation (p=0.022), duration of anesthesia (p=0.014), total fluid (p<0.001) and total crystalloid infusion (p=0.039) were higher in patients with transfusion. No coagulation-related blood products were administered to any patient. All patients were extubated in the operating room.

TEG data of patients who received and did not receive erythrocyte transfusion are shown in Table-3. According to these data, no coagulation abnormality that would lead to clinical bleeding was detected. A significant increase was found

only in postoperative MA in both transfused and non-transfused patients.

The relationship between the changes in TEG parameters and perioperative variables is given in Table-4 and Table 5. According to the postoperative TEG data, MA was significantly positively correlated with age and the amount of crystalloid administered (r=0.27, p=0.039 and r=0.29, p=0.027); and negatively correlated with the lowest temperature value (r=-0.28, p=0.029). A significant positive relationship was also found between CI and preoperative fibrinogen levels during this period (r=0.28, p=0.045) (Table-4).

According to the postoperative 24th hour TEG data, R time was negatively correlated with preoperative fibrinogen (r=-0.27, p=0.046); MA was positively correlated with aPTZ (r=0.28, p=0.041); CI was found to be positively correlated with age and fibrinogen level (r=0.27, p=0.043 and r=0.28, p=0.045) (Table-5).

Table-1. Demographic and intraoperative data

		Median (Min-max)	Mean ±SD	N /%	
Age (year)		50 (18-65)	46.8 ± 13.3		
Gender	Male			22	37.9%
	Female			36	62.1%
Weight (kg)		80 (41-110)	78 ± 15		
Height (cm)		165 (150-191)	168 ± 11		
BMI		27.28 (17.06-39.06)	28 ± 5		
Baseline Hemoglobin (g/dL)		13.5 (11-18)	13.4 ± 1.6		
Baseline Hematocrit (%)		39.95 (33-51)	40.3 ± 4.2		
Baseline Platelet count (/10^{-3})		246500 (104000-401000)	260362 ± 69727		
Baseline PT (sec)		11.6 (10-14)	11.6 ± 0.7		
Baseline APTT (sec)		25.4 (18.3-31.0)	25.4 ± 2.4		
Baseline INR		1 (0.9-1.2)	0.98 ± 0.07		
Fibrinogen (mg/dL)		305.5 (158-577)	327 ± 102		
Lowest temperature (ºC)		35.6 (34.5-36.5)	35.6 ± 0.4		
Lowest Intraoperative Hematocrit value (%)		35 (23-49)	35.1 ± 5.3		
Total amount of bleeding (ml/kg)		4.29 (0.66-22.0)	5.8 ± 4.7		
Total fluid volume (mL/kg)		22.41 (11-68)	24.9 ± 11.7		
Amount of crystalloid (mL/kg)		18.97 (10-40)	20 ± 7.3		
Amount of colloid (mL/kg)		3.685 (0-14)	3.8 ± 4.2		
Red Blood Cell (mL/kg)		0 (0-17)	1.15 ± 2.95		
Anesthesia duration (min)		160 (65-330)	160 ± 70		
Operation duration (min)		125 (45-265)	128 ± 63		
ASA score	I			28	48.3%
	II			30	51.7%
Surgery area	Brain			29	50.0%
	Spine			29	50.0%
Colloid type	None			27	46.6%
	4% Gelatine			19	32.8%
	6% HES			12	20.7%
RBC transfusion	No			47	81.0%
	Yes			11	19.0%

BMI, Body Mass Index; PT, prothrombin time; APTT, activated partial thromboplastin time; INR, international normalized ratio; ASA, The American Society of Anesthesiologists; HES, hydroxyethyl starch; RBC, red blood cell

Table-2. The relationship of transfusion with demographic and intraoperative characteristics.

		RBC Transfusion (+) N=11	**RBC Transfusion (-) N=47**	**p value**
Age (year)		51.7 ± 13.6	45.6 ± 13	0.097
Gender	Female	9 (%81.8)	27 (57.4%)	0.138
	Male	2 (%18.2)	20 (42.6%)	
Height	(cm)	162 ± 7	169 ± 11	**0.028***
Weight	(kg)	79 ± 19	78 ± 15	0.841
BMI		29.9 ± 7.3	27 ± 4.7	0.110
ASA	I / II / III	3 / 8 / 0	25 / 22 / 0	0.121
Surgery area	Brain	6	23	0.738
	Spine	5	24	
Anesthesia duration (min)		201 ± 53	150 ± 70	**0.022***
Operation duration (min)		168 ± 47	118 ± 63	**0.014***
Preoperative				
	Hemoglobin (g/dL)	12 ± 1.3	13.7 ± 1.5	**0.002***
	Hematocrit (%)	36.9 ± 3.7	41 ± 3.9	**0.003***
	Platelet (/10^{-3})	260 ± 76	260 ± 69	0.977
	Fibrinogen (mg/dL)	365 ± 164	317 ± 121	0.329
	PT (sec)	11.5 ± 1.5	11.7 ± 0.7	0.584
	INR	0.98 ± 0.1	0.98 ± 0.06	0.679
	APTT (sec)	25 ± 2.5	25.5 ± 2.4	0.524
Intraoperative				
	Lowest temperature (°C)	35.6 ± 0.4	35.6 ± 0.4	0.537
	Lowest Hematocrit (%)	27.4 ± 1.9	39.8 ± 4	**<0,001***
	Total amount of bleeding (mL/kg)	10.4 ± 6.2	4.7 ± 3.6	**<0,001***
	Total fluid and blood volumes (mL/kg)	38 ± 15	22 ± 8.5	**<0,001***
	Total crystalloid (mL/kg)	25 ± 9	19 ± 6.5	**0.039***
	Total colloid (mL/kg)	7 ± 4	3 ± 4	0.546
	HES / Gelatin /None (number of patients)	4 / 6 / 1	8 /13 / 26	0.922
	Total RBC transfusion (mL/kg)	6.1 ± 4.1	-	

BMI (Body Mass Index); PT (Prothrombin time); APTT (Activated partial thromboplastin time); INR (International normalized ratio); ASA (The American Society of Anesthesiologists); HES (H*ydroxyethyl starch); RBC (Red Blood Cells).* p<0.05*

Table-3. Perioperative TEG Data

		Total N=58	RBC Transfusion (+) N = 11	RBC Transfusion (-) N = 47
R (min)	Preoperative	5.6 ± 1.5	5.9 ± 1.5	5.6 ± 1.5
	Postoperative 1st hour	5.5 ± 2	5 ± 1.2	5.6 ± 2.2
	Postoperative 24th hour	5.8 ± 1.6	6 ± 1	5.7 ± 1.7
K (min)	Preoperative	2.4 ± 1.3	2.5 ± 1.5	2.3 ± 1.2
	Postoperative 1st hour	2.5 ± 2	1.8 ± 0.6	2.6 ± 2.1
	Postoperative 24th hour	2.1 ± 1	1.9 ± 1	2 ± 1
Angle (α)°	Preoperative	60 ± 10	59 ± 11	60 ± 10
	Postoperative 1st hour	61 ± 12	64 ± 9	60 ± 13
	Postoperative 24th hour	63 ± 10	63 ± 9	63 ± 10
MA (mm)	Preoperative	59 ± 7	59 ± 8	59 ± 7
	Postoperative 1st hour	58 ± 8	63 ± 9 *	57 ± 7
	Postoperative 24th hour	61 ± 6 *†	61 ± 6	61 ± 6 *†
CI	Preoperative	-0.57 ± 2.6	-0.77 ± 2.9	-0.52 ± 2.6
	Postoperative 1st hour	-0.54 ± 3.5	0.86 ± 1.9	-0.87 ± 3.7

	Postoperative 24th hour	-0.08 ± 2.5	-0.06 ± 2.1	-0.08 ± 2.7
Ly30 (%)	Preoperative	1 ± 1.3	0.52 ± 1.1	1 ± 1.4
	Postoperative 1st hour	0.6 ± 0.9 *	0.21 ± 0.5	0.7 ± 0.9
	Postoperative 24th hour	0.6 ± 0.7	0.49 ± 0.7	1.6 ± 0.7

RBC, Red Blood Cells; R, reaction time; K, coagulation time; (α) alpha angle; MA, maximum amplitude; CI, Coagulation index; LY30, percentage of lysis 30 min after MA.

**Compared to preoperative period, †Compared to postoperative1st hour period, p <0.05*

Table-4. Factors associated with preoperative and postoperative 1st hour TEG change.

		Preoperative/Postoperative 1st hour Change					
		R (min)	K (min)	MA (mm)	Angle α (°)	CI	Ly 30 (%)
Age	r	-0.216	-0.102	0.271	0.174	0.236	-0.046
	p	0.104	0.447	***0.039****	0.191	0.074	0.731
Weight	r	0.042	0.009	0.028	0.039	-0.009	0.049
	p	0.754	0.947	0.837	0.773	0.944	0.714
Height	r	0.081	-0.122	0.175	0.023	0.039	0.125
	p	0.547	0.360	0.188	0.865	0.769	0.351
BMI	r	-0.011	0.100	-0.087	0.025	-0.038	-0.03
	p	0.932	0.457	0.517	0.854	0.776	0.822
Baseline	r	-0.012	0.023	0.058	-0.007	0.004	0.147
Hemoglobin	p	0.928	0.864	0.663	0.958	0.977	0.271
Baseline Hematocrit	r	0.010	0.008	0.080	0.013	0.011	0.113
	p	0.941	0.951	0.551	0.921	0.934	0.397
Baseline Platelet	r	-0.064	-0.062	0.039	0.151	0.097	-0.072
Count	p	0.634	0.646	0.770	0.258	0.467	0.593
Baseline PT	r	-0.016	-0.181	0.02	0.094	0.070	0.181
	p	0.903	0.178	0.882	0.487	0.606	0.178
Baseline APTT	r	-0.084	-0.180	0.054	0.152	0.115	0.01
	p	0.534	0.181	0.688	0.259	0.394	0.939
Baseline INR	r	-0.039	-0.173	0.038	0.142	0.098	0.017
	p	0.772	0.194	0.778	0.287	0.463	0.897
Fibrinogen	r	-0.244	-0.206	0.230	0.24	0.279	0.216
	p	0.082	0.142	0.102	0.087	***0.045****	0.123
Lowest temperature	r	0.085	0.220	-0.287	-0.145	-0.202	0.070
	p	0.527	0.098	***0.029****	0.277	0.129	0.602
Lowest	r	0.073	0.084	-0.107	-0.029	-0.94	0.175
Intraoperative	p	0.586	0.532	0.423	0.832	0.481	0.190
Hematocrit							
Total amount of	r	-0.058	-0.052	0.158	-0.053	0.073	-0.08
bleeding	p	0.668	0.699	0.237	0.692	0.587	0.549
Total fluid volume	r	-0.192	-0.191	0.24	0.088	0.214	-0.082
	p	0.149	0.150	0.07	0.51	0.106	0.541
Amount of	r	-0.149	-0.186	0.291	0.059	0.2	-0.025
crystalloid	p	0.266	0.163	***0.027****	0.661	0.132	0.854
Amount of colloid	r	-0.198	-0.146	0.102	0.120	0.182	-0.19
	p	0.136	0.274	0.447	0.370	0.171	0.154
Red Blood Cell	r	-0.112	-0.092	0.085	0.035	0.095	0.004
Transfusion	p	0.401	0.491	0.525	0.793	0.477	0.976
Anesthesia duration	r	-0.184	-0.142	0.143	0.135	0.187	-0.033
	p	0.166	0.288	0.286	0.312	0.160	0.805
Operation duration	r	-0.196	-0.155	0.140	0.158	0.200	-0.039
	p	0.140	0.247	0.296	0.236	0.133	0.769

R, reaction time; K, coagulation time; (α) alpha angle; MA, maximum amplitude; CI, Coagulation index; LY30, percentage of lysis 30 min after MA, BMI, Body Mass Index; PT, prothrombin time; APTT, activated partial thromboplastin time; INR, international normalized ratio.
Pearson/Spearman correlation; r, Correlation Coefficient; ***p <0.05***

Table-5. Factors associated with postoperative 24th hour TEG change.

		Preoperative/ Postoperative 24th hour Change					
		R (min)	K(min)	MA (mm)	Angle (α)°	CI	Ly 30(%)
Age	r	-0.214	-0.262	0.193	0.229	0.274	0.068
	p	0.117	0.053	0.159	0.093	***0.043****	0.620
Weight	r	-0.175	-0.153	0.203	0.146	0.187	0.141
	p	0.200	0.263	0.137	0.289	0.172	0.303
Height	r	0.029	-0.103	0.260	-0.007	0.060	0.119
	p	0.833	0.454	0.055	0.961	0.664	0.385
BMI	r	-0.194	-0.100	0.053	0.159	0.158	0.079
	p	0.156	0.468	0.701	0.246	0.251	0.565
Baseline	r	0.018	0.077	0.024	-0.063	-0.046	0.008
Hemoglobin	p	0.895	0.578	0.864	0.650	0.736	0.954
Baseline	r	-0.056	-0.029	0.053	0.033	0.045	0.015
hematocrit	p	0.684	0.833	0.701	0.813	0.746	0.912
Baseline platelet	r	-0.193	-0.235	0.027	0.330	0.248	-0.072
count	p	0.158	0.085	0.845	***0.014****	0.068	0.603
Baseline PT	r	0.107	-0.030	0.119	-0.105	-0.055	-0.063
	p	0.440	0.828	0.391	0.451	0.693	0.652
Baseline APTT	r	-0.114	-0.191	0.280	0.193	0.203	0.012
	p	0.411	0.168	***0.041****	0.163	0.142	0.931
Baseline INR	r	0.177	-0.030	0.141	-0.099	-0.072	-0.080
	p	0.195	0.826	0.306	0.474	0.603	0.564
Fibrinogen	r	-0.278	-0.238	0.082	0.246	0.280	0.160
	p	***0.046****	0.089	0.562	0.078	***0.045****	0.258
Lowest	r	0.001	0.001	-0.045	0.004	-0.012	0.093
temperature	p	0.997	0.997	0.746	0.978	0.930	0.501
Perioperative	r	-0.011	0.024	0.040	-0.016	-0.009	0.052
lowest Hematocrit	p	0.936	0.863	0.775	0.907	0.950	0.705
Total amount of	r	-0.083	-0.012	-0.174	0.008	0.004	-0.071
bleeding	p	0.548	0.930	0.205	0.951	0.974	0.606
Total fluid volume	r	-0.053	-0.071	-0.050	0.030	0.035	-0.004
	p	0.699	0.606	0.719	0.828	0.799	0.977
Amount of	r	-0.081	-0.109	0.078	0.055	0.092	0.045
crystalloid	p	0.557	0.427	0.571	0.689	0.505	0.746
Amount of colloid	r	0.050	0.018	-0.158	-0.023	-0.062	-0.152
	p	0.715	0.896	0.249	0.869	0.654	0.267
RBC	r	-0.082	-0.037	-0.168	0.014	-0.001	0.088
	p	0.552	0.790	0.220	0.919	0.994	0.523
Anesthesia	r	-0.179	-0.201	-0.009	0.216	0.180	0.049
duration	p	0.190	0.141	0.947	0.113	0.189	0.722
Operation	r	-0.191	-0.206	0.006	0.227	0.191	0.045
duration	p	0.162	0.132	0.965	0.096	0.162	0.742

R, reaction time; K, coagulation time; (α) alpha angle; MA, maximum amplitude; CI, Coagulation index; LY30, percentage of lysis 30 min after MA, BMI, Body Mass Index; PT, prothrombin time; APTT, activated partial thromboplastin time; INR, international normalized ratio.
Pearson/Spearman correlation; r, Correlation Coefficient; ***p <0.05***

DISCUSSION

In our study, coagulation changes and their relationship with transfusion were evaluated in cranial and spinal surgery cases. It was determined that 18.9% of the patients required erythrocyte transfusion. When the characteristics of the patients who administered transfusion were compared with the patients who did not, it was seen that preoperative hemoglobin and hematocrit levels were lower, the durations of

surgery and anesthesia were longer. They had lower hematocrit measurements simultaneously with more intraoperative bleeding and total fluid requirement. The amount of bleeding and low hematocrit levels, based on the determined transfusion threshold, were the main reasons for transfusion in these patients. However, as the primary objective of our study, no significant change was found when TEG data of patients requiring transfusion were compared with those not receiving transfusion. In this case, it is not possible to blame coagulation disorders as the cause of bleeding and transfusion in our patients. During surgery, blood transfusion is performed to replace blood loss independent of coagulation. Here, it is important for teams to determine their own transfusion limits and approaches without creating a risk of decreased oxygen delivery to the tissues. In our model, during the study period, due to the logistical conditions of our institution, higher hematocrit levels were targeted compared to the restrictive approach applied today. Although the frequency of transfusion is not high in general, if lower hemoglobin levels were targeted, more patients could have been prevented from receiving transfusion. However, this issue does not change the aim of our study.

The issue that was evaluated in the study was to reveal how perioperative coagulation is affected in patients who underwent brain and neurosurgery. TEG evaluation revealed that coagulation parameters showed a similar profile in both transfused and non-transfused patients. Neither hypocoagulability nor hypercoagulability occurred in any patient. Pearson and Spearman's correlation tests also show that the coagulation of patients is not affected at a clinical level by factors such as preoperative characteristics, intraoperative infusion amount, fluid types, transfusion amount, body temperature and operation time. It should also be acknowledged that continuing surgical interventions in their normal course and without complications may have prevented adverse outcomes by ensuring that the factors remain within controllable limits. It appears that the preoperative fibrinogen level positively affects the postoperative CI, which is an indicator of clot quality. This relationship is not specific to our patients but is expected after most surgeries. Fibrinogen is a natural determinant of the coagulation index (11,12). This positive relationship continued at 24 hours postoperatively. However, it remained within clinical limits.

Overall, TEG evaluation revealed the expected results of surgery on coagulation in our patients. Age is a factor that often leads to increased coagulation (13,14). Although there was no significant difference in age distribution between the two groups, the age factor had a positive effect on clot quality over the postoperative MA and 24th hour CI, but the hypercoagulability limit was not exceeded.

Hypothermia is also a factor known to be the cause of perioperative bleeding. Hushan et al. (15), unlike our study, found that MA and α angle values decreased under the effect of hypothermia and stated that hypothermia decreased platelet aggregation and prolonged reaction and coagulation times. Wenjun Zhou Martini observed in a study on pigs that hypothermia did not cause an increase in the R value, a decrease in the α angle, and a change in MA and Lys 30 values (16). Taggart et al. found in a study on dogs that there was an increase in the K time under 30 ºC, a decrease in the α angle, but no significant change in MA and R times (17). However, in our patient group, hypothermia had no effect on coagulation or transfusion requirements. A negative relationship was detected between postoperative MA and the lowest temperature, but this was not significant enough to cause clinical bleeding.

The choice of colloid for intraoperative fluid replacement is also a factor known to have a negative effect on perioperative coagulation (5,18–20). The use of HES is considered contraindicated in coagulopathic patients due to its potential to exacerbate bleeding risks and impair coagulation. It is not a cause of bleeding or transfusion at the doses used in our study. There is no clear data showing a significant relationship between the amount of colloid used and TEG parameters. A positive relationship was found between MA and crystalloid volume at the end of the operation. This is related to the ability of low hemodilution rates to increase coagulation (19–21).

Boyd CJ et al. (22) stated that low hemodilution causes hypercoagulation and high hemodilution causes hypo coagulation. In our study, it was determined that the crystalloid we used in low volume at the end of the operation increased MA. However, this did not provide a distinction for

patients requiring transfusion. This effect probably disappeared with the removal of crystalloids at the 24th hour postoperatively (23). Although the duration of anesthesia and operation was also longer in cases where transfusion was performed, there was no significant relationship between both parameters and TEG data. In addition, the fact that fibrinolysis was not detected in any patient at the end of the operation or at the 24th hour postoperatively can be interpreted as the development of exposure to excessive coagulation activity.

It is difficult to explain the effect of bleeding during surgery on coagulation. Kenneth JT et al. (24) reported in a study using TEG that progressive blood loss in patients undergoing surgery under general anesthesia increased coagulation. The effects of additional factors such as trauma or similar stressful situations will affect the results. However, since it is not possible to avoid any fluid replacement in a patient who is bleeding during surgery, it is difficult to investigate the effect of isolated blood loss on coagulation. The study conducted by Ruttmann et al. on blood donors is also valuable (25). Blood samples taken from donors at certain intervals after 1 unit of blood was examined in TEG, and while the R period was shortened in the blood taken immediately after the blood was taken, it returned to normal values after 1 hour and did not change afterwards. In our study, RBC replacement was applied to approximately 19% of the patients. Interestingly, the postoperative MA value of this transfusion group, which cannot be considered as having a high transfusion volume, was found to be significantly higher than the preoperative MA value. In contrast, there was no significant increase in postoperative MA in the group that did not receive transfusion, but rather a decrease was observed. It is difficult to attribute the MA increase in those who received transfusion only to transfusion due to the complicated effects of patient characteristics and perioperative surgical conditions on coagulation.

Our study has some limitations. Especially the small number of patients who underwent transfusion, the fact that the team targeted 30% hematocrit levels as a transfusion threshold instead of restrictive transfusion targets may seem restrictive. However, it should be emphasized again that, apart from determining the need for transfusion, since our general aim was to determine the perioperative coagulation profile and the affecting factors in these patients, the number of patients can be considered sufficient to evaluate TEG.

CONCLUSION

In conclusion, no data favoring hypo coagulation or hypercoagulation could be obtained in patients undergoing brain and neurosurgery under normal operating conditions using TEG. We believe that coagulation in these patients is balanced. However, before making a general decision about the course of perioperative coagulation in brain and spinal surgery patients, our results need to be compared with studies in which restrictive transfusion regimens were applied.

Conflict of Interest / (if present): The authors declare that there is no conflict of interest. All authors declare that they contributed to the design, execution, and analysis of the review and approved its final version.

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