

Total Abdominal Histerektomide Eritrosit Süspansiyon Transfüzyonunu Tahmin Etmede Platelet İndekslerinin, Enflamatuvar Belirteçlerin ve Sistemik İmmün-İnflamasyon İndeksinin Değerlendirilmesi: Eşleştirilmiş Kohort Çalışması

Evaluating Platelet Indices, Inflammatory Markers, and the Systemic Immune-Inflammation Index as Predictors of Erythrocyte Suspension Transfusion in Total Abdominal Hysterectomy: A Matched Cohort Study

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ÖZ

Giriş: Total abdominal histerektomi yapılan hastalarda platelet indeksleri, inflamatuvar belirteçler ve Sistemik İmmün-İnflamasyon İndeksi (SII)'nin eritrosit süspansiyonu (ES) transfüzyon ihtiyacını belirlemedeki prediktif rolünü değerlendirmek.

Yöntem: Retrospektif eşleştirilmiş vaka-kontrol çalışmamızda, Ağustos 2020 ile Eylül 2022 arasında benign nedenlerle total abdominal histerektomi yapılan 176 hasta incelendi. Hastalar, yaş ve vücut kitle indeksi (VKİ) esas alınarak 1: 1 oranında transfüzyon alan ve transfüzyon almayan olmak üzere iki gruba ayrıldı. Demografik, klinik, cerrahi özellikler ve laboratuvar bulguları verileri toplandı. Preoperatif hemoglobin (HB) ve SII için ROC analizi ile prediktif eşik değerleri belirlendi. Multivaryant lojistik regresyon analizi, transfüzyon için bağımsız prediktörleri belirlemek amacıyla kullanıldı.

Bulgular: Transfüzyon grubunda preoperatif HB seviyeleri ($10,50 \pm 1,15$ g/dL vs. $12,25 \pm 1,30$ g/dL, $p < 0,001$) anlamlı olarak daha düşük ve SII değerleri ($721,62$ vs. $619,97$, $p = 0,043$) anlamlı olarak daha yüksekti. Preoperatif HB (odds oranı [OR] = $0,302$, $p < 0,001$) ve SII (OR = $1,001$, $p = 0,006$), ES transfüzyonunun bağımsız prediktörleri olarak belirlendi. ROC analizi, preoperatif HB $\leq 11,15$ g/dL'nin %73,9 duyarlılık ve %77,3 özgüllük ($p < 0,001$), SII $\geq 670,62$ 'nin ise %56,8 duyarlılık ve özgüllük ($p = 0,043$) gösterdiğini ortaya koydu.

Sonuç: Preoperatif HB ve SII, total abdominal histerektomi uygulanan hastalarda ES transfüzyonunun güvenilir prediktörleri olarak ortaya çıkmaktadır. Bu belirteçlerin rutin preoperatif değerlendirmelere entegrasyonu, perioperatif kan yönetimini önemli ölçüde iyileştirebilir. Farklı hasta popülasyonlarında ve klinik fazla doğrulama yapılması, bu belirteçlerin etkinliğini doğrulamak ve cerrahi sonuçları optimize etmek için gereklidir.

Anahtar Kelimeler ortamlarda daha: eritrosit süspansiyonu, hemoglobin, histerektomi, inflamatuvar belirteçler, platelet indeksleri, sistemik immün-inflamasyon indeksi, transfüzyon

ABSTRACT

Objective: To evaluate the predictive role of platelet indices, inflammatory markers, and the Systemic Immune-Inflammation Index (SII) in determining the need for erythrocyte suspension (ES) transfusion in patients undergoing total abdominal hysterectomy.

Method: This retrospective matched case-control study analyzed 176 patients who underwent total abdominal hysterectomy for benign indications between August 2020 and September 2022. Patients were categorized into transfusion and non-transfusion groups, matched 1: 1 based on age and body mass index (BMI). Data collection included demographic, clinical, surgical characteristics, and laboratory markers. Receiver operating characteristic (ROC) analysis identified predictive cutoffs for preoperative hemoglobin (HB) and SII. Multivariate logistic regression was used to identify independent predictors of transfusion.

Results: The transfusion group exhibited significantly lower preoperative HB levels (10.50 ± 1.15 g/dL vs. 12.25 ± 1.30 g/dL, $p < 0.001$) and higher SII values (721.62 vs. 619.97 , $p = 0.043$). Preoperative HB (odds ratio [OR] = 0.302 , $p < 0.001$) and SII (OR = 1.001 , $p = 0.006$) were identified as independent predictors of ES transfusion. ROC analysis revealed that preoperative HB ≤ 11.15 g/dL demonstrated a sensitivity of 73.9% and specificity of 77.3% ($p < 0.001$), while SII ≥ 670.62 showed a sensitivity and specificity of 56.8% ($p = 0.043$).

Conclusion: Preoperative HB and SII emerge as reliable predictors for ES transfusion in patients undergoing total abdominal hysterectomy. Integrating these markers into routine preoperative assessments could significantly enhance perioperative blood management. Further validation in diverse patient populations and clinical settings is essential to confirm their utility and optimize surgical outcomes.

Keywords: erythrocyte suspension, hemoglobin, hysterectomy, inflammatory markers, platelet indices, systemic immune-inflammation index, transfusion

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INTRODUCTION

Hysterectomy is one of the most commonly performed gynecological surgeries in the United States, with approximately 400,000 procedures conducted annually. Indications for hysterectomy include uterine fibroids, treatment-resistant abnormal uterine bleeding, adenomyosis, certain gynecological cancers, and chronic pelvic pain (1, 2).

Despite its prevalence, hysterectomy is associated with various complications, including urinary and gastrointestinal system injuries, wound infections, and blood transfusion requirements. Intraoperative bleeding is among the most frequent complications, often necessitating blood transfusions depending on the severity of hemorrhage. Although blood transfusion is generally considered a safe procedure in hospital settings, it carries potential life-threatening risks such as allergic reactions, iron overload, and infections (3). Several risk factors for bleeding during hysterectomy have been identified, including age, African-American race, American Society of Anesthesiologists (ASA) score, preoperative hematocrit levels, platelet count, and bleeding disorders (4). Menstrual irregularities and uterine fibroids also contribute to increased risk for bleeding and transfusion. Therefore, it is crucial to anticipate the potential need for transfusion in patients undergoing hysterectomy (5).

Recent studies have shown that platelet indices (PIs), including platelet count (PLT), plateletcrit (PCT), mean platelet volume (MPV), platelet-large cell ratio (P-LCR), and platelet distribution width (PDW), the neutrophil-to-lymphocyte ratio (NLR), an indirect marker of inflammation, and the Systemic Immune-Inflammation Index (SII = Platelets $\times$ Neutrophils / Lymphocytes) exhibit characteristic changes in various conditions. High SII values are associated with poor outcomes in cancer patients and other conditions, such as ischemic stroke, where elevated SII predicts mortality and hemorrhagic transformation (6, 7). These findings suggest that SII may also have prognostic value in acute bleeding scenarios, although further research is necessary to establish its diagnostic accuracy and threshold values (8). The literature includes studies that have evaluated the predictive value of these markers for bleeding risk in various conditions, such as gastrointestinal bleeding or platelet transfusion requirements following cardiopulmonary bypass surgery (9, 10).

To date, no study has assessed the role of platelet indices, inflammatory markers, and the SII as predictors of erythrocyte suspension (ES) transfusion in patients undergoing hysterectomy. Therefore, this study aims to evaluate the relationship between the need for ES transfusion and preoperative and postoperative PI values, platelet-to-lymphocyte ratio (PLR), NLR, and SII in patients undergoing hysterectomy. By investigating these associations, we aim to identify potential predictors of transfusion requirements in this population.

MATERIALS AND METHODS

This retrospective matched case-control study was conducted at a tertiary care center, and included patients who underwent hysterectomy between August 1, 2020, and September 1, 2022. The study adhered to the principles outlined in the Declaration of Helsinki and was approved by the institutional ethics committee (Approval Number: 2024-30). As this was a retrospective study, the requirement for informed consent was waived by the ethics committee.

A total of 1,543 hysterectomy cases were identified during the study period, of which 730 were total abdominal hysterectomies. Patients meeting the inclusion criteria were enrolled in the study. The study population consisted of women aged 30 to 65 years who underwent total abdominal hysterectomy for benign indications. Patients were categorized into two groups based on postoperative ES transfusion status: those who required ES transfusion >6 hours postoperatively (transfusion group) and those who did not require ES transfusion (non-transfusion group). Each group included 88 patients, matched 1:1 using case-control matching based on age (± 1 year) and body mass index (BMI, ± 1 kg/m²). Patients with incomplete medical records, pre-existing hematological disorders, malignancy, emergency hysterectomies, or postpartum hysterectomies were excluded from the study.

Data were extracted retrospectively from hospital electronic medical records, including demographic characteristics (age, BMI, gravidity, parity, history of abdominal surgery), clinical characteristics (surgical indication such as uterine fibroids or adenomyosis, and ASA score), and operative details (duration of surgery and surgical approach). Laboratory parameters such as preoperative and postoperative (6-hour) complete blood count values were collected. These included PLT, PCT, MPV, PDW, and P-LCR. Additionally, inflammatory markers such as NLR, PLR, and SII were calculated, along with hemoglobin (HB) and hematocrit (HCT) levels.

All statistical analyses were performed using [SPSS, 27.0]. Descriptive statistics summarized the data, with continuous variables presented as mean $\pm$ standard deviation (SD) or median (25-75 Percentiles) depending on data distribution, and categorical variables expressed as frequencies and percentages. The normality of data distribution was assessed using the Kolmogorov-Smirnov test. For normally distributed data, comparisons between groups utilized Student's t-test and one-way ANOVA for more than two groups. The Mann-Whitney U test was used for non-normally distributed data, and the Kruskal-Wallis test was applied for comparing more than two groups with non-normal distributions. Chi-square or Fisher's exact test was applied for categorical variables. Receiver operating characteristic (ROC) curve analysis was used to identify optimal cutoff values for preoperative parameters predicting ES transfusion, with the area under the curve (AUC) evaluating diagnostic performance. Multivariate logistic regression analysis identified independent predictors of ES transfusion, expressed as odds ratios (ORs) and 95% confidence intervals (CIs).

RESULTS

The demographic and clinical characteristics of the patients are summarized in Table 1. Among 176 patients, 88 were in the postoperative ES transfusion group and 88 in the non-transfusion group.

The mean age and BMI were comparable between the groups, with values of 47.43 ± 6.54 years and 29.58 ± 5.32 kg/m² in the non-transfusion group and 46.18 ± 5.92 years and 29.97 ± 4.64 kg/m² in the transfusion group. Gravidity, parity, and previous cesarean medians were also similar. A history of abdominal surgery was reported in 46 (52.3%) of non-transfusion and 43 (48.9%) of transfusion patients. Vaginal deliveries were more frequent than cesarean deliveries in both groups [51 (58,0%), 58 (65,9%)]. Uterine fibroids were the most common surgical indication,

observed in 77 (87.5%) of the non-transfusion and 71 (80.7%) of the transfusion group.

Surgical and hematological data are detailed in Table 2. The operation duration was significantly longer in the transfusion group (144.25 ± 67.70 min vs. 122.38 ± 49.04 min, $p = 0.015$). HB and HCT levels were significantly lower pre- and postoperatively in the transfusion group ($p < 0.001$ for both), with greater postoperative reductions in HB ($1.50 [0.72-2.20]$ g/dL vs. $1.00 [0.42-1.70]$ g/dL, $p = 0.007$).

Inflammatory markers showed significant differences. The NLR and SII were significantly higher preoperatively in the transfusion group ($p = 0.031$ and $p = 0.043$, respectively). Postoperatively, NLR and SII increased in both groups but were significantly lower in the transfusion group ($p < 0.001$ and $p = 0.008$, respectively). PLT counts showed no significant differences between groups, but postoperative reductions in PLT were significant in the non-transfusion group ($p < 0.001$).

Table 3 summarizes outcomes based on ASA scores. Patients in the ASA-3 group were older ($p = 0.007$) and had higher BMI ($p = 0.004$). Uterine fibroids were less frequent in the ASA-3 group, while

adenomyosis was more common ($p = 0.001$). Preoperative HB levels were higher in the ASA-3 group ($p = 0.020$), but postoperative differences were not significant ($p = 0.069$). There were no significant differences among the groups in ES transfusion rates ($p = 0.446$) or the number of transfusion units ($p = 0.755$).

Multivariate logistic regression identified preoperative HB (OR = 0.302, $p < 0.001$) and SII (OR = 1.001, $p = 0.006$) as significant predictors of ES transfusion (Table 4). Age, BMI, and previous abdominal surgery were not significant predictors ($p > 0.05$).

The predictive value of preoperative SII and hemoglobin (HB) levels for postoperative ES transfusion is presented in Table 5. Preoperative SII, with a cutoff value of 670.62, demonstrated a sensitivity of 56.8% and a specificity of 56.8% ($p = 0.043$). Preoperative HB levels, with a cutoff value of 11.15 g/dL, showed a sensitivity of 73.9% and a specificity of 77.3% ($p < 0.001$). For ASA-1 and ASA-2 patients, the cutoff value of 10.95 g/dL corresponded to a sensitivity of 73.1% and a specificity of 79.7% ($p < 0.001$). For ASA-3 patients, the cutoff value of 11.85 g/dL was associated with a sensitivity of 70.0% and a specificity of 78.6% ($p < 0.001$).

Table 1. Demographic and Clinical Characteristics of Participants by Transfusion Status

		Non-Transfusion Group (n:88)	Transfusion Group (n:88)	p value
Age ^a (years)		47.43 $\pm$ 6.54	46.18 $\pm$ 5.92	p=0.260
BMI ^b (kg/m ²)		29.58 $\pm$ 5.32	29.97 $\pm$ 4.64	p=0.609
Previous Abdominal Surgery ^c (n)		46 (52.3%)	43 (48.9%)	p=0.651
Gravidity ^b (n)		3.00 (2.00 - 4.00)	3.00 (2.00 - 5.00)	p=0.070
Parity ^b (n)		2.00 (2.00 - 3.00)	3.00 (2.00 - 4.00)	p=0.064
Number of Previous Cesarean Deliveries ^b (n)		0.00 (0.00 - 1.00)	0.00 (0.00 - 2.00)	p=0.590
Type of Delivery ^c	VD	51 (58.0%)	58 (65.9%)	p=0.277
	CS	37 (42.0%)	30 (34.1%)	
Indications ^c	Uterine Fibroids	77 (87.5%)	71 (80.7%)	p=0.231
	Adenomyosis	5 (5.7%)	4 (4.5%)	
	Abnormal Uterine Bleeding	6 (6.8%)	13 (14.8%)	

Abbreviations: BMI; Body-Mass Index, VD; Vaginal Delivery, CS; Cesarean-Section

^a Normal distribution, Mean $\pm$ SD

^b Non-normal distribution, Median (25-75 Percentiles)

^c Categorical data, Number (Percentage%)

Table 2. Comparison of Surgical and Perioperative Data Based on ES Transfusion Status

	Non-Transfusion Group (n:88)	Transfusion Group (n:88)	p value
Operation Duration^a (min)	122.38 ± 49.04	144.25 ± 67.70	p=0.015
Uterine Weight^b (gr)	199.19 (91.91 – 381.75)	168.50 (81.16 – 365.62)	p=0.328
Surgeon Experience^b (years)	6.00 (2.00 – 9.00)	3.50 (2.00 – 9.00)	p=0.290
ES Transfusion Unit^b (n)	0.00 (0.00 – 0.00)	2.00 (2.00 – 4.00)	p<0.001
HB Difference^b (g/dl)	1.00 (0.42 – 1.70)	1.50 (0.72 – 2.20)	p=0.007
HB^a (g/dl)			
Preoperative	12.25 ± 1.30	10.50 ± 1.15	p<0.001
Postoperative	11.24 ± 1.46	8.89 ± 1.13	p<0.001
p value	p<0.001	p<0.001	
HCT^a (%)			
Preoperative	37.95 ± 3.30	33.65 ± 3.39	p<0.001
Postoperative	34.60 ± 1.46	28.90 ± 3.55	p<0.001
p value	p<0.001	p<0.001	
WBC^b (×10⁹/L)			
Preoperative	7.08 (6.07 – 8.71)	7.89 (6.29 – 9.49)	p=0.074
Postoperative	13.93 (11.24 – 16.31)	12.55 (9.86 – 16.46)	p=0.124
p value	p<0.001	p<0.001	
PLT^b (×10⁹/L)			
Preoperative	285.50 (253.25 – 349.25)	301.00 (229.50 – 355.50)	p=0.846
Postoperative	263.00 (223.25 – 308.50)	264.50 (214.00 – 338.75)	p=0.622
p value	p<0.001	p=0.077	
LYM^b (×10⁹/L)			
Preoperative	2.07 (1.67 – 2.63)	1.78 (1.52 – 2.52)	p=0.065
Postoperative	0.71 (0.57 – 0.91)	0.92 (0.62 – 1.51)	p=0.003
p value	p<0.001	p<0.001	
MPV^a (fL)			
Preoperative	10.82 ± 0.96	10.63 ± 0.95	p=0.192
Postoperative	10.66 ± 0.88	10.40 ± 0.78	p=0.048
p value	p=0.014	p=0.156	
PDW^a (×10⁹/L)			
Preoperative	13.20 ± 2.46	12.76 ± 2.38	p=0.229
Postoperative	12.59 ± 2.19	12.04 ± 1.92	p=0.088
p value	p<0.001	p=0.051	
NEU^b (×10⁹/L)			
Preoperative	4.41 (3.40 – 5.32)	4.82 (3.62 – 6.47)	p=0.080
Postoperative	12.58 (9.76 – 14.85)	10.65 (7.52 – 14.38)	p=0.018
p value	p<0.001	p<0.001	
BAS^b (×10⁹/L)			
Preoperative	0.03 (0.02 – 0.05)	0.03 (0.02 – 0.05)	p=0.340
Postoperative	0.02 (0.01 – 0.02)	0.02 (0.01 – 0.03)	p=0.088
p value	p<0.001	p<0.001	
PCT^a (%)			
Preoperative	0.32 ± 0.07	0.31 ± 0.09	p=0.366
Postoperative	0.27 ± 0.07	0.31 ± 0.14	p=0.057
p value	p<0.001	p=0.904	
P-LCR^a			
Preoperative	31.84 ± 7.80	30.35 ± 7.49	p=0.203
Postoperative	30.07 ± 7.93	28.50 ± 6.43	p=0.164
p value	p=0.001	p=0.147	
NLR^b			
Preoperative	2.08 (1.63 – 2.82)	2.38 (1.85 – 3.44)	p=0.031
Postoperative	17.39 (13.21 – 24.60)	12.15 (5.27 – 20.88)	p<0.001
p value	p<0.001	p<0.001	
PLR^b			
Preoperative	132.88 (109.40 – 182.05)	148.67 (115.63 – 214.17)	p=0.095
Postoperative	357.03 (274.51 – 467.31)	270.83 (177.30 – 449.14)	p=0.020
p value	p<0.001	p<0.001	
SII^b			
Preoperative	619.97 (423.89 – 901.17)	721.62 (503.80 – 1070.29)	p=0.043
Postoperative	4474.88 (2867.84 – 6618.06)	2981.11 (1417.72 – 5436.50)	p=0.008
p value	p<0.001	p<0.001	

Abbreviations: BMI: Body-Mass Index, CS; Cesarean-Section, ES; Erythrocyte Suspension, NLR; Neutrophil-to-Lymphocyte Ratio, PLR; Platelet-to-Lymphocyte Ratio, SII; Systemic Inflammatory Index, VD; Vaginal Delivery, ^a Normal distribution, Mean ± SD,

^b Non-normal distribution, Median (25-75 Percentiles), ^c Categorical data, Number (Percentage%)

Table 3. Analysis of Patient Demographics, Surgical Outcomes, and Perioperative Variables by ASA Scores

		ASA-1 (n:52)	ASA-2 (n:100)	ASA-3 (n:24)	p value
Age ^a (years)		45.67 _a ± 4.31	46.68 _a ± 5.23	49.92 _b ± 7.81	p=0.007
BMI ^a (kg/m ²)		28.33 _a ± 4.60	29.90 _a ± 5.04	32.40 _b ± 4.54	p=0.004
Previous Abdominal Surgery ^c (n)		24 (46.2%)	51 (51.0%)	14 (58.3%)	p=0.609
Gravidity ^b (n)		3.00 (2.00 - 4.00)	3.00 (2.00 - 4.75)	3.00 (2.00 - 5.00)	p=0.643
Parity ^b (n)		2.00 (2.00 - 3.00)	2.00 (2.00 - 4.00)	3.00 (2.00 - 4.75)	p=0.201
Number of Previous Cesarean Deliveries ^b (n)		0.00 (0.00 - 2.00)	0.00 (0.00 - 1.75)	0.50 (0.00 - 1.00)	p=0.731
Operation Duration ^b (min)		122.50 (95.00 - 155.00)	130.00 (95.00 - 167.50)	117.50 (80.00-117.50)	p=0.902
Uterine Weight ^b (gr)		194.58 (93.91 - 322.46)	189.75 (93.75 - 381.91)	125.00 (45.64-390.00)	p=0.488
Surgeon Experience ^b (years)		6.00 (3.00 - 9.00)	2.00 (3.50 - 9.00)	4.00 (2.00 - 9.00)	p=0.773
Type of Delivery ^c	VD	32 (61.5%)	65 (65.0%)	12 (50.0%)	p=0.396
	CS	20 (38.5%)	35 (35.0%)	12 (50.0%)	
ES Transfusion ^c (n)		24 (46.2%)	54 (54.0%)	10 (41.7%)	p=0.446
ES Transfusion Unit ^b (n)		0.00 (0.00 - 3.75)	1.00 (0.00 - 2.00)	0.00 (0.00 - 2.00)	p=0.755
HB Difference (g/dl)		1.10 (0.70 - 1.97)	1.15 (0.52 - 1.97)	1.35 (0.42 - 1.80)	p=0.996
HB preoperative ^a		11.24 _a ± 1.43	11.26 _a ± 1.47	12.17 _b ± 1.57	p=0.020
HB postoperative ^a		9.90 ± 1.74	9.97 ± 1.61	10.83 ± 2.17	p=0.069
SII preoperative ^b		655.23 (503.80 - 837.07)	673.71 (463.20 - 987.07)	741.85 (412.44 - 1280.33)	p=0.821
Indications ^c	Uterine Fibroids	41 _{ab} (78.8%)	91 _b (91.0%)	16 _a (66.7%)	p=0.001
	Adenomyosis	0 _a (0.0%)	5 _{ab} (5.0%)	4 _b (16.7%)	
	Abnormal Uterine Bleeding	11 _a (21.2%)	4 _b (4.0%)	4 _{ab} (16.7%)	
Group	Measurement	ASA Class	n	Mean ± Std (g/dL)	p value
Non-Transfused	Preoperative Hemoglobin	ASA1	28	12.02 ± 1.36	p=0.108
		ASA2	46	12.20 ± 1.30	
		ASA3	14	12.90 ± 1.01	
		Total	88	12.25 ± 1.30	
	Postoperative Hemoglobin	ASA1 _{ab}	28	10.89 ± 1.41	p=0.016
		ASA2 _a	46	11.17 ± 1.40	
		ASA3 _b	14	12.22 ± 1.43	
		Total	88	11.24 ± 1.46	
Transfused	Preoperative Hemoglobin	ASA1	24	10.34 ± 0.91	p=0.149
		ASA2	54	10.46 ± 1.11	
		ASA3	10	11.16 ± 1.71	
		Total	88	10.51 ± 1.15	
	Postoperative Hemoglobin	ASA1	24	8.76 ± 1.37	p=0.781
		ASA2	54	8.96 ± 0.97	
		ASA3	10	8.90 ± 1.40	
		Total	88	8.89 ± 1.13	

Note: Each subscript letter denotes a subset of ASA score categories whose column proportions do not differ significantly from each other at the 0.05 level.
Abbreviations: ASA: American Society of Anesthesiologists, BMI: Body-Mass Index, CS: Cesarean-Section, ES: Erythrocyte Suspension, NLR: Neutrophil-to-Lymphocyte Ratio, PLR: Platelet-to-Lymphocyte Ratio, SII: Systemic Immune-Inflammation Index, VD: Vaginal Deliv
^a Normal distribution, Mean ± SD
^b Non-normal distribution, Median (25-75 Percentiles)
^c Categorical data, Number (Percentage%)

Table 4. Multivariate Binary Logistic Regression Analysis to Predict the Need For Postoperative ES Transfusion.

	B	OR	95% CI	p value
Age (years)	0.952	1.032	0.958 - 1.113	p=0.406
BMI (kg/m²)	0.000	1.025	0.944 - 1.113	p=0.561
Previous Abdominal Surgery (n)	0.006	1.025	0.468 - 2.243	p=0.952
Hb preoperative	0.406	0.302	0.211 - 0.434	p<0.001
SII preoperative	0.561	1.001	1.000 - 1.002	p=0.006

Abbreviations: B; Regression coefficient, BMI; Body-Mass Index, CI; confidence interval, ES; Erythrocyte Suspension, Hb; Hemoglobin, OR; odds ratio; SII; Systemic Immune-Inflammation Index

Table 5. HB and SII Cut-Off Values for Predicting Postoperative ES Transfusion

Parameters		AUC (%95 CI)	Cutoff According to Youden Index	Sensitivity (%)	Specificity (%)	p value
Preoperative SII		0.588 (0.504 – 0.672)	670.62	56.8	56.8	p=0.043
Preoperative HB		0.841 (0.783 – 0.900)	11.15	73.9	77.3	p<0.001
ASA-1,2	Preoperative HB	0.841 (0.773 – 0.902)	10.95	73.1	79.7	p<0.001
ASA-3	Preoperative HB	0.800 (0.584 – 1.000)	11.85	70.0	78.6	p<0.001

Abbreviations: AUC; Area Under Curve, CI; Confidence Interval, ES; Erythrocyte Suspension, SII; Systemic Inflammatory Index,

DISCUSSION

Our results revealed that the NLR and the SII were notably higher preoperatively in the transfusion group. Postoperatively, these markers increased in both groups, but the transfusion group showed a more substantial elevation. Multivariate logistic regression analysis revealed that preoperative HB levels and the SII were significant predictors of ES transfusion. These findings suggest that preoperative HB levels and SII could be valuable tools in predicting the need for ES transfusion in hysterectomy patients, potentially guiding perioperative management.

The findings of our study provide insights into the management of perioperative anemia and blood transfusion strategies in patients undergoing total abdominal hysterectomy. Notably, our results emphasize the variability in preoperative Hb levels and transfusion requirements across different ASA risk groups, highlighting the necessity for individualized transfusion protocols.

The mean preoperative Hb levels were significantly lower in patients who received ES transfusions compared to those who did not (10.50 ± 1.15 vs. 12.25 ± 1.30 ; $p<0.001$). Among ASA groups, preoperative Hb levels were unexpectedly higher in ASA-3 patients compared to ASA-1 and ASA-2 groups (12.17 ± 1.57 vs. 11.24 ± 1.43 and 11.26 ± 1.47 ; $p=0.020$). Despite this, the rate and volume of ES transfusions did not significantly differ among ASA groups ($p=0.446$ and $p=0.755$,

respectively). These findings are consistent with prior evidence suggesting that transfusion practices can be optimized when clinical decision-making incorporates individual patient characteristics and risk factors (11, 12)

Importantly, when investigating the retrospective indications for blood transfusion, we observed that postoperative transfusion decisions were influenced by clinical symptoms and 6-hour postoperative Hb levels. The mean postoperative Hb level was significantly lower in transfused patients (8.89 ± 1.13) compared to non-transfused patients (11.24 ± 1.46 , $p < 0.001$). Subgroup analysis based on ASA classification revealed that the mean postoperative Hb levels were 8.76 ± 1.37 for ASA-1 patients, 8.96 ± 0.97 for ASA-2 patients, and 8.90 ± 1.40 for ASA-3 patients, with no significant difference among the groups ($p = 0.781$). This practice underscores the need for tailoring transfusion strategies based on dynamic clinical assessments rather than rigid adherence to thresholds.

The preoperative Hb cut-off values for predicting postoperative ES transfusion were 10.95 g/dL for ASA 1–2 patients and 11.85 g/dL for ASA 3 patients. These findings suggest that ES transfusion may be anticipated in patients with Hb levels below these thresholds, and reserving an average of three units of ES preoperatively in such cases may be a practical approach.

Previous studies have investigated the role of PIs, the NLR, and the SII as biomarkers in various clinical conditions. PCT, which represents the

proportion of blood volume occupied by platelets, has been linked to postpartum hemorrhage when decreased, while PDW values $\geq 23\%$ were independently associated with increased risk (13). Elevated PCT levels have been reported in malignancies, including gynecological cancers, where increased platelet counts and PCT levels, alongside decreased MPV, have been observed (14). Additionally, studies on endometrial cancer have documented increases in PCT, MPV, and PDW levels (15). Conversely, endometriosis patients show elevated PCT and decreased MPV and PDW levels (16). Lower PCT values in breast cancer have been identified as independent prognostic indicators for improved survival (17). Furthermore, PCT may aid in differentiating between remission and active phases of chronic diseases such as Crohn's disease, where elevated PLT and PCT levels correlate with disease activity (18).

The significance of PCT in predicting postoperative platelet transfusion has been highlighted in recent research. For instance, patients requiring platelet transfusion after cardiopulmonary bypass surgery exhibited lower MPV and PCT values than those who did not require transfusion. A PCT value of $<0.01\%$ or MPV below 7.7 fL were identified as meaningful cutoff points for predicting transfusion needs (10). Additionally, the NLR, an indirect marker of inflammation, has been linked to gastrointestinal bleeding in children with Henoch-Schönlein purpura and poor outcomes in patients with intracranial hemorrhage (9, 19). Increased MPV and P-LCR values have been associated with poor neurological outcomes in subarachnoid hemorrhage and intraventricular bleeding (20). However, studies investigating the relationship between intraoperative hemorrhage and P-LCR remain scarce.

Inflammation plays a critical role in the pathogenesis of bleeding disorders, particularly in the context of sepsis. The systemic inflammatory response in sepsis is intricately linked to the activation of coagulation pathways, which can lead to disseminated intravascular coagulation (DIC), a condition characterized by widespread fibrin deposition and impaired fibrinolysis. Inflammatory mediators such as cytokines and chemokines activate tissue factor expression on monocytes and endothelial cells, driving thrombin generation while simultaneously suppressing physiological anticoagulant mechanisms, such as the protein C system and antithrombin (21). This dysregulation results in microvascular thrombosis and subsequent tissue ischemia, which contributes to organ dysfunction. Additionally, elevated levels of inflammatory biomarkers, including interleukins and tumor necrosis factor- α , correlate with DIC severity, underscoring the diagnostic and prognostic significance of inflammation in sepsis-associated coagulopathy (22). While bleeding disorders in sepsis are well-studied, current evidence highlights the interplay between inflammation and coagulation as a pivotal factor in disease progression and the associated morbidity and mortality.

The SII, introduced by Huang et al. (23) in 2019, reflects the role of these cell types in inflammation, with platelets and neutrophils contributing to active inflammation while lymphocytes regulate immune responses. High SII values are associated with poor outcomes in cancer patients and other conditions, such as ischemic stroke, where elevated SII predicts mortality and hemorrhagic transformation (6, 7). These findings suggest that SII may also have prognostic value in acute bleeding scenarios, although further research is necessary to establish its diagnostic accuracy and threshold values (8).

Additionally, the lack of significant differences in SII values among ASA groups ($p=0.821$) suggests that inflammatory states were comparable across risk categories, supporting the homogeneity of our cohort. However, the relationship between inflammation and transfusion outcomes warrants further exploration, as chronic inflammation may modulate both anemia severity and response to transfusion (24).

This study has several strengths, including its matched case-control design, which minimizes selection bias, and its reliance on common blood markers to predict transfusion requirements, enhancing the clinical relevance of the findings. Additionally, the focus on a well-defined patient population increases its applicability to similar surgical settings. Notably, this is the first study to assess the role of platelet indices, inflammatory markers, and the SII as predictors of ES transfusion in patients undergoing hysterectomy.

However, the study has certain limitations. Its retrospective design restricts causal inferences, and the sample size may be insufficient to detect rarer events. Moreover, the findings may not be generalizable to all patient populations. Future prospective studies with larger sample sizes are warranted to validate these results.

CONCLUSION

This study identifies preoperative hemoglobin levels and SII as significant predictors of ES transfusion in patients undergoing total abdominal hysterectomy. These findings suggest that preoperative low hemoglobin levels, elevated NLR and SII values may help identify patients at higher risk for transfusion, potentially guiding preoperative planning and blood management strategies. Further prospective studies are needed to validate these biomarkers as reliable tools for predicting transfusion requirements and to explore their role in personalized perioperative care.

Ethics Committee Approval: Ethical approval for the study was received from the Başakşehir Çam and Sakura City Hospital Ethics Committee on June 26, 2024, with the approval number e-96317027-514.10-246499987.

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REFERENCES

1. Cosson M, Rajabally R, Querleu D, Crepin G. Hysterectomy: indications, surgical routes, cases for adnexal or cervical conservation. *European journal of obstetrics, gynecology, and reproductive biology*. 1998;80(1):5-15.
2. McClurg A, Wong J, Louie M. The impact of race on hysterectomy for benign indications. *Current opinion in obstetrics & gynecology*. 2020;32(4):263-268.
3. Control CfD, Control PJACfD, Prevention. National healthcare safety network biovigilance component hemovigilance module surveillance protocol. 2018.
4. Elfazari T, Nayak AL, Mallick R, Arendas K, Choudhry AJ, Chen I. Surgical Indication and Approach are Associated with Transfusion in Hysterectomy for Benign Disease. *JSLs : Journal of the Society of Laparoendoscopic Surgeons*. 2022;26(2).
5. Sordia-Hernández LH, Rodríguez DS, Vidal-Gutiérrez O, Morales-Martínez A, Sordia-Piñeyro MO, Guerrero-González G. Factors associated with the need for blood transfusion during hysterectomy. *International journal of gynaecology and obstetrics: the official organ of the International Federation of Gynaecology and Obstetrics*. 2012;118(3):239-241.
6. Tian B-W, Yang Y-F, Yang C-C, Yan L-J, Ding Z-N, Liu H, et al. Systemic immune-inflammation index predicts prognosis of cancer immunotherapy: Systemic review and meta-analysis. 2022;14(18):1481-1496.
7. Huang YW, Yin XS, Li ZP. Association of the systemic immune-inflammation index (SII) and clinical outcomes in patients with stroke: A systematic review and meta-analysis. *Frontiers in immunology*. 2022;13:1090305.
8. Islam MM, Satici MO, Eroglu SE. Unraveling the clinical significance and prognostic value of the neutrophil-to-lymphocyte ratio, platelet-to-lymphocyte ratio, systemic immune-inflammation index, systemic inflammation response index, and delta neutrophil index: An extensive literature review. *Turkish journal of emergency medicine*. 2024;24(1):8-19.
9. Hong SH, Kim CJ, Yang EM. Neutrophil-to-lymphocyte ratio to predict gastrointestinal bleeding in Henoch: Schönlein purpura. *Pediatrics international : official journal of the Japan Pediatric Society*. 2018;60(9):791-795.
10. Mohr R, Martinowitz U, Golan M, Ayala L, Goor DA, Ramot B. Platelet size and mass as an indicator for platelet transfusion after cardiopulmonary bypass. *Circulation*. 1986;74(5 Pt 2):1153-1158.
11. Walsh TS, Boyd JA, Watson D, Hope D, Lewis S, Krishan A, et al. Restrictive versus liberal transfusion strategies for older mechanically ventilated critically ill patients: a randomized pilot trial. *Critical care medicine*. 2013;41(10):2354-2363.
12. Hébert PC, Wells G, Blajchman MA, Marshall J, Martin C, Pagliarello G, et al. A multicenter, randomized, controlled clinical trial of transfusion requirements in critical care. Transfusion Requirements in Critical Care Investigators, Canadian Critical Care Trials Group. *The New England journal of medicine*. 1999;340(6):409-417.
13. van Dijk WEM, Nijdam JS, Haitjema S, de Groot MCH, Huisman A, Punt MC, et al. Platelet count and indices as postpartum hemorrhage risk factors: a retrospective cohort study. *Journal of thrombosis and haemostasis : JTH*. 2021;19(11):2873-2883.
14. Yang W, Chen YY, Bi C, Shu KY, Ye ML, Li FF, et al. Predictive and prognostic values of preoperative platelet parameters in patients with gynecological tumors. *Journal of clinical laboratory analysis*. 2020;34(7):e23295.
15. Karateke A, Kaplanoglu M, Baloglu AJAPJoCP. Relations of platelet indices with endometrial hyperplasia and endometrial cancer. 2015;16(12):4905-4908.
16. Avcioglu SN, Altinkaya SÖ, Küçük M, Demircan-Sezer S, Yüksel HJISRN. Can platelet indices be new biomarkers for severe endometriosis? 2014;2014(1):713542.
17. Lu YJ, Cui MT, Liang ZW, Wang WJ, Jiang M, Xu MD, et al. Prognostic values of platelet-associated indicators in advanced breast cancer. *Translational cancer research*. 2019;8(4):1326-1335.
18. Tang J, Gao X, Zhi M, Zhou HM, Zhang M, Chen HW, et al. Plateletcrit: a sensitive biomarker for evaluating disease activity in Crohn's disease with low hs-CRP. *Journal of digestive diseases*. 2015;16(3):118-124.
19. Shi M, Li XF, Zhang TB, Tang QW, Peng M, Zhao WY. Prognostic Role of the Neutrophil-to-Lymphocyte Ratio in Intracerebral Hemorrhage: A Systematic Review and Meta-Analysis. *Frontiers in neuroscience*. 2022;16:825859.
20. Rzepliński R, Kostyra K, Skadorwa T, Sługocki M, Kostkiewicz B. Acute platelet response to aneurysmal subarachnoid hemorrhage depends on severity and distribution of bleeding: an observational cohort study. *Neurosurgical review*. 2021;44(5):2647-2658.
21. Levi M, van der Poll T. Coagulation and sepsis. *Thrombosis research*. 2017;149:38-44.
22. Patel P, Walborn A, Rondina M, Fareed J, Hoppensteadt D. Markers of Inflammation and Infection in Sepsis and Disseminated Intravascular Coagulation. *Clinical and applied thrombosis/hemostasis : official journal of the International Academy of Clinical and Applied Thrombosis/Hemostasis*. 2019;25:1076029619843338.
23. Huang H, Liu Q, Zhu L, Zhang Y, Lu X, Wu Y, et al. Prognostic Value of Preoperative Systemic Immune-Inflammation Index in Patients with Cervical Cancer. *Scientific reports*. 2019;9(1):3284.
24. Terekeci HM, Kucukardali Y, Onem Y, Erikci AA, Kucukardali B, Sahar B, et al. Relationship between anaemia and cognitive functions in elderly people. *European journal of internal medicine*. 2010;21(2):87-90.

