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Research article

Rotational thromboelastometry during Cesarean section as a predictive evaluation for the progression of persistent postpartum hemorrhage in parturients with placenta previa: A prospective observational study

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ABSTRACT

Background: The rotational thromboelastogram (ROTEM) has been used in the management of massive bleeding and transfusion strategy. This study investigated ROTEM parameters measured during Cesarean section as predictors for the progression of persistent postpartum hemorrhage (PPH) in parturients with placenta previa.

Methods: This prospective observational study recruited 100 women scheduled for elective Cesarean section after being diagnosed with placenta previa. Recruited women were divided into two groups according to the amount of estimated blood loss: the PPH group (PPH $>$ 1500 ml) vs. the non-PPH group. ROTEM with laboratory tests was performed three times, preoperative, intraoperative, and postoperative time, which were compared between the two groups.

Results: The PPH and non-PPH groups included 57 and 41 women, respectively. The area under the receiver-operating characteristic curve of postoperative FIBTEM A5 to detect PPH was 0.76 (95% CI = 0.64 to 0.87; P $<$ 0.001). When postoperative FIBTEM A5 was 9.5, the sensitivity and specificity were 0.74 (95% CI = 0.55 to 0.88) and 0.73 (95% CI = 0.57 to 0.86), respectively. When subgrouping the PPH group based on the postoperative FIBTEM A5 value of 9.5, intraoperative cEBL was similar between the two subgroups; however, postoperative RBC was transfused more in the subgroup with FIBTEM A5 $<$ 9.5 than the subgroup with FIBTEM A5 $\geq$ 9.5 (7.4 $\pm$ 3.0 vs 5.1 $\pm$ 2.3 units, respectively; P = 0.003).

Conclusion: Postoperative FIBTEM A5, with appropriate selection of the cut-off value, can be a biomarker for more prolonged PPH and massive transfusion following Cesarean section by placenta previa.

1. Introduction

When pregnant women with placenta previa undergo Cesarean section, there is a high possibility of massive bleeding [1,2]. Therefore, in addition to proper surgical hemostasis, rapid transfusion and pharmacological adjuncts to stop bleeding are required [3].

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However, it is difficult to predict in advance the massive bleeding and subsequent prolonged postpartum bleeding, and various prediction methods have been developed and validated [4,5].

Complete blood count, coagulation profile, and fibrinogen concentration are common as general laboratory tests related to bleeding and transfusion during surgery. In addition, there is rotational thromboelastometry (ROTEM) or thromboelastography (TEG), which is in the spotlight as a real-time and point-of-care test corresponding to the blood coagulation test. The ROTEM or TEG makes it possible to properly judge blood clotting factor deficiency, platelet function, fibrinolysis, etc., and also allows us to understand the interrelationship between platelets and clotting factors [6].

To date, a few studies have used ROTEM or TEG in postpartum hemorrhage (PPH) and reported that the transfusion rate and volume could be reduced by performing an appropriate and rapid transfusion based on ROTEM or TEG in overall PPH [7–9]. However, the causes of PPH are various, such as uterine atony, uterine rupture, placenta accreta, retained placenta, or clotting factor deficiency [3,10,11]. Therefore, the causes of PPH between surgical bleeding or microvascular bleeding by coagulopathy, should be differentiated with proper primary management. In addition, it seems necessary to determine whether ROTEM or TEG can be used as a predictor of PPH in each specific condition.

When Cesarean section is performed with placenta previa, it often progresses to persistent PPH with higher volumes of blood loss. This study investigated whether ROTEM parameters could distinguish PPH and predict the progression of persistent PPH after Cesarean section in parturients with placenta previa.

2. Methods

This study was approved by the Institutional Review Board (B-1910-571-304) of Seoul National University Bundang Hospital (Seongnam, South Korea) in October 2019, and registered on Clinicaltrials.gov (NCT04213755). Patients were recruited from January 2020 until August 2022. Adult patients scheduled to have Cesarean section after being diagnosed with placenta previa were enrolled in this study. Informed consent was obtained from all patients. Patients with an American Society of Anesthesiologists physical status 3 or higher, thrombocytopenia, coagulopathy, or medication of antiplatelet agents or anticoagulants within the previous month were excluded.

On arrival at the operating room, routine monitoring including electrocardiography, noninvasive arterial pressure, and pulse oximetry was initiated, and invasive arterial pressure was also established. Spinal anesthesia using 8–10 mg of heavy bupivacaine and 20 μg of fentanyl was performed initially. At the same time, 500 ml of 6% hydroxyethyl starch 130/0.4 (HES) was rapidly infused during spinal anesthesia to prevent the spinal-induced hypotension. Nevertheless, when hypotension occurred, therapeutic phenylephrine was primarily administered. When hypotension was accompanied by bradycardia, ephedrine was selectively administered. General anesthesia was only offered when regional anesthesia was failed or contraindicated. In case of complaints of surgical pain due to prolonged operation time, it was changed to general anesthesia. After induction of spinal anesthesia, an air-forced warmer was applied to the upper body for the entire period until the end of the operation to maintain the patient's body temperature.

ROTEM included EXTEM and FIBTEM tests. Clotting time (CT) of EXTEM, clot firmness at 5 min of EXTEM (EXTEM A5), and clot firmness at 5 min of FIBTEM (FIBTEM A5) were recorded, and PLTEM was calculated as EXTEM A5 – FIBTEM A5. Routine laboratory tests were hemoglobin (Hb), hematocrit (Hct), platelets count, international normalized ratio (INR) of prothrombin time, activated partial thromboplastin time (aPTT), and fibrinogen level. ROTEM and laboratory tests were performed three times; immediately after the arterial cannulation for the invasive arterial pressure monitoring, 10 min after delivery, and at the finishing operation.

Calculated estimated blood loss (cEBL) was derived by multiplying the blood volume of each pregnant woman by the percentage of lost blood volume. Two Hct values measured immediately after the arterial cannulation for the invasive arterial pressure monitoring and at the finishing operation were used for the pre- and postoperative Hct when calculating the percentage of lost blood volume. Pregnant woman's blood volume = (0.75 ([maternal height in inches $\times$ 50] + [maternal weight in pounds $\times$ 25]). The percentage of lost blood volume = (preoperative Hct − postoperative Hct)/preoperative Hct [12]. When red blood cells (RBC) were transfused intraoperatively, it might affect the postoperative Hct and cEBL. Thus, the transfused volume of RBC was added to cEBL for compensation. Recruited women were divided into two groups according to the cEBL: the PPH group (cEBL $>$ 1500 ml) or the non-PPH group.

We followed the transfusion strategies of our obstetrics and anesthesiology departments. In principle, red blood cells (RBC) were transfused when the hemoglobin (Hb) was $<$8 g/dl; however, when massive bleeding was expected to continue, RBC transfusion was performed even when the Hb level was greater than 8 g/dl [13]. Fresh frozen plasma (FFP) transfusion was indicated in patients with INR $\geq$2.0 [14]. FFP also could be transfused while active bleeding in the setting of massive transfusion without confirming INR. Platelets were transfused when the platelet concentration was $<$75,000/μl [14].

The primary outcomes were the ROTEM parameters and cEBL, and the secondary outcomes included the laboratory results, the amount of infused crystalloid, colloid, or transfusion, implementation of any method to control PPH, such as an intrauterine balloon, interventional radiology, or hysterectomy, and length of hospital or intensive care unit stay.

This study is conducted to estimate the accuracy of the specific ROTEM parameter to discriminate PPH. We assumed that the area under the receiver operating characteristic (ROC) curve of 0.67 for the ROTEM parameter would be significantly different from the null hypothesis value of 0.5. A total of 88 patients were calculated for a type I error of 0.05 and 80% of the power. Given that the same number of patients are expected to be enrolled in both groups, and the dropout rate is 10%, 49 patients in each group should be required.

Continuous or categorical outcomes were presented as the mean ± standard deviation (interquartile range) or number (%). After the normality test, Student's *t* or Mann-Whitney *U* test for continuous variables, and chi-square or fisher's exact test for categorical

variables were applied as appropriate. The area under the ROC curve was drawn with a 95% confidence interval (CI), and the optimal cut-off level was determined according to sensitivity and specificity. Statistical significance was set at $P < 0.05$ using IBM® SPSS® Statistics (ver. 25; IBM Corp., Armonk, NY, USA) or SigmaPlot 10.0(Systat Software, Inc., USA).

3. Results

A total of 100 patients were screened for this study, and two patients were excluded due to thrombocytopenia and medication of low-molecular-weight heparin for antiphospholipid syndrome. Finally, 98 patients participated and 57 and 41 were enrolled in the PPH and non-PPH groups based on the cEBL, respectively (Fig. 1). The characteristics of patients, surgery, and anesthesia are shown in Table 1. The placenta location was different between the two groups ($p = 0.009$); the placenta was mostly located on the anterior wall of the uterus in the PPH group, whereas was located on the posterior wall of the uterus in the non-PPH group. Bakri balloon was inserted more in the PPH group than in the non-PPH group ($p < 0.001$), and more patients in the PPH group were admitted to the ICU during the postoperative period than those in the non-PPH group ($p = 0.003$). In addition, the duration of hospital stay was longer in the PPH group than in the non-PPH group ($p = 0.002$).

Table 2 shows the ROTEM and laboratory results. Preoperative and intraoperative parameters were comparable. Postoperative hemoglobin and platelets were significantly lower in the PPH group than in the non-PPH group ($p = 0.030$ and $p = 0.002$, respectively), and activated partial thromboplastin time of the PPH group was significantly higher than that of the non-PPH group ($P < 0.001$), which were consistent with the consequences of massive bleeding. Among the postoperative ROTEM parameters, EXTEM A5, FIBTEM A5, and PLTEM were significantly lower in the PPH group than in the non-PPH group ($P < 0.05$).

The area under the ROC curve of postoperative FIBTEM A5 to detect PPH was 0.76 (95% CI 0.64 to 0.87; $P < 0.001$); however, those of EXTEM A5 and PLTEM were 0.57 (95% CI 0.43 to 0.70; $P = 0.33$) and 0.5 (95% CI 0.37 to 0.64; $P = 0.99$), respectively (Fig. 2). When postoperative FIBTEM A5 was 9.5, the sensitivity and specificity were 0.74 (95% CI = 0.55 to 0.88) and 0.73 (95% CI = 0.57 to 0.86), respectively.

The cEBL and intraoperative infused amount of crystalloid and colloid in the PPH group was significantly more than that of the non-PPH group ($P < 0.001$) (Table 3). All patients in the PPH group received RBC transfusion during the intra- and postoperative period, whereas 17% of the non-PPH group did. The proportion of patients who received FFP transfusion was more in the PPH group than in the non-PPH group (21.1% vs 4.9%; $P = 0.024$). Intra- and postoperative mean units of each blood component were calculated for the transfused patients, and the RBC transfused during the postoperative period was significantly more in the PPH group than in the non-PPH group (6.4 ± 2.7 units vs. 1.1 ± 0.9 units; $P < 0.001$) (Table 3).

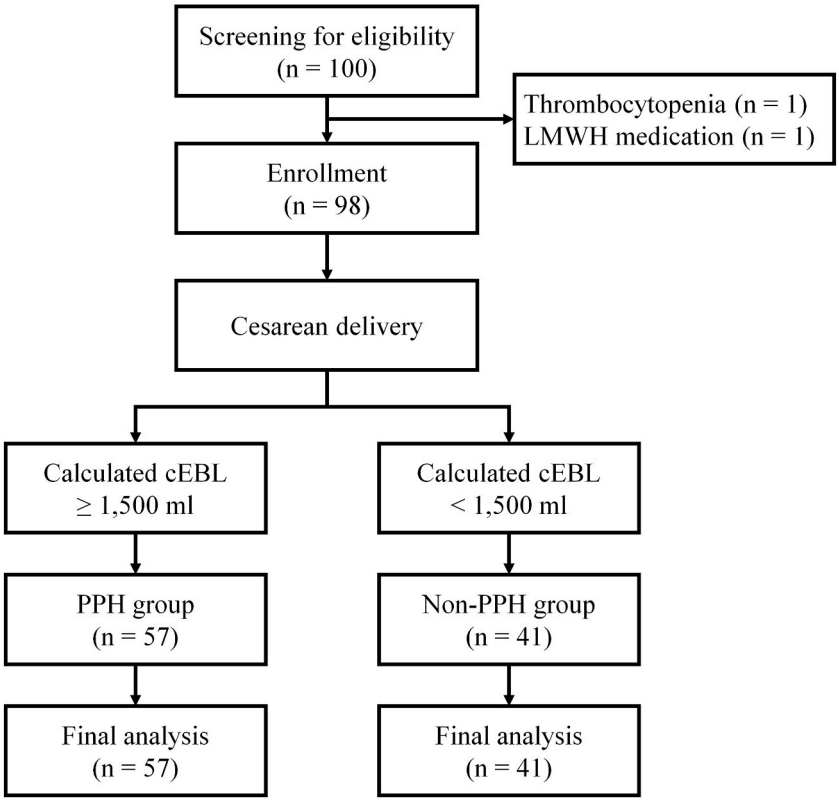

Fig. 1. Consort flowchart. LMWH, low-molecular-weight heparin; cEBL, calculated estimated blood loss.

Table 1
The characteristics of patients, surgery, and anesthesia.

	PPH group (n = 57)	Non-PPH group (n = 41)	P value
Age (years)	34.1 ± 5.6 (31–38)	34.2 ± 6.3 (30–38)	0.934
Height (cm)	166.2 ± 11.2 (158.9–173.5)	163.9 ± 9.5 (156.4–169.1)	0.289
Weight (kg)	73.6 ± 10.1 (65.1–79.4)	71.8 ± 8.9 (64.1–76.1)	0.363
Body mass index (kg/m^2)	27.7 ± 4.6 (25.1–31.1)	26.9 ± 6.8 (23.3–32.4)	0.489
Gestational age (weeks)	36.1 ± 1.1 (36–37)	36.3 ± 0.9 (36–37)	0.341
Fetal presentation			0.245
Head	38 (66.7%)	33 (80.5%)	
Breech	14 (24.5%)	7 (17.1%)	
Transverse	5 (8.8%)	1 (2.4%)	
Main location of placenta			0.009
Anterior wall	29 (50.9%)	14 (34.1%)	
Posterior wall	15 (26.3%)	23 (56.1%)	
Lateral wall	13 (22.8%)	4 (9.8%)	
Previous abdomen surgery			0.327
Cesarean section	19 (33.3%)	8 (19.5%)	
Gynecologic surgery	11 (19.3%)	13 (31.7%)	
Other abdominal surgery	5 (8.8%)	5 (12.2%)	
None	22 (38.6%)	15 (36.6%)	
Anesthesia type			0.277
Spinal	47 (82.5%)	37 (90.2%)	
/Conversion to general[a]	/7 (12.3%)	/1 (2.4%)	
General	10 (17.5%)	4 (9.8%)	
Operation time (min)	72.5 ± 24.5 (60–85)	65.9 ± 30.8 (40–80)	0.241
Anesthesia time (min)	85.1 ± 29.0 (70–110)	79.2 ± 23.4 (60–90)	0.285
Bakri balloon tamponade	45 (78.9%)	11 (26.8%)	<0.001
Uterine artery embolization	11 (19.3%)	4 (9.8%)	0.196
ICU admission	11 (19.3%)	1 (2.4%)	0.003

Data were expressed as mean ± standard deviation (interquartile range) or number (%).
[a] The number of patients was included in the number of patients under spinal anesthesia.

When subgrouping the PPH group based on the postoperative FIBTEM A5 value of 9.5, intraoperative cEBL was not significantly different between the two subgroups (2081 ± 718 ml in the FIBTEM A5 < 9.5 subgroup vs. 1888 ± 357 ml in the FIBTEM A5 ≥ 9.5 subgroup; P = 0.247). However, postoperative RBC was transfused more in the subgroup with FIBTEM A5 < 9.5 (n = 35) than the subgroup with FIBTEM A5 ≥ 9.5 (n = 22) (7.4 ± 3.0 vs 5.1 ± 2.3 units, respectively; P = 0.003).

4. Discussion

This study evaluated whether ROTEM parameters could identify clinically significant PPH in parturients after Cesarean section because of placenta previa. Postoperative FIBTEM A5 ≤ 9.5 mm could distinguish PPH ≥ 1500 ml properly; the sensitivity and specificity were 74% and 73%, respectively. It also could be a biomarker for persistent PPH and more RBC transfusion after Cesarean section. Unfortunately, pre- and intraoperative ROTEM evaluation did not reflect these findings significantly.

PPH is caused by uterine atony, uterine rupture or laceration, retained placenta or clots, and clotting-factor deficiency [3]. Previous studies targeting women with PPH were conducted by recruiting women who showed PPH above a certain level regardless of delivery mode [8,15]; however, Cesarean section was found to increase the severity of the PPH more than spontaneous vaginal delivery [16,17]. The risk factors of massive PPH in placenta previa include maternal old age, non-cephalic presentation, antepartum bleeding, placenta previa totalis, anterior placenta, multiple lacunae, and uteroplacental hypervascularity [18]. In this study, low postoperative FIBTEM A5 seemed to be an additional risk factor for persistent PPH and more transfusion. Similarly, previous study reported FIBTEM A5 as a predictor of more severe hemorrhage in women experiencing PPH [15]. The present study differs from the previous one where only women undergoing Cesarean section due to placenta previa were included and the relationship between FIBTEM A5 and PPH was evaluated.

According to the first guidelines about managing severe perioperative bleeding by the European Society of Anesthesiology, studies are required to predict massive bleeding and early transfusion decision-making using ROTEM or TEG in obstetric bleeding [19]. Thereafter, hypofibrinogenemia was reported to identify the risk of severe PPH, which can be monitored early by ROTEM or TEG [20]. Recent studies reported that ROTEM or TEG correlated well with fibrinogen levels in parturients with PPH [8,9]. A low level of FIBTEM A5 was proved to represent hypofibrinogenemia in parturients presenting PPH [8]. Thus, at the end of the Cesarean section, mothers with low FIBTEM A5 should be categorized as likely to have persistent PPH.

In this study, preoperative and intraoperative ROTEM parameters did not reflect the massive PPH. Although intraoperative ROTEM was measured 10 min after placenta removal, blood loss during that brief period did not lead to differences in ROTEM results between the two groups. EXTEM A5, FIBTEM A5, and PLTEM in ROTEM parameters were different only at a postoperative time between the PPH and the non-PPH groups, which could be the consequences of massive intraoperative blood loss in the PPH group and they have little value as predictors of massive intraoperative bleeding. However, Cesarean section is not a time-consuming operation, so

Table 2
ROTEM and laboratory results.

	PPH group (n = 57)	Non-PPH group (n = 41)	P value
Preoperative			
Hemoglobin (g/dl)	11.2 ± 0.9 (9.9–11.9)	10.9 ± 0.8 (9.9–11.1)	0.092
Platelets (10 [3]/μl)	241 ± 110 (174–314)	256 ± 99 (189–321)	0.489
INR	0.96 ± 0.12 (0.85–1.05)	0.94 ± 0.20 (0.81–1.10)	0.539
aPTT (sec)	35.0 ± 7.5 (31.5–41.1)	37.6 ± 6.4 (32.8–41.2)	0.075
Fibrinogen (mg/dl)	341 ± 112 (274–413)	323 ± 149 (218–425)	0.496
EXTEM CT (sec)	59 ± 13 (49–68)	60 ± 9 (51–65)	0.672
EXTEM A5 (mm)	66 ± 7 (61–71)	64 ± 9 (59–70)	0.219
FIBTEM A5 (mm)	18 ± 5 (15–22)	16 ± 6 (13–21)	0.076
PLTEM A5 (mm)	31 ± 9 (25–38)	34 ± 9 (28–39)	0.107
Intraoperative			
Hemoglobin (g/dl)	9.3 ± 1.1 (8.1–10.1)	9.5 ± 0.7 (8.7–9.9)	0.309
Platelets (10 [3]/μl)	211 ± 146 (107–294)	224 ± 105 (171–318)	0.628
INR	1.13 ± 0.52 (0.90–1.35)	1.01 ± 0.24 (0.91–1.23)	0.173
aPTT (sec)	36.3 ± 9.7 (29.9–43.1)	38.1 ± 7.1 (33.9–43.1)	0.316
Fibrinogen (mg/dl)	203 ± 85 (145–258)	215 ± 101 (144–279)	0.526
EXTEM CT (sec)	62 ± 11 (55–70)	60 ± 10 (54–68)	0.359
EXTEM A5 (mm)	48 ± 11 (39–54)	51 ± 10 (43–58)	0.170
FIBTEM A5 (mm)	11 ± 7 (6–16)	13 ± 5 (9–16)	0.121
PLTEM A5 (mm)	29 ± 10 (20–36)	31 ± 12 (22–37)	0.372
Postoperative			
Hemoglobin (g/dl)	8.1 ± 2.5 (7.1–9.9)	9.0 ± 0.9 (8.2–9.9)	0.030
Platelets (10 [3]/μl)	138 ± 101 (75–206)	203 ± 95 (109–256)	0.002
INR	1.35 ± 1.01 (0.91–2.29)	1.19 ± 0.38 (0.99–1.38)	0.435
aPTT (sec)	55.5 ± 11.9 (49.3–61.1)	41.1 ± 13.5 (35.2–51.1)	<0.001
Fibrinogen (mg/dl)	173 ± 94 (118–229)	211 ± 113 (143–285)	0.073
EXTEM CT (sec)	68 ± 15 (59–75)	62 ± 16 (51–72)	0.061
EXTEM A5 (mm)	34 ± 10 (26–41)	46 ± 13 (35–57)	<0.001
FIBTEM A5 (mm)	8 ± 6 (5–13)	12 ± 5 (8–16)	<0.001
PLTEM A5 (mm)	27 ± 9 (21–34)	33 ± 12 (25–40)	0.006

Data were expressed as mean ± standard deviation (interquartile range).
PPH, postpartum hemorrhage; INR, international normalized ratio of prothrombin time; aPTT, activated partial thromboplastin time.
PLTEM = EXTEM A5 – FIBTEM A5.
Intraoperative, 10 min after placenta removal; postoperative, after finishing operation.

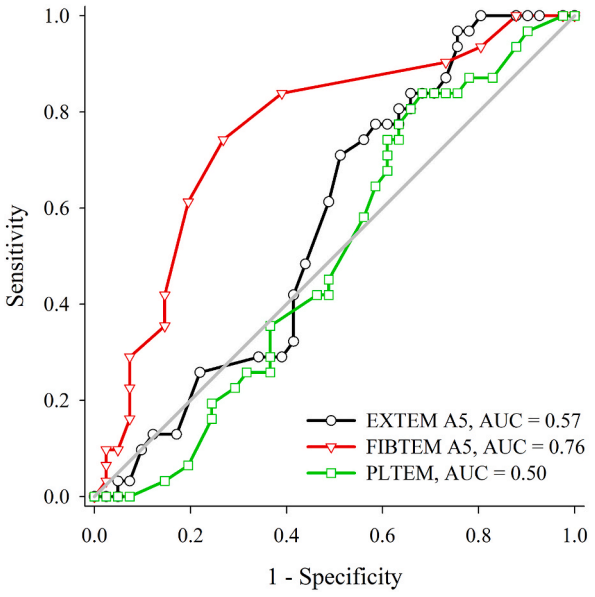

Fig. 2. Receiver-operating characteristic curve for postoperative EXTEM A5, FIBTEM A5, PLTEM to distinguish PPH ≥1500 ml. AUC, area under the curve.

Table 3
Intra- and postoperative input and output.

	PPH group (n = 57)	Non-PPH group (n = 41)	P value
Intraoperative input/output			
Crystalloid (ml)	2817 ± 807 (2500–3000)	1488 ± 254 (1000–1500)	<0.001
Colloid (ml)	904 ± 146 (1000–1250)	515 ± 88 (400–600)	<0.001
cEBL (ml)	1907 ± 904 (1255–2632)	759 ± 113 (718–841)	<0.001
Urine output (ml)	411 ± 113 (330–480)	215 ± 58 (150–240)	<0.001
Patients with transfusion (n)			
RBC	57 (100.0%)	7 (17.1%)	NA
FFP	12 (21.1%)	2 (4.9%)	0.024
Platelets	5 (8.8%)	1 (2.4%)	0.197
Intraoperative transfusion (unit)[a]			
RBC	3.9 ± 2.4	2.5 ± 1.2	0.136
FFP	2.3 ± 1.9 ()	0	NA
Platelets	0	0	NA
Postoperative transfusion (unit)[a]			
RBC	6.4 ± 2.7	1.1 ± 0.9	<0.001
FFP	4.7 ± 1.9	2.5 ± 0.7	0.142
Platelets	5.8 ± 3.5	5.0	NA

Data were expressed as mean ± standard deviation (interquartile range) or number (%).
PPH, postpartum hemorrhage; RBC, red blood cells; FFP, fresh frozen plasma; cEBL, calculated estimated blood loss; NA, not applicable.
[a] The unit of transfusion was calculated in patients who received transfusion.

postoperative continuing PPH should also be considered in addition to intraoperative bleeding. It is necessary to check whether the significant postoperative FIBTEM A5 results can be a predictor of continuous postoperative PPH or guidance for active transfusion management.

Previously, FFP transfusion based on FIBTEM A5 was reported to be feasible with proper hemostasis in parturients with severe PPH [21]. However, accurate thresholds are still insufficient, and further study should be conducted to determine whether the administration of fibrinogen should be prioritized over FFP or cryoprecipitate because FIBTEM correlated well with fibrinogen. Bell et al. proved that their obstetric bleeding strategy including ROTEM-guided fibrinogen replacement improved the outcomes of parturients with PPH [22], and recently suggested an algorithm for PPH included the fibrinogen as a goal-directed coagulation therapy [11]. Continuing studies will be necessary to confirm the effect of point-of-care coagulation test incorporation for transfusion resuscitation on the prognosis of parturients.

Although EXTEM A5 and PLTEM were different between the PPH and the non-PPH group, the area under the ROC curve of both parameters did not show statistical significances for distinguishing PPH properly. In addition, EXTEM CT and INR were not different between the two groups. There were several reports that EXTEM CT or EXTEM A5 correlated with requirement for massive transfusion [23,24]; however, the present study could not demonstrate the association of EXTEM CT or EXTEM A5 for massive PPH.

PLTEM is known to correlate well with platelet count in cardiac surgery patients [25,26], whereas PLTEM has not been well studied in parturients with PPH. Recent studies on PPH patients have proposed that PLTEM is related to platelet count in PPH patients [8,27]. In our study, only 6 patients (5 in the PPH group and 1 in the non-PPH group) received platelets due to thrombocytopenia $<75{,}000 \times 10^3/\mu l$. Mild thrombocytopenia was not found to be associated with PPH and RBC transfusion after Cesarean section [28]. The ROC curve of PLTEM and PPH does not appear to be significant because our cohort mostly included patients with normal or slightly reduced platelet counts. Whether PLTEM is associated with PPH after Cesarean section should be determined in patients with severe thrombocytopenia.

This study has several limitations. First, the threshold of RBC, FFP, and platelets was not precisely controlled and clinical judgment was intervened, although the transfusion strategies of our departments were generally followed. Massive bleeding caused by PPH sometimes requires a rapid transfusion, so it is difficult to rely on laboratory results every time to determine whether or not to transfusion and the unit of blood products. Based on the last laboratory Hb during the admission period (9.6 ± 1.9 in the PPH group and 10.2 ± 0.5 in the non-PPH group), it is expected that excessive RBC transfusions were rare. Second, 500 ml of HES was administered to all parturients. HES is known to make patients' blood hypocoagulable when tested with ROTEM, although the change is within the normal range [29,30]. Thus, this should be taken into account when interpreting the ROTEM results because HES was used more for volume replacement in the PPH group than in the non-PPH group during the intraoperative period. Last, there were no separate guidelines for fibrinogen administration in this study. Considering that FIBTEM A5 is related to fibrinogen, a fibrinogen administration policy will be required.

In conclusion, postoperative FIBTEM A5, with appropriate selection of the cut-off value, can be a biomarker for more prolonged PPH and massive transfusion following Cesarean section by placenta previa. Further study should be required whether FIBTEM-guided component transfusion decision will improve the postoperative outcomes in Cesarean section due to PPT.

Author contribution statement

Hyun-Jung Shin: Conceived and designed the experiments; Performed the experiments; Analyzed and interpreted the data; Wrote the paper.

Sun Woo Nam: Performed the experiments; Wrote the paper.
Bon-Wook Koo: Analyzed and interpreted the data.
Junkyu Kim: Performed the experiments.
Jung-Won Hwang: Performed the experiments; Contributed reagents, materials, analysis tools or data.
Sang-Hwan Do: Conceived and designed the experiments; Contributed reagents, materials, analysis tools or data. Hyo-Seok Na: Conceived and designed the experiments; Performed the experiments; Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data; Wrote the paper.

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Data availability statement

Data will be made available on request.

Declaration of interest's statement

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data statement

The data are not publicly available due to ethical restrictions of IRB. The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

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