**FIBTEM as a predictor of intra- and postoperative blood loss in revision total hip arthroplasty**

A prospective observational study

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**Abstract**

Revision total hip arthroplasty (THA) may cause intra- and postoperative massive bleeding. This prospective observational study evaluated if the maximum clot firmness of FIBTEM (MCF\textsubscript{FIB}) could act as a predictor of perioperative massive bleeding in revision THA.

Fifty-eight adult patients undergoing revision THA were included. Pre- and postoperative MCF\textsubscript{FIB}, hematomatological and hemostatic laboratory data, as well as the amount of intra- and postoperative blood loss (IBL and PBL) were obtained.

The change rate (MCF\textsubscript{FIB}-C) between the pre- and postoperative MCF\textsubscript{FIB} had a significant correlation with IBL (r = 0.431, P = 0.01). Moreover, PBL had a significant correlation with MCF\textsubscript{FIB}-C (r = 0.292, P = 0.026). The MCF\textsubscript{FIB}-C cut-off value of ≥ 29% showed the highest sensitivity and specificity for predicting IBL ≥ 1000 mL or PBL ≥ 500 mL. The incidence of red blood cell transfusion in the postoperative period was higher in patients showing MCF\textsubscript{FIB}-C ≥ 29% (34% vs 8%, P = 0.015).

The change rate between pre- and postoperative MCF\textsubscript{FIB} values was correlated well with the amount of IBL or PBL. Moreover, particular change rate of MCF\textsubscript{FIB} could predict massive bleeding in revision THA.

**Abbreviations:** α-angle = α angle, CFT = clot formation time, CT = clotting time, IBL = intraoperative blood loss, MCF = maximum clot firmness, MCF\textsubscript{FIB} = maximum clot firmness of FIBTEM, PBL = postoperative blood loss, THA = revision hip arthroplasty.

**Keywords:** blood loss, fibrinogen, FIBTEM, hip arthroplasty, revision

**1. Introduction**

With recent advancements in health care leading to extension of life span, the number of revision surgeries has been increasing. In the United States, the demand for primary total hip arthroplasty (THA) and revision THA is projected to increase by 174% and 137% by 2030, respectively, compared with the demand in 2005.[1]

Revision THA has 2- to 3-fold higher risk of major complications and mortality than primary THA, and it shows less improvement in postoperative functional status than primary THA.[2,3] In addition, revision THA is associated with substantial blood loss, and thus associated with higher probability of perioperative blood transfusion.[4] It has been documented that perioperative blood loss corresponds to approximately 4 units of red blood cells (RBCs), and a mean volume of RBC transfusion was about 3 units in revision hip arthroplasty.[5,6] Perioperative complications and mortality increase as blood loss increases,[7] which could ultimately increase the length of hospital stay and cost.[8] Therefore, it is important to predict the amount of intra- and postoperative blood loss (PBL) and to manage massive bleeding in revision THA appropriately.

Rotational thromboelastometry (ROTEM; Tem International GmbH, Munich, Germany) is one of the point-of-care (POC) tests, which can detect coagulation cascade abnormalities very rapidly and provides comprehensive assessment of the patient’s hemostatic status.[9,10] ROTEM test results can be used to guide coagulation therapy.[11,12] FIBTEM is one of the ROTEM parameters and provides information about the change of fibrinolytic system, including fibrinogen concentration and fibrin polymerization.[13] In recent years, a number of articles have reported the usefulness of ROTEM as a POC device in numerous clinical situations such as emergency care, cardiovascular surgery, liver transplantation, trauma surgery, and septic disseminated intravascular coagulation.[14–17] FIBTEM is reported as an effective early predictor for massive bleeding and transfusion in orthopedic hip surgery and trauma patients.[18,19]

In the present study, we evaluated the association between the maximum clot firmness of FIBTEM (MCF\textsubscript{FIB}) and perioperative blood loss in patients underwent revision THA for the purpose of finding a role of FIBTEM as one of the predictors to estimate massive bleeding in revision THA.

**2. Methods and materials**

**2.1. Study population**

The study was approved by the Institutional Review Board of Seoul National University Bundang Hospital, Seongnam-si, South Korea (protocol B-1502/288-320, March 10, 2015) and registered at the ClinicalTrials.gov (NCT02951741). Written
informed consent was obtained from all patients before participation. This study was conducted in Seoul National University Bundang Hospital between March 2015 and February 2017.

This prospective observational study enrolled 58 patients (age range: 20–85 years) with an American Society of Anesthesiologists physical status of 1 to 3, who were scheduled to undergo revision THA (acetabular, femoral, or dual components) under combined spinal-epidural anesthesia or general anesthesia. Preoperative exclusion criteria were as follows: pre-existing hematological disease, recent medications that may interfere with hemostasis (i.e., antiplatelet agent or anticoagulant), and history of transfusion within 1 month.

2.2. Anesthetic care

On arrival in the operating room, the standard monitoring was applied (pulse oximetry, electrocardiogram, and noninvasive arterial blood pressure). Combined spinal-epidural anesthesia was performed in the usual manner. When combined spinal-epidural anesthesia was impossible, general anesthesia was induced.

Combined spinal-epidural anesthesia was performed with the patients in the lateral decubitus position. After identifying the epidural space using epidural needle at L3–4 or L4–5, spinal needle was then passed through the epidural needle into the intrathecal space and the anesthetic drugs were administered (2.0–2.5 mL of 0.75% levobupivacaine with 15–20 μg of fentanyl). And then, an epidural catheter was placed after removing of the spinal needle. General anesthesia was induced with propofol 1.5 mg/kg, continuous infusion of remifentanil with 3.0 ng/mL via a target-controlled infusion pump (Orchestra; Fresenius Vial, France), and rocuronium 0.6 mg/kg intravenously. After confirming sufficient muscle relaxation using a nerve stimulator, endotracheal intubation was performed. General anesthesia was maintained with sevoflurane and air/O₂ (total fresh gas flow of 3 L/min, F₁O₂ 0.5).

After the completion of anesthetic induction, a 20-gauge angiocatheter was placed in the radial artery to continuously monitor arterial pressure and to perform blood tests. All patients’ upper trunks were covered with a forced-air warming blanket (Bair Hugger 52200; Arizant Healthcare Inc., 3M Company, Eden Prairie, MN) to maintain normal body temperature during surgery.

During the operation, a lactated Ringer’s solution was infused at 6 mL/kg/h as a maintenance fluid, and any intraoperative blood loss (IBL) was replaced with hydroxyethyl starch solution. We followed our transfusion protocol following massive bleeding (Fig. 1). Transfusion of RBCs was triggered when the hemoglobin level fell below 10 g/dL. After more than 4 units of RBC were administered, fresh frozen plasma (FFP) was transfused. Platelets were provided when the platelet count fell below 50,000/μL. Hypotension (systolic arterial pressure < 80% of baseline or < 90 mm Hg) or bradycardia (heart rate < 45 beats/min) was treated with ephedrine, phenylephrine, or atropine, as appropriate.

2.3. Hematologic, hemostatic, and FIBTEM analysis

Laboratory tests were performed at 2 time points: before the initiation of surgery (preoperative) and after the end of surgery (postoperative). Blood sample was collected in ethylenediaminetetraacetic acid (EDTA)-containing tubes (Becton Dickinson, Plymouth, UK) to determine the hemoglobin, hematocrit, and platelet counts. It was also put into citrate-containing tubes to determine the international normalized ratio of prothrombin time (PT-INR), activated partial thromboplastin time (aPTT), fibrinogen levels, and maximum clot firmness of FIBTEM (MCFFIB) (Pentapharm, Munich, Germany).

FIBTEM analyses were conducted according to the manufacturer’s recommendations. We obtained the MCFFIB value, which

![Figure 1. Transfusion protocol. FFP=fresh frozen plasma, Hb=hemoglobin, RBC=red blood cell.](image)
offers information of the change of fibrin polymerization, using the recommended reagent (fib-TEM:0.2 M CaCl2 20 μL with cytochalasin D and tissue factor 20 μL). The normal reference range of MCF_FIB value is 9 to 25 mm. The change rate of MCF_FIB was calculated using the following formula: change rate (\%) = (postoperative MCF_FIB – preoperative MCF_FIB) / postoperative MCF_FIB \times 100.

2.4. Other variables

IBL was calculated using the method described by Choi et al.\(^ {20}\) (volume in suction bottle – amount of irrigation fluid) + amount of blood on the surgical field + amount of blood on surgical pads (fully soaked: 20 mL; half soaked: 10 mL). The amount of blood drained via a hemovac (ID-VAC; Insung Medical Co., Yangpyung, Korea) during the 48-hour postoperative period was measured as the PBL. Crystalloid, colloid, and blood requirements were evaluated during the intra- and postoperative periods.

2.5. Sample size

In our previous study, the range of correlation coefficient between blood loss and MCF_FIB was between -0.297 and -0.475.\(^ {18}\) We assumed that the correlation coefficient between the preoperative MCF_FIB and amount of IBL would be approximately -0.37. Accordingly, we estimated that 55 patients were required aiming at a power of 80% and a type-1 error of 5%. Finally, we determined 62 patients with an overall dropout rate of 10%.

2.6. Statistical analysis

The data were presented as the median (interquartile range) or number (proportion). Wilcoxon signed-rank test was performed to compare the pre- and postoperative values. Spearman rank correlation coefficients were calculated between the amount of blood loss and the other clinical covariates.

The area under the receiver-operating characteristic (ROC) curve was calculated with 95% confidence interval (95% CI), and the most optimal cut-off value was determined in accordance with the sensitivity and specificity. Mann–Whitney U test was performed for subgroup analysis. Incidence was analyzed by Chi-square test or Fisher exact test.

All analyses were carried out using IBM SPSS Statistics version 21.0 (IBM Corporation, Armonk, NY) or Sigma Plot 10.0 (Systat Software, Inc., San Jose, CA), \( P < .05 \) was considered statistically significant.

3. Results

Initially, 70 patients were evaluated for eligibility and 58 patients were finally enrolled for this study (Fig. 2). The characteristics of patients, surgery, and anesthesia are provided in Table 1.

Table 2 summarizes the pre- and postoperative laboratory findings. Postoperative hemoglobin and hematocrit levels, platelets count, fibrinogen level, aPTT, and MCF_FIB were significantly decreased compared with the preoperative values (\( P < .001 \)). Postoperative PT-INR was significantly increased compared with the preoperative one (\( P < .001 \)).

We could not find any significant correlation between the blood loss and various clinical variables, including age, gender, height, weight, body mass index (BMI), type of surgery, anesthesia time, operation time, amounts of crystalloid and colloid infused, intra- and postoperative RBC/FFP transfused. In addition, no preoperative laboratory findings had a significant correlation with IBL and PBL. Postoperative platelet counts (\( p = .303, P = .021 \)), PT-INR (\( p = .461, P < .001 \)), fibrinogen level (\( p = .304, P = .021 \)), and MCF_FIB (\( p = .299, P = .023 \)) showed a significant correlation with IBL. Postoperative Hb (\( p = .283, P = .032 \)) and platelet counts (\( p = .342, P = .009 \)) were correlated with PBL significantly (Table 3).

When we calculated the change rate (\%) of MCF_FIB between the pre- and postoperative periods (MCF_FIB-C), it showed significant correlations with IBL (\( p = .431, P = .001 \)) and PBL (\( p = .032 \)). Postoperative Hb (\( p = .283, P = .032 \)) and platelet counts (\( p = .342, P = .009 \)) were correlated with PBL significantly (Table 3).

![Figure 2. Flow chart.](image)

Table 1

| Variables | Data (n = 58) |
|-----------|--------------|
| Age, y    | 50 (54–69)   |
| Gender (M/F) |            |
| Male      | 30 (62%)    |
| Female    | 28 (48%)    |
| Weight, kg | 62.4 (55.6–72.3) |
| Height, cm | 159.3 (154.0–164.8) |
| BMI, kg/m² | 25.1 (25.1–27.3) |
| ASA (1/2/3) | 15/42/1 (26%/72%/2%) |
| Comorbidities |          |
| Hypertension | 30 (62%)   |
| IHD        | 1 (2%)      |
| Diabetic mellitus | 8 (14%) |
| COPD       | 2 (3%)      |
| CKD        | 1 (2%)      |
| RA         | 1 (2%)      |
| Operation time, min | 175 (140–210) |
| Anesthesia time, min | 230 (195–261) |
| Crystalloid, mL | 1260 (1000–1663) |
| Colloid, mL | 500 (475–900) |
| Intraoperative RBC, units | 2 (0–3) |
| Intraoperative FFP, units | 0 (0–3) |
| Postoperative RBC, units | 0 (0–3) |
| Postoperative FFP, units | 0 (0–3) |
| IBL, mL    | 1000 (600–1350) |
| PBL, ml    | 370 (190–674) |
| Revision components |          |
| Acetabulum | 26 (48%) |
| Femoral stem | 10 (17%)  |
| Dual       | 20 (35%)    |

Data are the median (interquartile range) or number (proportion). ASA = American Society of Anaesthesiologists’ physical status classification, BMI = body mass index, COPD = chronic obstructive pulmonary disease, FFP = fresh frozen plasma, IBL = the amount of intraoperative blood loss, Hb = hemoglobin, IHD = ischemic heart disease, RA = rheumatoid arthritis, RBC = red blood cell.
When creating the ROC curves for MCFFIB-C to predict PBL of ≥ 500 mL, the most proper threshold was MCFFIB-C of 29%. The sensitivity and specificity of MCFFIB-C ≥ 29% for predicting PBL of ≥ 500 mL were 0.72 and 0.50, respectively (Table 4).

When patients were subdivided in accordance with the MCFFIB-C (low MCFFIB-C: <29%, high MCFFIB-C: ≥29%), the 2 groups showed significant differences in the postoperative platelets counts (P = .011) and PT-INR (P = .042) (Table 5). IBL was greater in the high MCFFIB-C group than in the low MCFFIB-C group (P = .001) (Table 5), A significantly larger amount of crystallloid (P = .005) and colloid (P < .001) was given during the operation in the high MCFFIB-C group than in the low MCFFIB-C group (Table 5). The unit or proportion of intraoperative RBC transfusion did not have a significant difference between the 2 groups; however, both the unit (P = .010) and the proportion (P = .015) of RBC transfusion were significantly greater in the high MCFFIB-C group than in the low MCFFIB-C group during the postoperative period (Table 5). During the intra- and postoperative periods, patients in the high MCFFIB-C group received more FFP both in amount (P = .024 and P = .007 at intra- and postoperative time, respectively) and in proportion (P = .028 and P = .005 at intra- and postoperative time, respectively; Table 5) than those in the low MCFFIB-C group.

4. Discussion

In this prospective observational study, we found that the postoperative platelets count and change rate of MCFFIB were correlated well with the amount of PBL in revision THA. Moreover, a specific change rate of MCFFIB could be used as a reference value to identify any increased likelihood of postoperative transfusion. Although several postoperative laboratory values showed a correlation with IBL, they could not act as meaningful factors for predicting IBL.

Revision THA frequently requires RBC transfusion at higher rates than the other orthopedic surgeries. For this reason, various methods have been attempted to reduce the allogenic blood transfusion requirements with its associated adverse effects. The following are ways to conserve blood and avoid transfusion: preoperative platelets are consumed due to bleeding, and volume replacement therapy using crystalloid and colloid cause dilutional coagulopathy via an impairment of fibrinogen/fibrin polymerization.

Despite recent improvements in surgical and anesthetic techniques, revision THA is still associated with significant blood loss and subsequent blood transfusion during the perioperative period. Therefore, it is important to be able to predict the massive bleeding for proper management.

During a major orthopedic surgery, coagulation factors and platelets are consumed due to bleeding, and volume replacement therapy using crystalloid and colloid cause dilutional coagulopathy via an impairment of fibrinogen/fibrin polymerization. Despite recent improvements in surgical and anesthetic techniques, revision THA is still associated with significant blood loss and subsequent blood transfusion during the perioperative period. Therefore, it is important to be able to predict the massive bleeding for proper management.
these factors showed a relatively low correlation coefficient; therefore, it cannot be a good correlation model. Furthermore, although the postoperative platelets count correlated with PBL, it was within the normal range and no additional platelets transfusion was required to reduce bleeding after surgery. The frequency of RBC and FFP transfusion was much higher when the transfusion was required to reduce bleeding after surgery. The therefore, it cannot be a good correlation model. Furthermore, functional decline of bleeding is accompanied with a low absolute values, and the results of this study demonstrate the key need for transfusion after revision THA compared with the single-component (either acetabular or femoral stem) and dual-component revision. Therefore, the range of blood loss was very broad from 500 to 4500mL. This may blunt the strength of correlation between the MCFβ in and postoperative value, PBL = the amount of postoperative blood loss, PT-INR = International normalized ratio of prothrombin time, RBC-I = red blood cell transfused intraoperatively, RBC-P = red blood cell transfused postoperatively.}

Table 5

| Subgroup analysis according to the change rate (%) of MCFβ | Change rate of MCFβ |
|----------------------------------------------------------|---------------------|
|                                                          | Low (< 29%) (n = 26) | High (>29%) (n = 32) |
|                                                          | Preoperative | Postoperative | Preoperative | Postoperative |
| Hb, g/dL                                                  | 12.7 (11.189–14.3) | 11.4 (10.5–12.9) | 13.1 (12.3–14.4) | 11.4 (10.7–12.1) |
| Hct (%)                                                  | 37.9 (35.6–42.8) | 34.7 (31.7–39.5) | 39.3 (37.1–43.1) | 34.2 (31.5–36.4) |
| Platelets, 10^9/L                                         | 271 (221–338) | 215 (155–246) | 247 (202–256) | 163 (123–214) |
| PT-INR                                                   | 1.00 (0.96–1.03) | 1.12 (1.06–1.18) | 1.02 (0.98–1.05) | 1.16 (1.10–1.26) |
| aPTT, s                                                  | 35.3 (33.8–38.7) | 33.1 (30.5–35.1) | 36.3 (32.3–39.5) | 34.5 (30.3–37.3) |
| Fibrinogen, mg/dL                                         | 322 (276–384) | 263 (209–334) | 318 (275–387) | 224 (194–274) |
| MCFβ, mm                                                  | 16 (12–20) | 13 (10–18) | 16 (14–21) | 9 (6–11) |

Data are the median (interquartile range).

aPTT = activated partial thromboplastin time, FFP-I = fresh frozen plasma transfused intraoperatively, FFP-P = fresh frozen plasma transfused postoperatively, Hb = hemoglobin, Hct = hematocrit, BL = the amount of intraoperative blood loss, MCFβ = maximum clot firmness of FIBTEM, MCFβ-c = percentage change of maximum clot firmness of FIBTEM between the pre- and postoperative value, PBL = the amount of postoperative blood loss, PT-INR = International normalized ratio of prothrombin time, RBC-I = red blood cell transfused intraoperatively, RBC-P = red blood cell transfused postoperatively.

* P<0.05
† P<0.01 vs low MCFβ-c.

According to the guidelines from the European Society of Anesthesiology for management of severe perioperative bleeding, treatment with fibrinogen is recommended when significant bleeding is accompanied with a low fibrinogen concentration or functional decline of fibrinogen. In addition, the ROTEM analysis is recently recommended for the management of perioperative bleeding as a POC tool in various guidelines. Especially, fibrinogen replacement therapy can be performed on the basis of the FIBTEM value, which has a strong correlation with the plasma fibrinogen level.

In our transfusion protocol, the Hb level of 10g/dL was used as a trigger of RBC transfusion. When performing RBC transfusion, it is important to consider the condition of patients. However, there are still controversies which transfusion technique is superior between the liberal and the restrictive transfusion in the mortality or morbidity. In addition, RBC:FPF transfusion ratio of 1:1 is recommended as the standard care of massive transfusion. Further study is needed to evaluate the efficacy of transfusion protocol incorporating FIBTEM parameter on the patients’ outcomes after revision THA.

There are limitations to be considered in the present study. First, this study targeted the revision THA, which included both single-component (either acetabular or femoral stem) and dual-component revision. Therefore, the range of blood loss was very broad from 500 to 4500mL. This may blunt the strength of correlation between the MCFβ and blood loss. It is necessary to study the effectiveness of MCFβ in more specific target of revision THA, such as dual-component revision THA. Second, this study did not address the policy of fibrinogen treatment. It will need to be confirmed in the future whether fibrinogen treatment is really necessary and how much fibrinogen should be given in cases of massive bleeding during the revision THA.

In conclusion, the change rate between the pre- and postoperative MCFβ value was correlated well with the amounts of PBL. In addition, a particular value of change rate of MCFβ could offer the predictive standard for the possibility of postoperative transfusion in revision THA. This would allow early and effective management of patients with blood replacement and hemostatic treatment. However, to get more strong predictable values of FIBTEM, further study is required in patients undergoing specific type of surgery (i.e., dual components revision THA).

**Author contributions**

Conceptualization: Byung-Hun Min. Data curation: Byung-Hun Min. Formal analysis: Hyun-Jung Shin. Funding acquisition: Byung-Hun Min.
References

[1] Patel A, Pavlou G, Mujica-Mota RE, et al. The epidemiology of revision total knee and hip arthroplasty in England and Wales: a comparative analysis with projections for the United States. A study using the National Joint Registry dataset. Bone Joint J 2013;95-B:1076–81.

[2] Mahomed NN, Barrett JA, Katz JN, et al. Rates and outcomes of primary and revision total hip replacement in the United States medicare population. J Bone Joint Surg Am 2001;83-A:1622–9.

[3] Katz JN, Losina E, Barrett J, et al. Association between hospital and surgeon procedure volume and outcomes of total hip replacement in the United States medicare population. J Bone Joint Surg Am 2001;83-A:1622–9.

[4] Bridgens JP, Evans CR, Dobson PM, et al. Intraoperative red blood-cell salvage in revision hip surgery. A case-matched study. J Bone Joint Surg Am 2007;89:270–5.

[5] Callaghan JJ, O’Rourke MR, Liu SS. Blood management: issues and options. J Arthroplasty 2005;20:51–4.

[6] Noordm N, Waters TS, Garbuza DS, et al. Tranexamic acid reduces allogenic transfusion in revision hip arthroplasty. Clin Orthop Relat Res 2011;469:541–6.

[7] Mahadevan D, Challet C, Keenan J. Revision total hip replacement: predictors of blood loss, transfusion requirements, and length of hospitalisation. J Orthop Traumatol 2010;11:159–65.

[8] Naphen DR. Anemia and patient blood management in hip and knee surgery: a systematic review of the literature. Anesthesiology 2010;113:482–95.

[9] Johansson PI, Stenshalle J. Effect of haemostatic control resuscitation on mortality in massively bleeding patients: a before and after study. Vox Sang 2009;96:111–8.

[10] Carroll KC, Craft RM, Langdon RJ, et al. Early evaluation of acute traumatic coagulopathy by thrombelastography. Transl Res 2009;154:34–9.

[11] Schoch H, Nienaber U, Hoffer G, et al. Goal-directed coagulation management of major trauma patients using thrombelastometry (ROTEM)-guided administration of fibrinogen concentrate and prothrombin complex concentrate. Crit Care 2010;14:R35.

[12] Rahe-Meyer N, Solomon C, Winterhalter M, et al. Thromboelastometry-guided administration of fibrinogen concentrate for the treatment of excessive intraoperative bleeding in thoracoabdominal aortic aneurysm surgery. J Thorac Cardiovasc Surg 2009;138:694–702.

[13] Bock G, Kokor M, Sznepka M, et al. Platelet reactivity in thrombelastometry. Revision of the FITBEM test: a basic study. Scand J Clin Lab Invest 2017;77:216–22.

[14] Momeni M, Carlier C, Balee P, et al. Fibrinogen concentration significantly decreases after on-pump versus off-pump coronary artery bypass surgery: a systematic point-of-care ROTEM analysis. J Cardiothorac Vasc Anesth 2015;29:5–11.

[15] Koami H, Sakamoto Y, Ohita M, et al. Can rotational thrombelastometry predict septic disseminated intravascular coagulation? Blood Coagul Fibrinolysis 2015;26:778–83.

[16] Schoch H, Cotton R, Inaba K, et al. ROTEM provides early prediction of massive transfusion in trauma. Crit Care 2011;15:R265.

[17] Alamo JM, Leon A, Mellado P, et al. Is “intra-operating room” thrombelastometry useful in liver transplantation? A case-control study in 303 patients. Transplant Proc 2013;45:3637–9.

[18] Na HS, Shin HJ, Do SH. FIBTEM provides prediction of massive bleeding in total hip replacement arthroplasty. Blood Coagul Fibrinolysis 2016;27:340–6.

[19] Vegaa PV, Callium J, Rizoli S, et al. A systematic review on the rotational thrombelastometry (ROTEM(R)) values for the diagnosis of coagulopathy, prediction and guidance of blood transfusion and prediction of mortality in trauma patients. Scand J Trauma Resusc Emerg Med 2016;24:114.

[20] Choi SJ, Aho HJ, Chung SS, et al. Hemostatic and electrolyte effects of hydroxyethyl starches in patients undergoing posterior lumbar interbody fusion using pedicle screws and cages. Spine (Phila Pa 1976) 2010;35:829–34.

[21] Saleh F, McClelland DB, Hay A, et al. Prevalence of anaemia before major joint arthroplasty and the potential impact of preoperative investigation and correction on perioperative blood transfusions. Br J Anaesth 2007;99:801–8.

[22] Tenholder M, Cushner FD. Intraoperative blood management in joint replacement surgery. Orthopedics 2004;27:8663–8.

[23] Lemaire R. Strategies for blood management in orthopaedic and trauma surgery. J Bone Joint Surg Br 2008;90:1128–36.

[24] Ghoz A, Al-Khateeb H, Rajkumar S, et al. Use of a thrombin fibrin sealant in reducing blood loss in revision hip arthroplasty. Open Orthop J 2015;9:511–4.

[25] Mittermayr M, Streif W, Haas T, et al. Hemostatic changes after crystallloid or colloid fluid administration during major orthopedic surgery: the role of fibrinogen administration. Anesth Analg 2007;105:905–17. table of contents.

[26] Zarj N, Grosvenor D, Schurman D, et al. Efficacy of intraoperative blood collection and reinfusion in revision total hip arthroplasty. J Bone Joint Surg Am 2003;85-A:2147–51.

[27] Ketchum L, Hess JR, Huppala S. Indications for early fresh frozen plasma, cryoprecipitate, and platelet transfusion in trauma. J Trauma 2006;60:531–8.

[28] Kozek-Langenecker SA, Afshari A, Albaladejo P, et al. Management of severe perioperative bleeding: guidelines from the European Society of Anaesthesiology. Eur J Anaesthesiol 2013;30:270–382.

[29] Rossaint R, Bouillon B, Cerny V, et al. The European guideline on management of major bleeding and coagulopathy following trauma: fourth edition. Crit Care 2016;20:100.

[30] Force AsaAT. Practice guidelines for perioperative blood management: an updated report by the American Society of Anesthesiologists Task Force on Perioperative Blood Management*. Anesthesiology 2015;122: 241–75.

[31] Huissoud C, Carrabin N, Audibert F, et al. Bedside assessment of fibrinogen level in postpartum haemorrhage by thrombelastometry. BJOG 2009;116:1097–102.

[32] Force ASoAT. Practice guidelines for perioperative blood management: an updated report by the American Society of Anesthesiologists Task Force on Perioperative Blood Management*. Anesthesiology 2015;122: 241–75.

[33] Force AsaAT. Practice guidelines for perioperative blood management: an updated report by the American Society of Anesthesiologists Task Force on Perioperative Blood Management*. Anesthesiology 2015;122: 241–75.

[34] Force AsaAT. Practice guidelines for perioperative blood management: an updated report by the American Society of Anesthesiologists Task Force on Perioperative Blood Management*. Anesthesiology 2015;122: 241–75.