

Thromboelastography after Cardiopulmonary Bypass: Does it Save Blood Products?

Omar Hasan, M.D.¹, Robert C. Tung, M.D.², Hadley Freeman, M.D.¹, Whitney Taylor, M.D.¹, Stephen D. Helmer, Ph.D.¹, Jared Reyes, Ph.D.¹, Brett E. Grizzell, M.D.¹

¹University of Kansas School of Medicine-Wichita, Wichita, KS
Department of Surgery

²Cedars-Sinai Medical Center, Los Angeles, CA
Department of Surgery

Received Aug. 17, 2021; Accepted for publication Oct. 4, 2021; Published online Jan. 11, 2022
<https://doi.org/10.17161/kjmvol15.15789>

ABSTRACT

Introduction. This study aimed to determine if thromboelastography (TEG) is associated with reduced blood product use and surgical re-intervention following cardiopulmonary bypass (CPB) compared to traditional coagulation tests.

Methods. A retrospective review was conducted of 698 patients who underwent CPB at a tertiary-care, community-based, university-affiliated hospital from February 16, 2014 to February 16, 2015 (Period I) and from May 16, 2015 to May 16, 2016 (Period II). Traditional coagulation tests guided transfusion during Period I and TEG guided transfusion during Period II. Intraoperative and postoperative administration of blood products (red blood cells, fresh frozen plasma, platelets, and cryoprecipitate), reoperation for hemorrhage or graft occlusion, duration of mechanical ventilation, hospital length of stay, and mortality were recorded.

Results. Use of a TEG-directed algorithm was associated with a 13.5% absolute reduction in percentage of patients requiring blood products intraoperatively (48.2% vs. 34.7%, $p < 0.001$). TEG resulted in a 64.3% and 43.1% reduction in proportion of patients receiving fresh frozen plasma (FFP) and platelets, respectively, with a 50% reduction in volume of FFP administered (0.3 vs. 0.6 units, $p < 0.001$). Use of TEG was not observed to decrease postoperative blood product usage or mortality significantly. The median length of hospital stay was reduced by one day after TEG guided transfusion was implemented (nine days vs. eight days, $p = 0.01$).

Conclusions. Use of TEG-directed transfusion of blood products following CPB appeared to decrease the need for intraoperative transfusions, but the effect on clinical outcomes has yet to be clearly determined. *Kans J Med* 2022;15:27-30

INTRODUCTION

Reversal of anticoagulation and re-establishment of hemostasis following cardiopulmonary bypass (CPB) always has been a challenge for the surgical team. The accurate assessment of anticoagulant reversal not only affects operative times, but also has significant implications, including use of blood products.¹ Blood product administration carries its own risk profile medically and also results in significant cost to healthcare. Additionally, patients requiring blood transfusion during or after CPB

have increased long-term mortality.² Therefore, accurate assessment of coagulability following CPB best ensures hemostasis and minimizes the unnecessary transfusion of blood products and its associated morbidity and mortality.

Traditional tests for assessment of coagulability include activated clotting time (ACT), partial thromboplastin time (PTT), prothrombin time (PT), fibrinogen level, and platelet count. Collectively, these laboratory tests are used to direct blood product administration following cardiac surgery. However, some evidence suggested that functional coagulation tests, such as thromboelastography (TEG), can lead to reduced blood product transfusion rates following cardiac surgery.³⁻⁷ It was hypothesized that measuring mechanical properties of blood clot formation and fibrinolysis predicts bleeding more accurately as compared to the traditional coagulation assessments. However, little evidence existed showing the ultimate clinical implications of such changes.^{3,5,7} Thus, there is still disagreement as to whether TEG results are equivalent, or superior, to traditional testing.

Some investigators found that TEG findings were not comparable to traditional tests,⁸⁻¹⁰ while Shore-Lesserson et al.⁴ found TEG to be accurate in assessing coagulability and associated with lower transfusion rates. The effect of TEG-directed transfusions following CPB on long- and short-term clinical outcomes such as infections, immunological reactions, or mortality have yet to be determined.¹¹ In an effort to reduce unnecessary transfusions, many hospitals have adopted transfusion protocols, as opposed to clinician-directed transfusion based on professional discretion.¹² As TEG use has been shown to be associated with reduced transfusion rates in the trauma resuscitation setting, it also has been adopted for assessment of coagulability following CPB in some centers.¹³ Therefore, the purpose of this study was to evaluate whether adoption of TEG-directed transfusion for CPB was associated with improved patient outcomes and reduced blood product use.

METHODS

This study was approved for implementation by the Institutional Review Board of Ascension Via Christi Hospitals Wichita, Inc.

A retrospective chart review was conducted of all patients who underwent CPB at a single tertiary-care hospital from February 16, 2014 to February 16, 2015 (Period I) and from May 16, 2015 to May 16, 2016 (Period II). Period I represented a time in which patient coagulability was assessed using traditional coagulation tests (platelets, INR, PTT, ACT, and fibrinogen) and comprised our control group. Period II represented the period in which TEG was implemented fully as the standard for assessment of coagulability intra-operatively and comprised our comparison group. A three-month washout period was implemented for the transition as to allow for adoption of TEG as the primary laboratory test for evaluation of blood coagulability. Patient data during this three-month washout interval between the two periods was not used, as TEG use was initiated at the start of the washout period. Upon completion of the CPB, standard labs including coagulation values and TEG were drawn to direct proper heparin reversal. The TEG specimens were collected with and without heparinase to eliminate confounding from any additional heparin yet to be reversed by protamine. The anesthesia team received the results and directed any need for intraoperative transfusion of blood products.

Data collection was performed by retrospective review of both the local Society of Thoracic Surgeons (STS) registry and patient medical records for those who met inclusion criteria. The information collected from each subject meeting the inclusion criteria included: demographics (age, gender, race), intra-operative and post-operative blood products transfused (packed red blood cells (RBC), fresh frozen plasma, platelets, cryoprecipitate), need for reoperation, length of time on mechanical ventilation, length of hospital stay, and mortality. The TEG values collected and used to evaluate patient coagulability included: reaction time (R), amplification (K), propagation (α -angle), maximum amplitude (MA), clot lysis (CL), and clot stability (LY30%).

Intraoperative transfusions were directed by the cardiac anesthesia team in both periods. For Period II, lab referenced normal values were used to determine necessity of blood product usage based on TEG values.

Patient data were abstracted and summarized as means \pm standard deviations for continuous variables with approximately normal distributions [-N(O,D)]. For ordinal variables and continuous variables with either skewed distributions or distributions not assumed to follow a normal distribution, medians and interquartile ranges are presented. For nominal variables, proportions were used to summarize the data. Comparisons between study groups were made using t-tests for continuous variables that were distributed normally. A Mann-Whitney U test was used to compare variables with skewed or ordinal distributions. Comparisons between nominal variables were completed with the use of a Chi squared test or Fischer's Exact test. All tests were conducted as two-tailed tests and were considered statistically significant if the resultant p value was less than or equal to 0.05. All analyses were conducted using SPSS version 19 (IBM® Corp., Somers, New York).

RESULTS

Overall, there were a total of 689 patients included with 311 (45.1%) in the traditional coagulation testing arm (Period I) and 378 (54.9%) in the TEG testing arm (Period II). There was no significant difference between groups with regard to age or gender; however, there was a slightly higher proportion of Caucasian and Asian patients in the TEG group (Table 1).

A significant difference was observed in blood product administration intra-operatively, with a 13.5% absolute reduction, and 28.0% overall reduction in the percentage of patients in the TEG guided group receiving blood products as compared to those in the control group (34.7% vs. 48.2%, respectively, $p < 0.001$; Table 2). There was no significant difference in proportion of patients receiving RBC's or cryoprecipitate, and the volume of RBCs and cryoprecipitate administered to these patients was also equivalent for those requiring transfusion of these products. As with total intraoperative products received, the proportion of patients requiring transfusion of FFP and platelets was reduced significantly in Period II with a 64.3% and 43.1% overall reduction in proportion of patients needing FFP and platelets, respectively. Those patients requiring FFP also received less FFP in the TEG group intraoperatively. Of all patients requiring FFP, those in the TEG group received 50% less FFP than those in the control group. While fewer patients in the TEG group required platelets, platelet requirements of those needing platelets were not different between the two study

groups. Total volume of blood products received intraoperatively for those patients that required transfusion was not different between the study groups. There was no significant difference observed in the post-operative blood product usage between groups (Table 3).

Table 1. Comparison of demographics between study groups.

Parameter*	Study Period I Coagulation panel guided	Study Period II TEG guided	p Value
Number of observations	311 (45.1%)	378 (54.9%)	---
Age, years	65.4 \pm 11.4	66.4 \pm 12.4	0.284
Male sex	205 (65.9%)	262 (69.3%)	0.343
Race†			0.050
White or Caucasian	252 (85.7%)	332 (89.0%)	
Black or African American	25 (8.5%)	28 (7.5%)	
Asian	6 (2.0%)	11 (2.9%)	
Native American	4 (1.4%)	2 (0.5%)	
Native Hawaiian or Pacific Islander	3 (1.0%)	0(0.0%)	
Other	4 (1.4%)	0 (0.0%)	

*Data are expressed as the number of observation (percent) or Mean \pm SD.
†Variable contains missing values; reported percentages are based on number of cases with values entered.

Table 2. Comparison of intraoperative blood product administration between study groups.

Parameter*	Study Period I Coagulation panel guided	Study Period II TEG guided	p Value
Number of observations	311 (45.1%)	378 (54.9%)	---
Received intraoperative blood products	150 (48.2%)	131 (34.7%)	<0.001
Received red blood cells	99 (31.9%)	97 (25.7%)	0.070
Red blood cell units†	1.3 \pm 1.3; 1 (0 - 2)	1.2 \pm 1.0; 1 (0 - 2)	0.684
Received fresh frozen plasma	39 (12.6%)	17 (4.5%)	<0.001
Fresh frozen plasma units†	0.6 \pm 1.2; 0 (0 - 1)	0.3 \pm .8; 0 (0 - 0)	0.004
Received platelets	85 (27.4%)	59 (15.6%)	<0.001
Platelet units†	0.7 \pm 0.7; 1 (0 - 1)	0.6 \pm .7; 0 (0 - 1)	0.197
Received cryoprecipitate	28 (9.0%)	27 (7.1%)	0.363
Cryoprecipitate units†	0.3 \pm 0.6; 0 (0 - 0)	0.4 \pm .7; 0 (0 - 0)	0.563
Total blood products, units†	2.8 \pm 2.7; 2 (1 - 4)	2.4 \pm 1.8; 2 (1 - 3)	0.414

*Data are expressed as the number of observations, Mean \pm standard deviation, or Median (interquartile range).
†Data provided only for those patients that received that blood product.

Table 3. Comparison of post-operative blood usage between study groups.

Parameter*	Study Period I Coagulation panel guided	Study Period II TEG guided	p Value
Number of observations	311 (45.1%)	378 (54.9%)	---
Received blood products	112 (36.0%)	123 (32.6%)	0.351
Received red blood cells	100 (32.2%)	110 (29.2%)	0.399
Red blood cell units†	1.8 ± 1.5; 1 (1 - 2)	1.9 ± 1.4; 1 (1 - 3)	0.817
Received fresh frozen plasma	14 (4.5%)	9 (2.4%)	0.125
Fresh frozen plasma units†	0.3 ± .8; 0 (0 - 0)	0.1 ± .5; 0 (0 - 0)	0.179
Received platelets	25 (8.0%)	35 (9.3%)	0.565
Platelet units†	0.3 ± .5; 0 (0 - 0)	0.4 ± .7; 0 (0 - 1)	0.210
Received cryoprecipitate	17 (5.5%)	25 (6.6%)	0.525
Cryoprecipitate units†	0.2 ± .5; 0 (0 - 0)	0.3 ± .7; 0 (0 - 0)	0.234
Total blood products, units†	2.5 ± 2.1; 2 (1 - 3)	2.7 ± 2.3; 2 (1 - 3)	0.949

*Data are expressed as the Number of observations, Mean ± standard deviation, or Median (interquartile range).

†Data provided only for those patients that received that blood product.

Quality markers of the STS registry including reoperation for bleeding, reintervention for graft occlusion, mechanical ventilation hours, and mortality were not significantly different between the two groups (Table 4). However, median hospital length of stay was significantly shorter in the TEG guided group (p = 0.010).

Table 4. Comparison of complications and hospital outcomes between study groups.

Parameter	Study Period I Coagulation panel guided	Study Period II TEG guided	p Value
Number of observations	311 (45.1%)	378 (54.9%)	---
Number of coronary grafts	112 (36.0%)	123 (32.6%)	0.351
Reoperation for bleed	100 (32.2%)	110 (29.2%)	0.399
Reintervention for graft occlusion*	1.8 ± 1.5; 1 (1 - 2)	1.9 ± 1.4; 1 (1 - 3)	0.817
Mechanical ventilation hours	7.2 (5.4 - 12.1)	6.5 (5.0 - 11.6)	0.157
Hospital length of stay (d)	9 (7 - 12)	8 (6 - 12)	0.010
Mortality	6 (1.9%)	11 (2.9%)	0.413

*Variable contains missing values; reported percentages are based on number of cases with values entered.

DISCUSSION

Comparisons of TEG-directed transfusion versus traditional coagulation tests directed transfusion have been explored in several different surgical and resuscitation settings.^{5,6,13,14} A review by Wikkelso et al.⁶ found that TEG-directed resuscitation in patients with bleeding may reduce need for blood products. Similarly, a review by Deppe et al.⁷ found that TEG-based coagulation management decreased the risk of allogenic blood product exposure. However, routine use of TEG as a test to measure coagulability in patients needing massive transfusion or with trauma induced coagulopathy have been shown to have variable outcomes.^{11,15} With the hope to reduce transfusion rates, our institution adopted a transfusion model directed by TEG following CPB. This model appeared to be the most successful in the literature thus far for minimizing blood product usage.^{6,12} Our findings were in concordance with this idea as we saw a 13.5% absolute reduction and 28% overall reduction in the percentage of patients requiring blood product usage intraoperatively. However, once patients were deemed to need transfusions, the units of blood products administered per patient (with the exception of FFP) were not significantly different between TEG and traditional coagulation tests groups.

Effect of TEG on Blood Product Use in Cardiac Surgery. Others have found utilization of blood products during complex cardiac procedures to be reduced with implementation of TEG-directed algorithms.^{3,5-7} Bolliger et al.³ found TEG-directed transfusion to result in a 73% decrease in FFP use and a 38% decrease in RBC use. Similarly, Fleming et al.⁵ showed that TEG-directed management of blood product administration during complex cardiac surgeries reduced units of blood products received perioperatively by 40%. However, similar to our study, they found no significant reduction in blood product usage more than 24 hours postoperatively. Shore-Lesserson et al.⁴ found TEG-directed transfusion following cardiac surgery to be restrictive in the transfusion of RBCs, FFP, and platelets. However, unlike our study, and that of Fleming et al.⁵, they also found decreased post-operative transfusions.

Effect of TEG on Clinical Outcomes. We also were interested in the impact of adopting TEG-directed transfusions on the clinical course following CPB related to rebleeding, need for reoperations, and mortality. Re-operative rates for bleeding were similar between treatment groups in our study with five re-explorations for bleeding (1.6%) in Period I and eight re-explorations (2.1%) in Period II. Similarly, some others in the literature also have not found significant differences in re-operation rates when adopting TEG-directed transfusion algorithms.^{5,13} In contrast though, in a review by Deppe et al.⁷, TEG-based coagulation management not only decreased risk of allogenic blood product exposure, but also resulted in a 44% decrease in surgical re-explorations. Impacts on mortality also were not significant both in our findings and by others in the literature.^{3,5,7} Specifically, the review by Bolliger et al.³ found that transfusions triggered by TEG were more restrictive, but they did not observe improvements in mortality or additional clinical outcomes.

Challenges to TEG Implementation. Surgeons have been wary of changes to standard assessments of coagulability because the implications are significant and adjusting to differences in how the values are reported takes time. At our institution, TEG can be reported live in

the operating room as the sample is being processed; however, the final values generally are reported over a period of 30 minutes, and reporting is slower than the traditional coagulation lab result times. Lack of system-wide integration has made it difficult for TEG to function in the same capacity outside the operating room because the proprietary software was not available throughout the entire hospital. This often led the team managing the patient to use traditional coagulability labs beyond the operating room and was a possible reason why we did not show a difference in blood product utilization in the post-operative period. With resolution of this systems limitation, it would be easier to explore the impact of TEG on the post-operative management of patients after CPB at our facility.

Heparinase was used in the TEG samples collected after CPB. This was intended to mitigate the effects of heparinization on the sample given its short half-life and use of protamine. Further analysis directly comparing traditional coagulation tests and TEG with heparinase may be warranted to determine if any discrepancy exists.

Limitations. Our study was limited by its retrospective design. Inconsistency in clinical charting contributed to areas of missing data, as data were collected prior to knowledge of this study. Also, as the study data were collected retrospectively, clinical decision-making dictated timing of lab orders and what labs were ordered, rather than how and when labs would have been ordered in a prospective study setting, and as such may have affected the results obtained. Additionally, our sample size was likely too small to sufficiently analyze the confounding variables on very low occurrence events such as re-operation or mortality. The ability to determine confounding influence of clinical variables also was limited by the retrospective nature of this study. Large randomized prospective trials with strict adherence to transfusion algorithms would be best suited to obtain generalizable conclusions to evaluate the effect of TEG implementation on clinical outcomes including mortality and need for surgical re-intervention.

CONCLUSIONS

Use of a TEG-directed algorithm for transfusion of blood products following CPB appeared to decrease the need for intraoperative transfusions, but effects on other clinical outcomes have yet to be determined clearly. Further investigation with the utilization of TEG throughout the recovery period following CPB may impact utilization of specific blood products. Also, the effect of heparinase on blood product utilization must be clarified further.

REFERENCES

- Eder AF, Chambers LA. Noninfectious complications of blood transfusion. *Arch Pathol Lab Med* 2007; 131(5):708-718. PMID: 17488156.
- Engoren MC, Habib RH, Zacharias A, Schwann TA, Riordan CJ, Durham SJ. Effect of blood transfusion on long-term survival after cardiac operation. *Ann Thorac Surg* 2002; 74(4):1180-1186. PMID: 12400765.
- Bolliger D, Tanaka KA. Roles of thrombelastography and thromboelastometry for patient blood management in cardiac surgery. *Transfus Med Rev* 2013; 27(4):213-220. PMID: 24075802.
- Shore-Lesserson L, Manspeizer HE, DePerio M, Francis S, Vela-Cantos F, Ergin MA. Thromboelastography-guided transfusion algorithm reduces transfusions in complex cardiac surgery. *Anesth Analg* 1999; 88(2):312-319. PMID: 9972747.
- Fleming K, Redfern RE, March RL, et al. TEG-directed transfusion in complex cardiac surgery: Impact on blood product usage. *J Extra Corpor Technol* 2017; 49(4):283-290. PMID: 29302119.

⁶ Wikkelso A, Wetterslev J, Møller AM, Afshari A. Thromboelastography (TEG) or thromboelastometry (ROTEM) to monitor haemostatic treatment versus usual care in adults or children with bleeding. *Cochrane Database Syst Rev* 2016; 2016(8):CD007871. PMID: 27552162.

⁷ Deppe AC, Weber C, Zimmermann J, et al. Point-of-care thromboelastography/thromboelastometry-based coagulation management in cardiac surgery: A meta-analysis of 8332 patients. *J Surg Res* 2016; 203(2):424-433. PMID: 27363652.

⁸ Chen GY, Ou Yang XL, Wu JH, et al. [Comparison of thromboelastography and routine coagulation tests for evaluation of blood coagulation function in patients.] [Chinese] *Zhongguo Shi Yan Xue Ye Xue Za Zhi* 2015; 23(2):546-551. PMID: 25948222.

⁹ Sharma AD, Al-Achi A, Seccombe JF, Hummel R, Preston M, Behrend D. Does incorporation of thromboelastography improve bleeding prediction following adult cardiac surgery? *Blood Coagul Fibrinolysis* 2014; 25(6):561-570. PMID: 24717423.

¹⁰ Ågren A, Wikman AT, Holmström M, Östlund A, Edgren G. Thromboelastography (TEG[®]) compared to conventional coagulation tests in surgical patients—a laboratory evaluation. *Scand J Clin Lab Invest* 2013; 73(3):214-220. PMID: 23402666.

¹¹ Hunt H, Stanworth S, Curry N, et al. Thromboelastography (TEG) and rotational thromboelastography (ROTEM) for trauma induced coagulopathy in adult trauma patients with bleeding. *Cochrane Database Syst Rev* 2015; 2015(2):CD010438. PMID: 25686465.

¹² Avidan MS, Alcock EL, Da Fonseca J, et al. Comparison of structured use of routine laboratory tests or near-patient assessment with clinical judgement in the management of bleeding after cardiac surgery. *Br J Anaesth* 2004; 92(2):178-186. PMID: 14722166.

¹³ Mohamed M, Majeske K, Sachwani GR, Kennedy K, Salib M, McCann M. The impact of early thromboelastography directed therapy in trauma resuscitation. *Scand J Trauma Resusc Emerg Med* 2017; 25(1):99. PMID: 28982391.

¹⁴ Fassl J, Matt P, Eckstein F, et al. Transfusion of allogeneic blood products in proximal aortic surgery with hypothermic circulatory arrest: Effect of thromboelastometry-guided transfusion management. *J Cardiothorac Vasc Anesth* 2013; 27(6):1181-1188. PMID: 23962459.

¹⁵ Afshari A, Wikkelso A, Brok J, Møller AM, Wetterslev J. Thromboelastography (TEG) or thromboelastometry (ROTEM) to monitor haemostasis versus usual care in patients with massive transfusion. *Cochrane Database Syst Rev* 2011; (3):CD007871. PMID: 21412912.

Keywords: surgical blood loss, cardiac anesthesia, cardiopulmonary bypass, thromboelastography