University of Groningen

An Assessment of Clinical Interchangeability of TEG (R) and RoTEM (R) Thromboelastographic Variables in Cardiac Surgical Patients

Venema, L.F.; Post, W.J.; Hendriks, H.G.D.; Huet, R.C.G.; de Wolf, J.T.W.; de Vries, A.J.

Published in:
Anesthesia and Analgesia

DOI:
[10.1213/ANE.0b013e3181e368bc](https://doi.org/10.1213/ANE.0b013e3181e368bc)

IMPORTANT NOTE: You are advised to consult the publisher's version (publisher's PDF) if you wish to cite from it. Please check the document version below.

Document Version
Publisher's PDF, also known as Version of record

Publication date:
2010

[Link to publication in University of Groningen/UMCG research database](#)

Citation for published version (APA):

Venema, L. F., Post, W. J., Hendriks, H. G. D., Huet, R. C. G., de Wolf, J. T. W., & de Vries, A. J. (2010). An Assessment of Clinical Interchangeability of TEG (R) and RoTEM (R) Thromboelastographic Variables in Cardiac Surgical Patients. *Anesthesia and Analgesia*, 111(2), 339-344.
<https://doi.org/10.1213/ANE.0b013e3181e368bc>

Copyright

Other than for strictly personal use, it is not permitted to download or to forward/distribute the text or part of it without the consent of the author(s) and/or copyright holder(s), unless the work is under an open content license (like Creative Commons).

The publication may also be distributed here under the terms of Article 25fa of the Dutch Copyright Act, indicated by the "Taverne" license. More information can be found on the University of Groningen website: <https://www.rug.nl/library/open-access/self-archiving-pure/taverne-amendment>.

Take-down policy

If you believe that this document breaches copyright please contact us providing details, and we will remove access to the work immediately and investigate your claim.

Downloaded from the University of Groningen/UMCG research database (Pure): <http://www.rug.nl/research/portal>. For technical reasons the number of authors shown on this cover page is limited to 10 maximum.

An Assessment of Clinical Interchangeability of TEG[®] and RoTEM[®] Thromboelastographic Variables in Cardiac Surgical Patients

Lieneke F. Venema, MD,* Wendy J. Post, PhD,† Herman G. D. Hendriks, MD, PhD,*
Rolf C. G. Huet, MD, PhD,* Joost Th. W. de Wolf, MD, PhD,‡ and Adrianus J. de Vries, MD, PhD*

BACKGROUND: Bedside thromboelastography is increasingly used, but an assessment of the clinical interchangeability of the 2 major systems, TEG[®] (Hemoscope) and RoTEM[®] (Pentapharm), has not been performed.

METHODS: We measured blood samples from 46 cardiac surgical patients after induction of anesthesia with kaolin TEG[®] (kaoTEG), native TEG[®] (natTEG[®]), intrinsic RoTEM[®] (inTEM), and extrinsic RoTEM (exTEM). Each measurement consisted of reaction time (R), coagulation time (K), maximum amplitude (MA), and angle (α). Bland–Altman plots and mixed-model analysis were used. To assess repeatability, we made 7 replicated measurements in rapid succession in 2 volunteers.

RESULTS: One hundred sixty-six measurements were available for analysis. The R time of the kaoTEG[®] (345 ± 102 seconds, mean $\pm$ sd) was longer than that of the inTEM (179 ± 74 seconds, $P < 0.001$) and the exTEM (55 ± 28 seconds, $P < 0.001$). The K time of the kaoTEG[®] (78 ± 18 s) was not different from that of the inTEM (75 ± 52 seconds, $P = 0.60$) but was longer than the K time of the exTEM (61 ± 24 seconds, $P < 0.003$). The MA of the kaoTEG[®] (71 ± 6.5 mm) was larger than the MA of the inTEM (67 ± 5.2 mm, $P < 0.02$) and almost similar to that of the exTEM (69 ± 6.3 mm). The α of the kaoTEG[®] ($72^\circ \pm 4.1^\circ$) was not significantly different from that of both the inTEM ($76^\circ \pm 7^\circ$) and the exTEM ($79^\circ \pm 4.5^\circ$). The variability for MA and α was $<10\%$. The repeatability of the R and K times was poor in both devices, whereas the repeatability of the MA and α was sufficient for clinical purposes.

CONCLUSIONS: The TEG[®] and RoTEM[®] measurements demonstrated a close correlation for the MA, but the α did not for the R and K variables. The kaoTEG[®] had the best agreement with the exTEM measurement. Therefore TEG[®] and RoTEM[®] measurements are not completely interchangeable, and the clinical interpretation of thromboelastographic data should be used with caution. (Anesth Analg 2010;111:339–44)

Thromboelastography is increasingly used for point-of-care assessment of the viscoelastic clot strength in whole blood. Clinically, 2 major systems are used: the TEG[®] system and the RoTEM[®] system. There are several differences between these 2 systems affecting the results of the measurements. As a consequence, the clinical interpretation of the obtained results with each device may be different.

Simultaneous use of both systems has been reported in clinical settings.^{1–3} Both systems were compared in a laboratory setting with purified and activated plasma.⁴ These studies suggest that the results obtained with both devices are not completely interchangeable.

However, a clinical comparison of both systems has not been performed in patients. This is important, because several transfusion algorithms have been published that use thromboelastography for interventions.^{5–7} In addition, thromboelastography is increasingly used in a variety of conditions to guide clinical management, for example, the

application of recombinant factor VIIa,^{2,8} and the hypercoagulability in patients with malignancies.⁹

The aim of this study was to assess the interchangeability of TEG[®] and RoTEM[®] thromboelastographic variables in a clinical setting with patients scheduled for cardiac surgery in a 2×2 study design (2 devices, 2 different measurements on each device, each measurement consisting of 4 variables) using Bland–Altman (BA) plots and mixed-model analysis. To assess the repeatability of the 2 devices, we made 7 replicated consecutive measurements in 2 volunteers using the same 2×2 design.

METHODS

Study Design

In this study 2 devices were used: the TEG[®] system (Hemoscope, Niles, Illinois) and the RoTEM[®] system (Pentapharm, München, Germany). In the TEG[®] system, 2 measurements were performed: the kaolin TEG[®] (kaoTEG[®], i.e., with the addition of kaolin as activator) and the native TEG[®] (natTEG[®], i.e., without addition of activator). In the RoTEM[®] system 2 measurements were also performed: the intrinsic RoTEM[®] (inTEM, i.e., with the addition of partial thromboplastin/phospholipids and CaCl_2) and the extrinsic RoTEM[®] (exTEM, i.e., with the addition of tissue factor and CaCl_2). For each device, each measurement consisted of the following 4 variables. For the TEG[®]: reaction time (R), the time from the start of the recording until the amplitude reaches 2 mm; coagulation

From the *Department of Anesthesiology, †Department of Epidemiology, and ‡Department of Hematology, University Medical Centre Groningen, University of Groningen, Groningen, The Netherlands.

Accepted for publication February 22, 2010.

Address correspondence to F. Venema, Department of Anesthesiology, University Medical Centre Groningen, University of Groningen, P.O. Box 30.001, 9700 RB Groningen, The Netherlands. Address e-mail to f.venema@anest.umcg.nl.

Copyright © 2010 International Anesthesia Research Society
DOI: 10.1213/ANE.0b013e3181e368bc

time (K), the time from the end of the reaction time until the amplitude reaches 20 mm; maximum amplitude (MA), which represents the absolute strength of the clot; and angle (α), formed by the slope from the R value to the K value. These parameters correspond with the RoTEM[®] for coagulation time (CT), clot formation time (CFT), maximum clot firmness (MCF), and angle (α), respectively. For sake of clarity the abbreviations R, K, MA, and α will be used for both systems.

Patients

After ethical committee approval and written informed consent, 46 patients scheduled for elective cardiac surgery were included. Patients older than 80 years of age and patients with known coagulation abnormalities were excluded. Anticoagulation therapy was discontinued according to institutional guidelines.

Immediately after induction of anesthesia, native blood samples (Vacutainer, 4 mL, BD Diagnostics, Plymouth, United Kingdom) and citrated blood samples (Vacutette, 3.5 mL with sodium citrate 3.2%, Greiner, Austria) were taken from a 20-G radial artery pressure monitoring line without heparin flush. Within 4 minutes after the blood was collected, 1 TEG[®] cup was filled with 360 μ L native blood by using a manually operated micropipette. One milliliter of blood was put into a tube containing the proprietary kaolin/phospholipid mixture, and a second TEG[®] cup with 360 μ L of this kaolin-activated blood was filled. The TEG[®] system was set at 37°C. After installation of the blood samples in the TEG[®] system, the citrated blood sample was used for the RoTEM[®] system, also set at 37°C. Using an electronic calibrated micropipette, we filled 1 RoTEM[®] cup with 20 μ L CaCl₂, 20 μ L partial thromboplastin/phospholipid activator, and 300 μ L of blood according to the instructions on the computer screen to assess the intrinsic coagulation pathway (inTEM). Then, again using an electronic calibrated micropipette, we filled another RoTEM cup with 20 μ L CaCl₂, 20 μ L thromboplastin activator, and 300 μ L of blood according to the instructions on the computer screen to assess the extrinsic coagulation pathway (exTEM).

Repeatability Measurements in 2 Volunteers

The comparison of the repeatability of each method is relevant to method comparison studies, because the reproducibility of 2 methods of measurement limit the amount of agreement that is possible. Therefore 7 blood samples from 2 volunteers were determined in rapid succession. Thus, each of the 7 measurements started with a new venapuncture. After puncture of an antecubital vein with a 21-G Venoject Quick Fit Needle (Terumo, Leuven, Belgium), the tourniquet was removed and free-flowing blood sampled. The first 4 mL was discarded to minimize contamination of the samples by tissue thromboplastins released at the time of venapuncture. Four milliliters of native blood was then collected in a tube without additives (Vacutainer, BD Diagnostics, Plymouth, United Kingdom), and 3.5 mL of blood was collected in a citrated tube (Vacutette, sodium citrate 3.2%, Greiner, Austria). These blood samples were processed by the same operator in the TEG[®] and RoTEM[®] systems as is described above.

Table 1. Number of Outliers in the Variables of Log-Converted TEG[®] and RoTEM[®] Measurements in 46 Patients

Procedure	R	K	MA	α	Sum
natTEG [®]	1	0	1	1	3
kaoTEG [®]	2	0	1	0	3
inTEM	5	2	0	5	12
exTEM	5	0	0	0	5
Sum	13	2	2	6	

Outliers were defined as having values of at least 3 SD from the mean. R, K, MA, and α refer to the elements of the thromboelastographic tracings: R is reaction time, K is coagulation time, MA is maximum amplitude, and α is the angle alpha. KaoTEG[®], the kaolin TEG[®]; natTEG[®], the native TEG[®]; inTEM, intrinsic RoTEM[®]; exTEM, extrinsic RoTEM[®]. There was a difference between the TEG[®] and RoTEM[®] systems ($P < 0.01$, chi-square test).

Table 2. Descriptive Data of the TEG[®] and the RoTEM[®] Systems from 166 Measurements in 46 Patients

	R (seconds)	K (seconds)	MA (mm)	α (degrees)
kaoTEG [®]	345 $\pm$ 102 311–379 156–738	78 $\pm$ 18 72–84 48–126	71 $\pm$ 6.5 69–73 44–82	72 $\pm$ 4.1 71–73 62–79
natTEG [®]	1141 $\pm$ 561 966–1316 228–3768	462 $\pm$ 41 325–600 85–2160	57 $\pm$ 11.8 53–60 26–75	38 $\pm$ 18.3 32–43 7–78
inTEM	179 $\pm$ 74 157–202 0–391	75 $\pm$ 52 59–91 32–294	67 $\pm$ 5.2 65–68 57–78	76 $\pm$ 7.0 74–78 51–83
exTEM	55 $\pm$ 28 46–63 6–166	61 $\pm$ 24 53–68 28–129	69 $\pm$ 6.3 67–71 58–83	78 $\pm$ 4.5 77–80 68–84

Values are given as mean $\pm$ SD (upper row), 95% confidence limits for the mean (middle row), and range (lower row).

R, K, MA, and α refer to the elements of the thromboelastographic tracings: R is reaction time, K is coagulation time, MA is maximum amplitude, and α is the angle alpha. KaoTEG[®], the kaolin TEG[®]; natTEG[®], the native TEG[®]; inTEM, intrinsic RoTEM[®]; exTEM, extrinsic RoTEM[®].

Data Presentation and Statistics

Analysis was performed using BA plots.¹⁰ The BA method calculates the mean difference between the 2 methods of measurement, called the *bias*. The limits of agreement refer to ± 2 standard deviations of the mean difference. These values define the range within which 95% of the differences between measurements by the 2 methods will lie. Because the BA plots suggested a relationship between the difference and the mean, a logarithmic transformation was performed for all data according to Bland and Altman.¹⁰ As a consequence, the bias and the limits of agreement are presented as a dimensionless ratio due to back-transformation.¹¹

This study started as an observational study, and therefore a power analysis was not performed. However, to assess the power of a study, one can also use confidence limits of relevant values. We felt, on the basis of expert opinion, that a difference of 10% of the MA would be clinically relevant. The confidence intervals are presented in Table 3 and are for the kaoTEG[®], the inTEM, and the exTEM within the 10% MA limits. This indicates that the study has sufficient power. To test whether the mean values of the measured variables were equal, we used linear mixed-model statistics (Mlwin version 2.02). A P value ≤ 0.05 was considered significant.

Table 3. Results of the Mixed-Model Analysis of Log-Converted TEG[®] and RoTEM[®] Measurements in 46 Patients

	R	K	MA	α
kaoTEG [®]	1 (0.92–1.08)	1 (0.92–1.08)	1 (0.96–1.04)	1 (0.95–1.05)
inTEM	0.50 (0.41–0.62) <0.001*	0.85 (0.68–0.96) 0.11*	0.94 (0.90–0.99) 0.02*	1.05 (0.92–1.20) 0.43*
exTEM	0.14 (0.12–0.18) <0.001*	0.73 (0.60–0.90) 0.003*	0.98 (0.93–1.03) 0.38*	1.09 (0.96–1.24) 0.17*

Values are given as a ratio with kaoTEG[®] as reference in the upper row. The 95% confidence limits for the ratios are given within parentheses. The *P* values are indicated with an asterisk.

R, K, MA, and α refer to the elements of the thromboelastographic tracings: R is reaction time, K is coagulation time, MA is maximum amplitude, and α is the angle alpha. KaoTEG[®], the kaolin TEG[®]; inTEM, intrinsic RoTEM[®]; exTEM, extrinsic RoTEM[®].

Figure 1. Bland-Altman plots with limits of agreement of the kaolin-activated TEG[®] (kaoTEG) and the RoTEM[®] intrinsic (upper panels; inTEM) and extrinsic (lower panels; exTEM) activated coagulation in 46 patients presenting for cardiac surgery. Data were log converted; see text. Reaction time (R), the time from the start of the recording until the amplitude reaches 2 mm; coagulation time (K), the time from the end of the reaction time until the amplitude reaches 20 mm; maximum amplitude (MA), which represents the absolute strength of the clot; and angle (α), formed by the slope from the R value to the K value.

Thus, the mixed-model analysis reflects the differences between the groups, whereas the BA plots reflect the individual measurements.

RESULTS

The 46 patients (34 men and 12 women) were 66.8 ± 11.3 years old and had scheduled first-time surgery for coronary artery bypass grafting ($n = 29$), aortic valve replacement ($n = 10$), or a combination ($n = 7$). In total there were $46 \times 4 = 184$ measurements. Seventeen measurements were missing (device used for other patient (3), run out of reagent (3) or cup (1), wrong site of blood collection (2), technical computer failure (2), do not know(6)), leaving 167 measurements for analysis. From the 167 available separate measurements the number of outliers, defined as values exceeding at least 3 standard deviations, was determined. This is shown in Table 1. Most of the outliers were in the R time. Table 1 also suggests that outliers occurred more in the RoTEM[®] than in the TEG[®] measurements. The outliers were included in the statistical analysis. However, if at least 3 variables of 1 measurement were designated as outlier, this measurement was discarded. Therefore, 1 additional measurement (inTEM) was discarded, leaving a total number of 166 measurements for analysis.

KaoTEG[®] Versus inTEM

The kaoTEG[®] had a longer R time than did the inTEM ($P < 0.001$, Tables 2 and Table 3). The kaoTEG[®] R time had a bias of 0.76, indicating that the kaoTEG[®] R time was about twice the inTEM R time ($e^{0.76} = 2.14$; Fig. 1, panel A). In contrast, the kaoTEG[®] K time was not different from the inTEM K time ($P = 0.11$, Table 3). The K time had a bias of 0.22 with wide limits of agreement. This was caused by 2 extreme measurements, as is shown in Figure 1, panel B. Omitting these 2 extreme measurements resulted in an improvement of the limits of agreement from $-0.6/1.1$ to $-0.3/0.9$, about 30%. The MA had a small bias of 0.05 (Fig. 1, panel C) and a good agreement, indicating that the MA could be used interchangeably. The α also had a low bias and a good agreement (Fig. 1, panel D).

KaoTEG[®] Versus exTEM

The kaoTEG[®] had a longer R time than did the exTEM ($P < 0.001$, Tables 2, 3) with a large variability. This resulted in a high bias of 1.97, indicating that the kaoTEG[®] R time was about 7 times larger than was the exTEM R time ($e^{1.97} = 7.2$; Fig. 1, panel E). The K time did not agree either. The bias was 0.36 with wide limits of agreement, quite similar to the limits of agreement of the inTEM measurements (Fig. 1,

Table 4. Repeatability Assessment from 7 Samples in 2 Volunteers

	Subject	R (seconds)	K (seconds)	MA (mm)	α (degrees)
kaoTEG [®]	1	367 $\pm$ 98	98 $\pm$ 12	69 $\pm$ 2.5	67 $\pm$ 2.4
		276–456	86–109	67–72	65–70
		198–498	84–120	66–73	64–71
	2	319 $\pm$ 47	83 $\pm$ 7.3	65 $\pm$ 4.2	70 $\pm$ 1.6
		276–360	76–90	61–69	69–72
		266–420	78–108	60–70	69–73
natTEG [®]	1	1114 $\pm$ 187	543 $\pm$ 75	47 $\pm$ 6.9	24.3 $\pm$ 4.1
		918–1308	464–622	40–55	20–29
		948–1398	444–606	34–53	21–29
	2	922 $\pm$ 266	428 $\pm$ 51	49 $\pm$ 2.4	29.6 $\pm$ 3.1
		678–1170	380–475	47–51	27–32
		498–1332	372–492	44–52	27–35
inTEM	1	280 $\pm$ 59	105 $\pm$ 32	63 $\pm$ 4.2	70 $\pm$ 5.3
		225–334	75–134	59–67	65–75
		191–348	69–147	54–66	63–76
	2	283 $\pm$ 99	96 $\pm$ 43	62 $\pm$ 1.9	72 $\pm$ 8.0
		191–374	56–136	60–64	65–79
		141–379	48–178	60–66	57–81
exTEM	1	44 $\pm$ 20.7	59 $\pm$ 10.7	69 $\pm$ 1.0	79 $\pm$ 2.8
		24–63	49–69	68–70	76–81
		10–78	46–79	68–70	74–82
	2	70 $\pm$ 51.6	85 $\pm$ 11.5	62 $\pm$ 1.8	73 $\pm$ 2.3
		23–118	74–96	61–64	71–75
		38–186	75–101	59–64	70–75

Values are given as mean $\pm$ SD (upper row), 95% confidence limits for the mean (middle row), and range (lower row).

R, K, MA, and α refer to the elements of the thromboelastographic tracings: R is reaction time, K is coagulation time, MA is maximum amplitude, and α is the angle alpha. KaoTEG[®], the kaolin TEG[®]; natTEG[®], the native TEG[®]; inTEM, intrinsic RoTEM[®]; exTEM, extrinsic RoTEM[®].

panels F and B). Both MA and α had a small bias (0.01 and 0.10) and a good agreement (Fig. 1, panels G and H). The exTEM MA is slightly closer to the kao MA than is the inTEM MA.

NatTEG

Because of the fact that in the natTEG[®] measurements no activator was added, the R time and the K time were naturally longer than those of the other measurements (Table 2). Similarly, the MA and α were smaller than in the other measurements. However, the variability in the measurements had a similar pattern, as in the other 3 types of measurement (Table 2).

Repeatability Measurements

The variability for the R and K times was in both devices greater than that for the MA and α (Table 4). The repeatability of the R time was poor. The repeatability of the K time was slightly better, but only the repeatability of the MA and α , with variability $<10\%$, would be sufficient for clinical purposes. The kaoTEG[®] measurements showed the best repeatability in the TEG[®] device, whereas the exTEM measurements showed the best repeatability in the RoTEM[®] device.

DISCUSSION

This study has 2 important findings. First, it demonstrates that the MA and the α correlate between both devices, whereas the R and K times had variability. Second, on the basis of the reproducibility and the good agreement of the

MA and α , the kaoTEG[®] and the exTEM had the best agreement.

Previous reports note differences that exist between the TEG[®] and the RoTEM[®] systems.^{12,13} First, in the TEG[®] system the cuvette with blood rotates around a fixed wire. In the RoTEM[®] system the wire rotates in a fixed cuvette with blood. Important differences as a result of friction forces could be reflected in the MA values, but was not found in our study. The MA and α measurements had a low bias and a good precision in the activated samples in both devices, suggesting that rotation of the wire or rotation of the cup does not influence the MA or α .

A second difference between the TEG[®] and RoTEM[®] systems is the larger and less diluted blood volume in the cuvette of the TEG[®] system. This might have implications for the R and K times. Ruttman et al. demonstrated an increased coagulation profile with a shortening of the R and K times after dilution with normal saline.¹⁴ Nielsen also found a shortening of the R time after dilution.¹⁵ In the RoTEM[®] system the blood is diluted by about 10%. This may in part explain the faster onset of the coagulation in the RoTEM[®] system, and could also explain the differences in R time that we found while the K time was similar in the kaoTEG[®] and the inTEM because the dilution effects were most obvious in the R time.¹⁴

Third, in the TEG[®] system a kaolin/phospholipid mixture is commonly used as activator of the coagulation process, whereas in the RoTEM[®] system either partial thromboplastin/phospholipid (inTEM) or thromboplastin extracted from rabbit brain (exTEM) is used. We found that the kaoTEG[®] measurements had the best agreement with the exTEM measurements, and on the basis of the type of activator, agreement with the inTEM measurements was more likely. However, this agreement does not necessarily mean that the mechanism is similar. The data also suggest that the type of activator is important. We found the shortest times to clot formation in the exTEM measurements. Tissue factor is a potent activator of coagulation.¹⁶ Our data suggest that a potent activator such as tissue factor shortens the time to obtain results but does this at the cost of a reduced repeatability of R and K values of the measurements. This is in contrast to the findings of Sorensen et al. Using a velocity-based TEG[®] parameter, they found that the variability of the measurement decreased with the addition of tissue factor.¹⁶ Nielsen also found in his in vitro study a shorter R time in the inTEM measurement with an almost similar variability in the kaoTEG[®] and the inTEM, but did not give data for the K time.⁴

The addition of an activator did not result in different MAs in either system. Our data suggest that once the incubation with activator is completed, the further the measured coagulation process is activator independent. One explanation may be that once thrombin is generated, indicated by the R time, the final step of fibrin polymerization, indicated by the MA, is minimally affected. This is supported by the findings of Taketomi et al., who demonstrated that once a certain thrombin level was present, α and MA values were relatively constant.¹⁷ Sorensen et al. reported that the initial activation of the coagulation system determined the thrombin burst, indicating that a higher initial activation should result in a higher MA.¹⁶ On the

other hand, Nielsen et al. found a reduction in MA when more tissue factor was added.¹⁸

Several studies addressed normal values and inter- and intraobserver variability of the TEG[®] and the RoTEM[®] systems.^{4,19–21} Some interassay observations had a high agreement. However, these observations were made with plasma in a strict laboratory setting. We found larger differences. Our repeatability measurements also included the retrieval of blood from the volunteers and were therefore not limited to the performance of the devices itself. In our view this most accurately represents the actual clinical point-of-care use of these devices. Thromboelastography is listed as a moderate complexity test by the Clinical Laboratory Improvement Amendment (Centers for Disease Control and Prevention, Atlanta, Georgia), requiring certain operator skills. In our study the measurements in the patients were performed by 4 investigators and in the volunteers by 1 investigator. The similar variability in the patient and volunteer observations suggests that interobserver effects are limited. However, this should be the subject of further study, because in daily practice different measurements may be performed for 1 patient by different observers.

Outliers influence the limits of agreement. Omitting the 2 extreme measurements shown in Figure 1, panel B, resulted in improvement in the limits of agreement of 30%. Outliers were included in the statistical analysis, except for 1 measurement (inTEM) that consisted of 3 outlier values. The other measurements of this patient (kaoTEG[®], inTEM, and exTEM) did not demonstrate outlier values. Therefore, it is likely that there were inaccuracies with the inTEM measurement itself.

Repeated measurements in the patient group would have improved the relevance of the data as proposed by Bland and Altman,¹⁰ but this approach was not feasible because of the long duration of the natTEG[®] measurements. We performed repeated measurements in 2 volunteers and found similar, acceptable variability in both. There is no reason to believe that the degree of within-subject variability would be significantly different in different subjects.

Another limitation is the number of missing data. Seventeen of 184 measurements were missing. It is important, however, in that these failures occurred in a random order and were not attributable to 1 device or 1 measurement. Thus it is highly unlikely that these missing data would affect the reported results.²⁰

This study may have clinical implications. Several transfusion algorithms use the R time to guide the transfusion of freshly frozen plasma and platelet concentrates.^{5–7,22} This study demonstrates that this determination has large variability in both devices. Thus, transfusion algorithms based on these determination are likely to be affected by type I errors, and therefore each device should be individually tested in parallel with more conventional laboratory determinations (prothrombin time, activated partial thromboplastin time, fibrinogen) to determine whether they are useful for guiding freshly frozen plasma transfusion. When α or MA values are used to guide cryoprecipitate or fibrinogen concentrate, either device seems to be reasonable.

Another drawback of transfusion algorithms using thromboelastography is that reference values are used from the normal population. Only Lang et al. presented normal values for cardiac surgical patients, who are different from the normal population.²⁰ Our data agree with their values. One additional benefit of this study is that we obtained normal values for a typical population of cardiac surgical patients for both devices.

In conclusion, the TEG[®] and the RoTEM[®] measurements correlated for the MA and the α , but not for the R and K. The measurements that are obtained with these 2 devices are therefore not completely interchangeable in a clinical setting, although the kaoTEG[®] correlated with the exTEM measurements. Given the poor repeatability of R and K times and the different patient populations and settings in which the devices are used, these measurements should be used with caution. The measurements of MA and α could be used interchangeably for both devices, but for a proper interpretation the whole coagulation process should be considered. ■■

REFERENCES

1. Coakley M, Reddy K, Mackie I, Mallett S. Transfusion triggers in orthotopic liver transplantation: a comparison of the thromboelastometry analyzer, the thromboelastogram, and conventional coagulation tests. *J Cardiothorac Vasc Anesth* 2006;20:548–53
2. Carr ME, Martin EJ, Kuhn JG, Ambrose H, Fern S, Bryant PC. Monitoring of hemostatic status in four patients being treated with recombinant factor VIIa. *Clin Lab* 2004;50:529–38
3. Pivalizza EG, Escobar MA. Thromboelastography-guided factor VIIa therapy in a surgical patient with severe hemophilia and factor VIII inhibitor. *Anesth Analg* 2008;107:398–401
4. Nielsen VG. A comparison of the Thrombelastograph and the ROTEM. *Blood Coagul Fibrinolysis* 2007;18:247–52
5. Royston D, von Kier S. Reduced haemostatic factor transfusion using heparinase-modified thrombelastography during cardiopulmonary bypass. *Br J Anaesth* 2001;86:575–8
6. Spiess BD, Gillies BS, Chandler W, Verrier E. Changes in transfusion therapy and reexploration rate after institution of a blood management program in cardiac surgical patients. *J Cardiothorac Vasc Anesth* 1995;9:168–73
7. Spalding GJ, Hartrumpf M, Sierig T, Oesberg N, Kirschke CG, Albes JM. Cost reduction of perioperative coagulation management in cardiac surgery: value of 'bedside' thromboelastography (ROTEM). *Eur J Cardiothorac Surg* 2007;31:1052–7
8. James KM, Melikian CN, Chowdary P, Mallett SV. Thromboelastography-guided recombinant factor VIIa administration in a patient with refractory autoimmune idiopathic thrombocytopenia. *Anesth Analg* 2008;107:402–5
9. Francis JL, Francis DA, Gunathilagan GJ. Assessment of hypercoagulability in patients with cancer using the Sonoclot Analyzer and thromboelastography. *Thromb Res* 1994;74:335–46
10. Bland JM, Altman DG. Statistical methods for assessing agreement between two methods of clinical measurement. *Lancet* 1986;1(8476):307–10
11. Bland JM, Altman DG. Measuring agreement in method comparison studies. *Stat Methods Med Res* 1999;8:135
12. Luddington RJ. Thromboelastography/thromboelastometry. *Clin Lab Haematol* 2005;27:81–90
13. Ganter MT, Hofer CK. Coagulation monitoring: Current techniques and clinical use of viscoelastic point-of-care coagulation devices. *Anesth Analg* 2008;106:1366–75
14. Ruttman TG, Lemmens HJ, Malott KA, Brock-Utne JG. The haemodilution enhanced onset of coagulation as measured by the thrombelastogram is transient. *Eur J Anaesthesiol* 2006;23:574–9

15. Nielsen VG. Effects of PentaLyte and Voluven hemodilution on plasma coagulation kinetics in the rabbit: role of thrombin-fibrinogen and factor XIII-fibrin polymer interactions. *Acta Anaesthesiol Scand* 2005;49:1263–71
16. Sorensen B, Johansen P, Christiansen K, Woelke M, Ingerslev J. Whole blood coagulation thrombelastographic profiles employing minimal tissue factor activation. *J Thromb Haemost* 2003;1:551–8
17. Taketomi T, Szlam F, Vinten-Johansen J, Levy JH, Tanaka KA. Thrombin-activated thrombelastography for evaluation of thrombin interaction with thrombin inhibitors. *Blood Coag Fibrinolysis* 2007;18:761–7
18. Nielsen VG, Audu P, Cankovic L, Lyster RT, Steenwyk BL, Armstead V, Powell G. Qualitative thrombelastographic detection of tissue factor in human plasma. *Anesth Analg* 2007;104:59–64
19. Artang R, Jensen E, Pedersen F, Frandsen NJ. Thromboelastography in healthy volunteers, patients with stable angina and acute chest pain. *Thromb Res* 2000;97:499–503
20. Lang T, Bauters A, Braun SL, Poetzsch B, Von Pape KW, Kolde HJ, Lakner H. Multi-centre investigation on reference ranges for ROTEM thromboelastometry. *Blood Coagul Fibrinolysis* 2005;16:301–10
21. Rubin DB. Inference and missing data. *Biometrika* 1976;63:581–92
22. 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;88:312–9