ORIGINAL RESEARCH

The Other Side of the Coin: Using Rotational Thromboelastometry to Stop or Avoid Blood Transfusions in Trauma Patients

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Abstract

Aim: To assess rotational thromboelastometry (ROTEM) as a tool to stop or avoid unnecessary transfusions in trauma patients.

Materials and methods: Retrospective analysis in a period of 12 months, including all adult patients with a ROTEM assay upon arrival. In an initial analysis, patients were assigned to one of the two groups—"normal (NL) ROTEM" or "abnormal ROTEM." The "NL ROTEM" group had all ROTEM parameters within the normal range. Sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), and odds ratio (OR) were calculated, which was repeated in subgroups of patients with ISS ≥ 16 and with systolic blood pressure (SBP) ≤90 mm Hg. In a second analysis, prediction models for the transfusion of each blood product were created by multivariate logistic regression, including all ROTEM parameters and the SBP on hospital admission. The prediction models were analyzed by the area under the receiver operating characteristics curve (AUROC).

Results: A total of 793 patients fulfilled the inclusion criteria (80.2% blunt trauma and 73.5% male). NL ROTEM was observed in 604 (76.2%) patients. The NL ROTEM NPV for transfusion of any blood product (BBP), plasma (PLS), platelets (PLT), and >9 units of red blood cells (>9 RBC) were, respectively, 94.7, 98.3, 98.8, and 99.7%. Regarding patients with ISS ≥ 16, the NL ROTEM NPV for BBP, PLS, PLT, and >9 RBC were, respectively, 83.8, 92.5, 96.3, and 98.8%. In the subgroup of patients admitted with SBP ≤ 90 mm Hg, NL ROTEM predicted 93.3% of cases in which massive transfusion did not happen. Considering all patients, the AUC observed for the prediction model of >9 RBC was 0.982.

Conclusion: Patients with an NL ROTEM assay at admission had a lower need for blood transfusions in the first 24 hours after trauma, even in subgroups sustaining severe injuries and hemodynamic instability.

Clinical significance: The NL ROTEM seems to be a useful tool to avoid transfusions in trauma patients.

Keywords: Blood transfusion, Coagulopathy, Diagnostics, Hemorrhage, Injury, Massive transfusion, Rotational thromboelastometry, Shock, Trauma, Viscoelastic.

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Introduction

Despite the recent advances in the evaluation and management, coagulopathy and hemorrhage remain major causes of death and morbidity in trauma.[1] Trauma-induced coagulopathy (TIC) is an early event associated with shock (hypoperfusion) and tissue destruction (severity of trauma).[2] The recognition of the importance and frequency of TIC and the enormous modifications adopted to address it have led to a revolution in trauma resuscitation in the XXI century.[3] Crystalloid restriction and early transfusion of blood products aiming to correct hypovolemia and TIC are the new an widely-implemented standards of trauma resuscitation[4].

The ideal management of TIC, however, is still open to debate. Early PLS, PLT, and RBC concentrate in preestablished ratios of 1:1:2 (or 1:1:1), as well as the use of hemostatic agents such as tranexamic acid (TXA), are among the most widely adopted strategies.[4,5] The role of static coagulation tests is debatable due to major limitations in diagnosing and guiding the early management of TIC in complex trauma patients. Consequently, most surgeons blindly initiate blood transfusions during early resuscitation of patients with apparent significant bleeding prior to confirming the diagnosis of TIC and irrespective of the lab coagulation tests. Despite only one out of four (25%) severely injured patients having TIC, empiric early blood product transfusion is widely accepted as the current gold standard for trauma resuscitation.[6]

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However, empiric resuscitation with early transfusion of large amounts of blood and blood products to severely injured patients has drawbacks. The correct time to initiate or to stop blood transfusion cannot be objectively determined, and most massive transfusion protocols (MTP) are initiated at the physician's discretion (gestalt). There are numerous scoring systems that assist physicians

in making the clinical decision to initiate transfusion protocols. Invariably the existing scoring systems are openly considered insufficient, frequently leading to inappropriate MTP activations and irrational transfusions.[7,8] Furthermore, inappropriate blood transfusions, particularly to patients without TIC, have significant harmful side effects, and also blood products are costly and scarce. Inappropriate blood transfusions are becoming more common in trauma resuscitation,[9] as well as their consequences such as acute lung injury, multiple organ failure, thromboembolic events, increase in costs, and resource utilization, among others.[10,11]

In view of the central role of blood product transfusion in the early management of TIC and the limitations of static coagulation tests to diagnose and direct TIC management, a growing number of studies have proposed the use of viscoelastic hemostatic assays (VHA), particularly TEG® (Thromboelastography, Haemonetics Corporation, United States of America) and ROTEM® (ROTEM, Werfen International).[12] Three recent randomized control trials (RCT) demonstrated the superiority of viscoelastic assays in diagnosing and guiding the management of injured patients, which may have reduced mortality.[13–15] Gonzales et al., in an RCT, observed that the use of a TEG-based resuscitation protocol led to a significant reduction in mortality.[16] VHA are known to predict coagulopathy and the need and type of transfusion, thereby reducing inappropriate blood transfusion and being cost-effective. Other studies also suggested that viscoelastic-based resuscitation is superior to empiric or static lab test-based management, with a significant impact on mortality. European and North American Societies guidelines recommend the use of TEG/ROTEM-based protocols.[17,18]

Nevertheless, definitive evidence supporting the use of viscoelastic tests in trauma is still lacking.[19–21] Irrespective of the growing role of VHA in trauma, no study to date has explored whether they could be used to stop ongoing blood transfusions or even prevent the initiation of transfusion protocols in early trauma resuscitation.

We hypothesize that ROTEM is a tool that could be used not only to trigger but also to halt the initiation or to discontinue blood transfusion in early trauma resuscitation. Our objective is to assess ROTEM as a tool to stop or avoid unnecessary transfusions in trauma patients.

Materials and Methods

The Ethics Review Board of the hospital approved the study (REB **#:** 15-339).

We performed a retrospective cohort analysis of all injured adult (over 14 years of age) patients admitted to the trauma center (level I) over a 12-month period starting in November 2014. Only patients with a ROTEM viscoelastic assay performed on hospital arrival were included. The following data was collected from all patients—mechanisms of trauma, vital signs, static laboratory tests [international normalized ratio (INR), partial thromboplastin time (PTT), complete blood count (CBC) including PLT count] done in the first 24 hours of hospital admission, base deficit, ROTEM assays, and ISS as per the abbreviated injury scale (AIS-2005). Patients were considered "stable" if the SBP on admission was higher than 90 mm Hg and the concomitant heart rate was below 100 bpm.

During the study period, all decisions concerning blood transfusion, including initiation of the MTP, were mostly clinical decisions by the lead physician and not based on any lab test results, including ROTEM. Lead physician's discretion also dictates TXA administration, commonly of 2 gm and given liberally to potentially bleeding patients, as in the CRASH-2 trial.[5]

The study analyzed the following ROTEM parameters—EXTEM Coagulation Time (CT), EXTEM Clot firmness (Amplitude) at 10 min (A10), EXTEM Maximum Clot Firmness (MCF), EXTEM Clot Formation Time (CFT), EXTEM maximum lysis (ML), EXTEM Angle, FIBTEM A10, and FIBTEM MCF. The normal range of the ROTEM parameters was established by the manufacturer.

The use of blood bank products in the first 24 hours after admission was defined by the following variables:

- BBP: Transfusion of any blood product.
- RBC: Transfusion of any amount of red blood cells.
- PLS: Transfusion of any amount of plasma.
- PTL: Transfusion of any amount of platelets.
- CRY: Transfusion of any amount of cryoprecipitate.
- PL-PT-CRY: Transfusion of any amount of plasma, platelets, or cryoprecipitate.
- RBC > 9: Transfusion of 10 or more units of RBC.
- RBC > 5: Transfusion of 6 or more RBC.
- PLS > 5: Transfusion of 6 or more units of plasma.
- PTL2: Transfusion of 2 or more apheresis platelets.
- CRY2: Transfusion of 2 or more units of cryoprecipitate.

The association between ROTEM and blood products transfusion was assessed in two ways:

The "ROTEM" Variable

Patients were assigned to one of two groups—"NL ROTEM" or "abnormal ROTEM." The "NL ROTEM" group had all ROTEM parameters within the normal range. The "abnormal" group had a single, multiple, or all ROTEM parameters outside the normal range. The two groups (NL or abnormal ROTEM) were compared according to the blood product transfusion (abovementioned variables) in 2 × 2 tables. Sensitivity, specificity, PPV, NPV, and OR were calculated. Chi-squared and Fisher's exact tests were used for statistical analysis, considering $p < 0.05$ as significant. The Statistical Package for the Social Sciences 23.0 software (IBM) was used for the analysis. This analysis was then repeated in two subgroups of patients, those with an ISS ≥ 16 (severe trauma) and SBP ≤ 90 mm Hg (shock). The NPV and OR (95% interval) were calculated. Prediction models derived from the ROTEM parameters and SBP.

For each blood product variable, a multivariate logistic regression analysis was carried out by the "enter" method, including all ROTEM parameters, as well as the systolic SBP on hospital admission. The prediction models were analyzed by the AUROC. This analysis was repeated for the RBC10 variable in the subgroups of patients with ISS ≥ 16 and SBP of <100 mm Hg.

Results

From November 2014 to November 2015 (12-month study period), a total of 793 adult patients were admitted to the trauma center and had a ROTEM assay on arrival.

Descriptive data of the sample are depicted in (Table 1). Blunt trauma accounted for 80.2% of the admissions, and 73.5% of the patients were male. Age ranged from 15–96 years old, with a median of 42 (28–58 years old). A total of 46 patients (5.8%) had SBP ≤ 90 mm Hg on admission, and 161 (20.3%) sustained a significant traumatic brain injury defined as AIS head >2. ISS ranged from 1 to 75, with a median of 9 (2–19), and 269 patients suffered a severe trauma defined as an ISS ≥ 16 (33.9%).

Table 1: General characteristics of the sample. Continuous variables are depicted as median and interquartile ranges (25th and 75th percentile)

Variable	*Description*
Number of patients	793
Gender, male (%)	583 (73.5)
Age, years	42 (28–58)
Trauma mechanism, blunt (%)	636 (80.2)
SBP, mm Hg	135 (120–149)
SBP <90 mm Hg, *N* (%)	46 (5.8)
AIS Head > 2, *N* (%)	161 (20.3)
ISS	9 (2–19)
ISS >15, *N* (%)	269 (33.9)
BBP, *N* (%)	92 (11.6)
RBC, *N* (%)	86 (10.8)
PLS, *N* (%)	34 (4.3)
PTL, *N* (%)	28 (3.5)
CRY, *N* (%)	39 (4.3)
RBC10, *N* (%)	13 (1.6)
RBC6, *N* (%)	21 (2.6)
PLS6, *N* (%)	13 (1.6)
CRY2, *N* (%)	11 (1.4)
PTL2, *N* (%)	12 (1.5)
EXTEM CT	69 (61–76)
EXTEM CFT	85 (73–101)
EXTEM A10	55 (51–59)
EXTEM MCF	63 (59–66)
EXTEM ML	6 (4–9)
EXTEM Angle	73 (70–75)
FIBTEM A10	15 (12–18)
FIBTEM MCF	16 (13–20)
NL ROTEM, *N* (%)	604 (76.2)
Tranexamic acid trauma bay, *N* (%)	152 (19.2)

BBP, transfusion of any blood product; CRY, transfusion of any amount of cryoprecipitate; RBC, transfusion of any amount of red blood cells; CRY2, transfusion of 2 or more units of cryoprecipitate; PLS, transfusion of any amount of plasma; PTL, transfusion of any amount of platelets; PTL2, transfusion of 2 or more apheresis of platelets; PLS6, transfusion of 6 or more units of plasma; RBC6, transfusion of 6 or more RBC; RBC10, transfusion of 10 or more units of RBC

At least one unit of blood or blood products was transfused to 92 (11.6% of the patients) in the first 24 hours of admission. "NL ROTEM," defined as all ROTEM parameters were within normal ranges, was observed in 604 (76.2%) patients. It could then be inferred that according to the initial ROTEM, approximately a quarter (23.8% or 189 patients) had TIC.

ROTEM Variables

Including all 793 patients, the values for sensitivity, specificity, PPV, NPV, and OR for ROTEM to predict the need for blood product transfusions are shown in (Table 2). All differences between "normal" and "abnormal" ROTEM were statistically significant ($p < 0.05$). Sensitivity varied between 79.1% (RBC) to 92.3% (RCB > 9 and PLS >5). Numbers for specificity were lower than 46.8%, and PPV values did not exceed 16.6%. On the contrary, the NPV varied from 94.8% (BBP and RBC) to 99.7% (RBC > 9 and PLS > 5).

The subgroup of 267 patients with ISS ≥ 16 (severe trauma) is summarized in (Table 3). The NPV of each ROTEM variable to detect the need for different types of blood products ranged from 83.8 to 98.8%. The ORs varied from 1.9 (for PLS) to 5.4 (for RBC > 9). A total of 72 patients out of 80 with a "NL ROTEM" (90%) did not receive any PLS, PTL, or CRY transfusions in the first 24 hours. Only one patient out of 80 with "NL ROTEM" required 10 or more units of RBC in the first 24 hours of admission.

Table 4 depicts the values of NPV and OR 95% confidence of interval (CI) for each ROTEM variable in identifying the need for transfusion in the 46 patients admitted with SBP ≤ 90 mm Hg (shock group). NPV ranged from 66.7% (for BBP and RBC) to 93.3% (for RBC > 9, PLS > 5, PLT2, CRY2). A total of 14 of the 15 patients (93.3%) admitted with an "NL ROTEM" and SBP ≤ 90 mm Hg (shock) did not require transfusion of 10 or more units of RBC in the first 24 hours. Only one out of 15 patients admitted with an "NL ROTEM" and SBP ≤ 90 mm Hg was transfused > 6 units of PLS.

Prediction Models

The prediction models were initially calculated, including the data of 793 patients (total sample). For each blood product variable, a prediction model was created. The AUCs for the prediction models for each blood product variable are depicted in (Table 5). A higher AUC was observed for the prediction of RBC >9 (0.982) (Table 5 and Fig. 1).

When we included only the data of the 267 patients with ISS ≥ 16, the AUC for predicting the need for RBC >9 (derived from the multivariate logistic regression that included all ROTEM variables and SBP) reached 0.972. For the 46 patients admitted in shock (SBP ≤ 90 mm Hg), the AUC for predicting the transfusion of 10 or more units of RBC (RBC > 9) reached 1.0.

Discussion

Trauma-induced coagulopathy (TIC) is common, occurs immediately after the injury, and carries high mortality by causing or worsening life-threatening bleeding. TIC is usually not a single hemostatic disorder but a combination of many, which can range from fibrinolysis shutdown (lower than expected fibrinolysis) to overwhelming hyperfibrinolysis, for example.[22] A recent study by Gomez–Builes et al. proposes that not all changes in hemostasis after trauma are harmful but may be interpreted as physiologic responses that augment the patient's chances of surviving.[23]

Of all adult trauma patients admitted to a trauma center, roughly one in four (23.8%) had an abnormal admission ROTEM study, indicating the presence of TIC. Dujardin et al., in 2022, reported that 40% of trauma patients sustained some ROTEM derangement in a prospective observational multicenter study with 1828 patients. These authors also found an association between abnormal ROTEM and coagulation factors levels, as well as mortality.[24]

Our study sample reflects well the reality of many trauma centers across the world. Most patients were male with blunt trauma. Approximately a third of the patients suffered severe trauma (ISS ≥ 16), and 20% had significant brain injuries (AIS > 2). Shock, defined by SBP ≤ 90 mm Hg, was not frequent, occurring in <6% of the admitted patients. Blood and blood product transfusions were administered to twice as many (12%), and 1.6% received >9 units of RBC in the first 24 hours.

The empirical and blind transfusions of PLS, PLT, and CRY for life-threatening hemorrhage are currently acceptable considering

Table 2: Sensibility, specificity, PPV, NPV, and OR for the ROTEM variable in predicting the need for blood products transfusion in 793 trauma patients

Variable	*Sensitivity*	*Specificity*	*PPV*	*NPV*	*p*	*OR 95% CI*
BBP	74/92 (80.4%)	327/698 (46.8%)	74/445 (16.6%)	327/345 (94.8%)	<0.001	3.6 (2.1–6.2)
RBC	68/86 (79.1%)	327/704 (46.4%)	68/445 (15.3%)	327/345 (94.8%)	<0.001	3.2 (1.9–5.6)
PLS	28/34 (82.4%)	339/756 (44.8%)	28/445 (6.3%)	339/345 (98.3%)	0.001	3.8 (1.5–9.2)
PLT	24/28 (85.7%)	341/762 (44.8%)	24/445 (5.4%)	341/345 (98.8%)	0.001	4.8 (1.6–14.1)
Cryo	32/39 (82.1%)	338/751 (45.0%)	32/445 (7.2%)	338/345 (98.0%)	0.001	3.7 (1.6–8.5)
PL/PT/CR	43/52 (82.7%)	336/738 (45.5%)	43/445 (9.7%)	336/345 (97.4%)	<0.001	4.0 (1.9–8.3)
RBC > 9	12/13 (92.3%)	344/777 (44.3%)	12/445 (2.7%)	344/345 (99.7%)	0.006	9.5 (1.2–73.7)
RBC > 5	18/21 (85.7%)	342/769 (44.5%)	18/445 (4.0%)	342/345 (99.1%)	0.004	4.8 (1.4–16.4)
PLS > 5	12/13 (92.3%)	344/777 (44.3%)	12/445 (2.7%)	344/345 (99.7%)	0.006	9.5 (1.2–73.7)
Plat > 2	11/12 (91.7%)	344/778 (44.2%)	11/445 (2.5%)	344/345 (99.7%)	0.010	8.7 (1.1–67,9)
Cryo > 2	10/11 (90.9%)	344/779 (44.2%)	10/445 (2.2%)	344/345 (99.7%)	0.017	7.9 (1.0–62.1)

BBP, transfusion of any blood product; Cryo, transfusion of any amount of cryoprecipitate; Cryo > 2, transfusion of 2 or more units of cryoprecipitate; RBC, transfusion of any amount of red blood cells; Plasma > 5, transfusion of 6 or more units of plasma; PLS, transfusion of any amount of plasma; Plat > 2, transfusion of 2 or more apheresis platelets; PL-PT-CR, transfusion of any amount of plasma, platelets or cryoprecipitate; PTL, transfusion of any amount of platelets; RBC > 5, transfusion of 6 or more RBC; RBC > 9, transfusion of 10 or more units of RBC

Table 3: ROTEM NPV and OR 95% CI for predicting blood products transfusion in 267 trauma patients with ISS ≥ 16

Blood product	*NPV*	*OR 95% CI*	*p*
BBP	67/80 (83.8%)	2.5 (1.3–4.9)	0.003
RBC	67/80 (83.8%)	2.2 (1.1–4.2)	0.013
PLS	74/80 (92.5%)	1.9 (0.7–4.8)	0.123
PTL	77/80 (96.3%)	3.6 (1.0–12.3)	0.022
CRY	74/80 (92.5%)	2.3 (0.9–5.9)	0.044
RBC10	79/80 (98.8%)	5.4 (0.7–42.1)	0.061
RBC6	77/80 (96.3%)	2.2 (0.8–9.5)	0.079
PLS/CRY/PLT	72/80 (90.0%)	2.3 (1.0–5.3)	0.023
PLS6	79/80 (98.8%)	5.3 (0.7–42.1)	0.061
PLT2	79/80 (98.8%)	4.9 (0.6–38.7)	0.082
CRY2	79/80 (98.8%)	4.4 (0.5–35.2)	0.110

BBP, transfusion of any blood product; Cryo, transfusion of any amount of cryoprecipitate; Cryo > 2, transfusion of 2 or more units of cryoprecipitate; Plasma > 5, transfusion of 6 or more units of plasma; PLS, transfusion of any amount of plasma; PL-PT-CR, transfusion of any amount of plasma, platelets or cryoprecipitate; RBC, transfusion of any amount of red blood cells; PTL, transfusion of any amount of platelets; RBC > 9, transfusion of 10 or more units of RBC; RBC > 5, transfusion of 6 or more RBC

Table 4: ROTEM variable NPV and OR 95% CI and for predicting blood products transfusion in 46 patients admitted with SBP ≤ 90 mm Hg

Blood product	*NPV*	*OR 95% CI*	*p*
BBP	10/15 (66.7%)	2.4 (0.7–8.8)	0.146
RBC	10/15 (66.7%)	2.4 (0.7–8.8)	0.146
PLS	12/15 (80.0%)	1.2 (0.2–5.3)	0.582
PTL	14/15 (93.3%)	4.1 (0.4–36.8)	0.181
CRY	13/15 (86.7%)	2.3 (0.4–12.3)	0.288
RBC10	14/15 (93.3%)	2.7 (0.3–25.3)	0.351
RBC6	13/15 (86.7%)	1.6 (0.3–8.8)	0.478
PLS/CRY/PLT	12/15 (80.0%)	1.9 (0.4–8.3)	0.308
PLS6	14/15 (93.3%)	2.7 (0.3–25.3)	0.351
PLT2	14/15 (93.3%)	2.1 (0.2–20.3)	0.468
CRY2	14/15 (93.3%)	2.1 (0.2–20.3)	0.468

BBP, transfusion of any blood product; Cryo, transfusion of any amount of cryoprecipitate; Cryo > 2, transfusion of 2 or more units of cryoprecipitate; Plasma > 5, transfusion of 6 or more units of plasma; Plat > 2, transfusion of 2 or more apheresis platelets; PL-PT-CR, transfusion of any amount of plasma, platelets or cryoprecipitate; PLS, transfusion of any amount of plasma; PTL, transfusion of any amount of platelets; RBC > 5, transfusion of 6 or more RBC; RBC > 9, transfusion of 10 or more units of RBC; RBC, transfusion of any amount of RBC

the nonexistence of readily available blood components and/or pharmacologic agents as well as accurate ways to timely determine their need. Considering the side effects, cost, and scarcity of blood, on top of the fact that most patients may not need any blood transfusion, it seems logical to pursue better guidance. The transfusion of PLT to a patient with low levels of fibrinogen will not treat the core problem and may be harmful. Empirical transfusions using blood product ratios were established historically when existing conventional laboratory tests (INR, PTT, and PLT count) did not provide the necessary direction. Despite the inability to even establish the existence of ongoing bleeding, conventional static lab tests have a long turnaround time, and the late results have no or little value in managing fast or massive bleeding patients undergoing resuscitation and are incapable of depicting the patient's current coagulation status.

Abnormal viscoelastic tests are associated with active ongoing bleeding, and the results are readily available when used as point-of-care. There is an open field for research concerning the clinical usefulness of these tests in trauma. VHA-based protocols have been proposed to guide early resuscitation and blood transfusions in trauma, although more evidence about their efficacy would be desirable. The normal range and cutoff values for each blood product are also a matter of debate.

In the present study, ROTEM values were within the "normal" range in three-fourths of the patients (76.2%). Interestingly, ROTEM was also "normal" in roughly 30% of the severely injured and hypotensive patients, which suggests that many such patients may not have an underlying coagulopathy. Bleeding in these patients would more likely be "mechanical," without any underlying coagulopathy, and in whom blood transfusion would be not only unnecessary but also potentially harmful.

The NPV of any ROTEM parameter indicates that blood product transfusion (hemostatic transfusion) was not invariably necessary, even in actively bleeding and hypotensive patients. Very few

Table 5: Area under the ROC curve for the prediction models derived from the multivariate logistic regression analysis, which included all ROTEM variables together with the SBP on admission, in 793 trauma patients

Blood product	*AUC*
Blood bank products (at least 1 unit)	0.812
RBC (at least 1 unit)	0.811
CRY (at least one apheresis)	0.890
PLS (at least 1 unit)	0.887
PLT (at least one apheresis)	0.859
RBC (> 9 units) RBC10	0.982
RBC (> 5 units) RBC6	0.921
PLS (> 5 units) PLS6	0.944

	B	*S.E.*	*Wald*	*df*	*Sig.*	*Exp(B)*	*95% CI, for EXP(B)*	
							Lower	*Upper*
Bp in trauma bay	–0.078	0.02	15.104	1	0	0.925	0.889	0.962
ROTEM EXTEM CT	–0.052	0.026	3.962	1	0.047	0.949	0.902	0.999
ROTEM EXTEM CFT	0.024	0.022	1.127	1	0.288	1.024	0.98	1.07
ROTEM EXTEM Alpha Angle	0.07	0.244	0.083	1	0.773	1.073	0.665	1.732
ROTEM EXTEM A10	–0.201	0.292	0.474	1	0.491	0.818	0.462	1.449
ROTEM EXTEM MCF	0.128	0.235	0.298	1	0.585	1.137	0.717	1.802
ROTEM EXTEM ML	0.076	0.025	9.57	1	0.002	1.079	1.028	1.133
ROTEM FIBTEM A10	0.073	0.149	0.238	1	0.626	1.075	0.803	1.44
ROTEM FIBTEM MCF	–0.348	0.224	2.416	1	0.12	0.706	0.456	1.095
Constant	5.811	15.522	0.14	1	0.708	334.023		

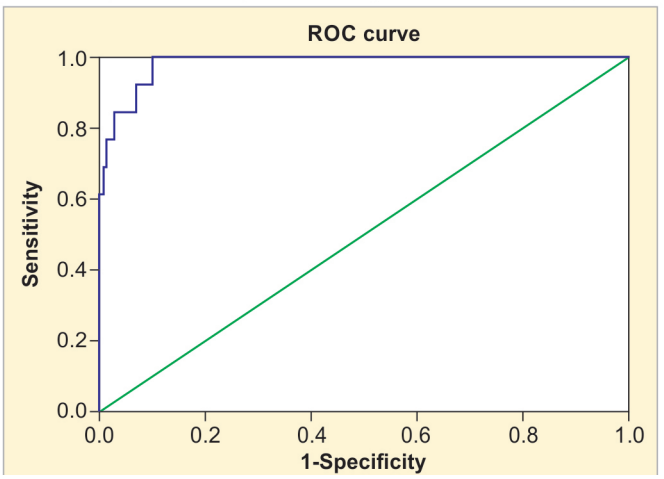

Fig. 1: ROC curve for the prediction of RCB10, derived from the multivariate logistic regression analysis, which included all ROTEM variables together with the SBP on admission in 793 trauma patients. The AUC was 0.982

patients with normal ROTEMs needed any blood transfusion in the first 24 hours of arrival to the trauma center. Considering the entire cohort of almost 800 injured patients, the OR provide reasonable evidence that a NL ROTEM is linked to a very low probability of blood transfusions.

The present study also explored whether the ROTEM has the same power when tested in severely injured (ISS ≥ 16) and/or in shock patients (SBP ≤ 90 mm Hg). While the ROTEM NPV reduced in these two groups of patients, it remained above 90% in detecting massive transfusion (RBC > 9), >5U PLS or ≥ 2U apheresis PLT, and ≥ 2U CRY. So, even for hemodynamically unstable and severely injured trauma patients, a "NL ROTEM" (when all parameters are normal) is a strong indication that (at least) massive transfusion (if any transfusion at all) is not required. This finding offers a very important piece of information, especially to appraise massive transfusion activation protocols.

It is important to note that ROTEM PPV was not as strong, indicating that an "Abnormal ROTEM" test was not associated with the transfusion of blood products. David et al., in 2022, observed that mortality and blood requirements were different when comparing three different EXTEM CT categories (EXTEM CT—< 91 s (no TIC), 91–130 s (moderate TIC), 131–200 s (severe TIC) and >200 s (major TIC).[25] So, an "abnormal" ROTEM needs a deeper analysis, considering all the different parameters. Nevertheless, the focus of our analysis is to present the opposite view, particularly of the power of a "NL ROTEM" (all parameters are normal) to withhold transfusion, which is better assessed by specificity and NPV.

To address the question of whether ROTEM could predict (or not) the need for the transfusion of blood products, we performed a multivariate logistic regression using the method "enter," which included all ROTEM parameters in the prediction model. We also included the SBP due to its strong association with severity and blood transfusions in trauma. The AUC was high for most of the blood product predictive models. Particularly for massive transfusion (transfusion of >9U RBC), transfusion of >5U RBC (RBC > 5), and PLT (PLS6). The AUC was higher than 0.9, which is considered an optimal relation. This exceptional AUC performance was also reached when predicting massive transfusion (transfusion of >9U RBC) in severely injured (ISS ≥ 16) and hypotensive patients.

Brill et al., in 2021, reviewed the literature about the role of VHA (TEG and ROTEM) in damage control resuscitation.[26] They suggest that guided transfusions are preferable to empiric ones in trauma patients. Another series, published in 2022, showed that ROTEM-guided resuscitation decreased mortality and increased the use of hemostatic agents in trauma patients.[27] Our data also suggest that guided resuscitation can bring benefits. Differently, we looked at the other side of the coin, observing that all ROTEM parameters can be used together when they are normal as one piece of information. "NL ROTEM" is a strong indication that transfusions are probably not necessary.

However, this study has significant limitations. First, we are assuming that all blood transfusions were correctly indicated, which is false. Another limitation is the small sample size when analyzing severely injured and hypotensive trauma patients. Future studies are needed to determine the role of ROTEM-based resuscitation protocols and blood product transfusion in trauma patients.

The present analysis indicates that when all ROTEM parameters are within the normal range, transfusions are probably not required. Even in severely injured and hemodynamically unstable patients, a "NL ROTEM" indicates that massive blood transfusion is unlikely.

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