Original Article

Does a Simple Blood Gas Analysis and the Clinical Impression Predict Trauma-Induced Coagulopathy?

Results from an International Trauma Registry

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Abstract

Objectives Trauma-induced coagulopathy (TIC) is common in severely injured patients and is associated with significant morbidity and mortality.
Method The association of two parameters of blood gas analysis (hemoglobin [Hb], base excess [BE]) with standard coagulation tests (SCTs) and rotational thrombelastometry (ROTEM) using the database of the TraumaRegister DGU between 2015 and 2022 was studied. In a stepwise approach, the occurrence of a TIC, the correlations between Hb/BE levels and SCT, as well as ROTEM were calculated respectively. Then we aimed to detect relations between different Hb/BE levels and the occurrence of TIC, using standard clotting studies and/or ROTEM respectively.
Results TIC occurred in 17.2% of the 68,996 primarily admitted adult patients with Injury Severity Score $\geq$9. A high correlation was found between Hb/BE and SCT. With a decrease in Hb and BE, the frequency of TIC increased and at an admission Hb $<$8 g/dL and BE < -6 mmol/L, $>$60% of patients presented with TIC. Clinical conditions associated with TIC were Glasgow Coma Scale $\leq$8, blood pressure $\leq$90 mmHg on the scene or at hospital admission, prehospital volume $>$1,000 mL, serious injuries to the head and/or the thorax and/or the abdomen and/or the extremities.
Conclusion Almost one-sixth of patients present with a TIC at hospital admission. Blood gas analysis samples showed relevant correlations between Hb/BE levels and SCT. The combined closer inspection of Hb/BE and the clinical presentation of the patient is able to predict TIC in the majority of patients.

Keywords
- trauma-induced coagulopathy
- ROTEM
- blood gas analysis
- correlation
- trauma registry

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Introduction

Massive hemorrhage is a leading cause of death in the first few hours following severe trauma.[1–3] Hemorrhage-related clotting disorders, better known as trauma-induced coagulopathy (TIC), are common problems in this population of patients, particularly when the patients are hemodynamically unstable and require fluid resuscitation.[2] TIC is often associated with significant bleeding, transfusion requirements, inflammation, morbidity, and mortality.[4] For these reasons, stopping the bleeding and an early and aggressive treatment of TIC are believed to reduce mortality.[5] Point-of-care diagnostic devices (POCs), such as thromboelastography and thrombelastometry (e.g., TEG or ROTEM), are recommended in these patients for early detection of possible TIC.[6–9] Unfortunately, the mentioned POCs are not available in all trauma centers and in centers without POCs, generally performed clotting tests, like thromboplastin time (PT), international normalized ratio (INR), activated partial thromboplastin times (aPTT), are standard of care. The results from these coagulation tests are often delayed by at least 30 to 53 minutes.[10,11] In time-sensitive emergency settings, this delay might be too long for appropriate therapeutic treatment. Therefore, an available surrogate parameter within the first minutes of emergency room management would be a desired option. The parameters of a simple blood gas analysis (BGA) are quickly available in the resuscitation room and are possibly helpful to detect if the patient has a high probability of having or developing a TIC and to help the trauma-team assess if coagulation therapy is necessary.[11]

In the present study, we investigated the association of two different parameters of BGA (hemoglobin [Hb] and base excess [BE]) with standard coagulation tests and ROTEM parameters using the database of the TraumaRegister DGU (TR-DGU) of the German Trauma Society (Deutsche Gesellschaft für Unfallchirurgie, DGU) between 2015 and 2022. If such associations were evident, a simple BGA at hospital admission could be a useful tool for an early detection of TIC.

Materials and Methods

TR-DGU was founded in 1993. The aim of this multicenter database is a pseudonymized and standardized documentation of severely injured patients. Data are collected prospectively in four consecutive time phases from the site of the accident until discharge from hospital: (1) prehospital phase, (2) emergency department (ED) and initial surgery, (3) intensive care unit (ICU), and (4) discharge. The documentation includes detailed information on demographics, injury pattern, comorbidities, pre- and in-hospital management, course on ICU, relevant laboratory findings including data on transfusion and outcome of each individual. The inclusion criterion is a hospital admission via emergency room with vital signs upon arrival, and subsequent ICU/intermediate care unit care or exitus before admission to ICU. The infrastructure for documentation, data management, and data analysis is provided by Academy for Trauma Surgery (AUC—Akademie der Unfallchirurgie GmbH), a company affiliated to the German Trauma Society. The scientific leadership is provided by the Committee on Emergency Medicine, Intensive Care, and Trauma Management (Sektion NIS) of the German Trauma Society. The participating hospitals submit their data pseudonymized into a central database via a web-based application using a standard documentation form or a quality management (QM) documentation form, with less information contained. Level 1 trauma centers are obliged to use the standard form and the QM form is mainly used by local and regional or trauma centers of levels 3 and 2. Scientific data analysis is approved according to a peer review procedure laid down in the publication guideline of TR-DGU.

After approval by the review board of the TR-DGU and by the Ethical Committee of the Medical Association Saxony-Anhalt, Germany, we analyzed the database.

Inclusion criteria: age $\geq$16 years, direct admission to trauma center, Injury Severity Score (ISS) $\geq$9, and availability of the following standard clotting and, if measured, ROTEM parameters, measurements taken in the ED immediately after admission: Hb, BE, Quick's value (PT), INR, aPTT, CT (clotting time), Fibtem-A10, MCF (maximum clot firmness), and platelet counts (PLT). ROTEM parameters are only available from hospitals using the standard documentation form and TEG parameters are not available within the TR-DGU. Data regarding transfusion (frequency and volume) are available for the time period until ICU admission.

Exclusion criteria: patients from outside German-speaking countries and patients who underwent early (<48 hours) interhospital transfer after admission were excluded. In German-speaking countries, prehospital trauma care is similar. To avoid the effect of different prehospital care strategies, patients from outside German-speaking countries were excluded. Patients taking any oral anticoagulant agents like aspirin, warfarin, or NOACs (non-vitamin K antagonist oral anticoagulant) were not excluded to provide "real-world" data.

In a first step we determined the rate of occurrence of TIC in the study cohort using standard clotting tests and ROTEM, if available. TIC using standard coagulation parameters was defined according to the Berlin Definition (BerDef) of "Polytrauma" by Pape et al with INR >1.4, or aPTT >40 seconds (at least one of these conditions).[12] If INR was not available, Quick's value $\leq$60% was applied instead because both parameters represent the PT. Using ROTEM, TIC was defined according to the Philadelphia Consensus Conference (Philadelphia definition—PhilDef) as PLT <100,000/µL, MCF <50 mm, CT >80 seconds, which are the defined cut-off levels providing an indication for replacement therapy.[6,13] Furthermore, we have studied the need for transfusion from hospital admission up to ICU admission in the different TIC groups.

In a second step, correlations between Hb levels, BE levels, the above-mentioned standard laboratory parameters, and ROTEM parameters were calculated.

Correlations were tested using Pearson's (r) or Spearman (rho) test respectively with a two-tailed significance level of

$p < 0.05$. Correlation coefficients were classified as moderate (0.2–0.4), good (0.4–0.7), or excellent (>0.7).

In a third step, we aimed to detect associations between different Hb/BE levels and the rate of TIC, using standard clotting studies or ROTEM respectively and clinical factors associated with TIC.

The statistic is mainly descriptive, using mean ± standard deviation and frequency of occurrence with percentage. Statistical tests (Chi-squared test for categorical data and *t*-test for continuous data) were performed where appropriate. All computations were made using SPSS version 24 (IBM Inc., Armonk, New York, United States).

Ethical Considerations

Study approval was obtained from the review board of the TR-DGU (project ID 2017-011). The study is in line with current general European data protection regulation and was approved by the Ethical Committee of the Medical Association Saxony-Anhalt, Germany.

Results

General Data

In the study period, 289,160 patients were recorded in the TR-DGU and in 68,996 cases the inclusion criteria were fulfilled and sufficient data for analysis were available.

►**Table 1** shows the demographic data and basic characteristics of the study cohort including important lab results at hospital admission.

Table 1 Demographic data and basic characteristics of the study cohort including laboratory results at hospital admission

	Whole cohort, *n* = 68,996
Age (years)	54.3/55 (21.0)
Male sex (*n*, %)	49,218 (71.3%)
ISS	21.6/18 (11.5)
Relevant head injury (AIS 3 +)	25.518 (44.1%)
GCS prehospital	12.0/14 (4.3)
Admission SBP (mm Hg)	133/132 (31)
Admission heart rate (1/min)	89/87 (21)
Admission respiratory rate (1/min)	15/15 (5)
Prehospital volume resuscitation (mL)	698/500 (583)
ED volume resuscitation (mL)	1394/700 (1813)
Hemoglobin, Hb (g/dL)	12.9/13.4 (2.2)
Base excess, BE (mmol/L)	−1.9/−1.1 (4.6)
aPTT (s)	29/26 (14)
INR	1.18/1.07 (0.51)
Quick's value (%)	86/90 (22)
Blood transfusion (*n*, %)	7,895 (11.4%)
Coagulopathy, any (*n*, %)	11,125 (16.1%)
ROTEM (*n*, %)	6,677 (9.7%)

Abbreviations: aPTT, activated partial thromboplastin time; ED, emergency department; GCS, Glasgow Coma Scale; Hb, hemoglobin; INR, international normalized ratio; ISS, Injury Severity Score; Quick, prothrombin time in %; SBP, systolic blood pressure.
Note: Continuous values are given with mean/median (SD).

1. Step

Trauma-Induced Coagulopathy—Rate of Occurrence

Out of the 68,996 patients, 16.1% ($n = 11{,}125$) presented with TIC at hospital admission. According to the BerDef, 9,264 patients (13.4%) had a TIC. ROTEM analysis was carried out in only 6,677 patients (9.7%) and in 5,932 patients, data were sufficient to determine TIC according to the PhilDef. In these 5,932 patients, 46.1% ($n = 2{,}733$) had a TIC. In 32% ($n = 872$) of the patients with TIC according to PhilDef also, TIC according to the BerDef of polytrauma was found (see ►**Fig. 1**). When considering only patients with an ISS ≥16 ($n = 45{,}900$), TIC was detectable in 19.8% ($n = 9{,}088$) of patients. Of these, 16.5% ($n = 7{,}574$) had a TIC according to BerDef. In the patients with sufficient data to determine TIC according to PhilDef, 48.1% ($n = 2{,}732$) had a TIC and 1,218 had a TIC according to BerDef and PhilDef.

Transfusion Depending on TIC Definition

In the 8,392 patients fulfilling the classical definition of TIC according to BerDef, 31.9% were transfused before ICU admission and in the 1,861 patients that had a TIC according to PhilDef, 24.4% were transfused before ICU admission. In the 872 patients fulfilling both TIC definitions, 50.0% were transfused before ICU admission. In patients without TIC, 7.5% were transfused.

Comparison between Patients with and without Coagulopathy

Patients with a detectable TIC at hospital admission had an older age, higher ISS, lower Glasgow Coma Scale (GCS), lower systolic blood pressure (SBP), higher heart rate (HR), and a lower admission Hb and BE. ►**Table 2** compares the results between patients with and without TIC. Due to the large sample sizes in both groups, all included parameters differ highly significant between the groups, but one has to remember that some significant differences are clinically more important (e.g., injury severity) than others (e.g., HR) in this table.

2. Step

Hemoglobin and Base Excess Correlation with Clotting Parameters

►**Table 3** illustrates the correlation between Hb and BE with different clotting data. A moderate correlation around 0.20 was found for Hb/BE with the most standard values (Quick's value, INR, aPTT, fibrinogen, platelet). The highest correlation with Hb was found for Quick's value (0.415), and with BE for

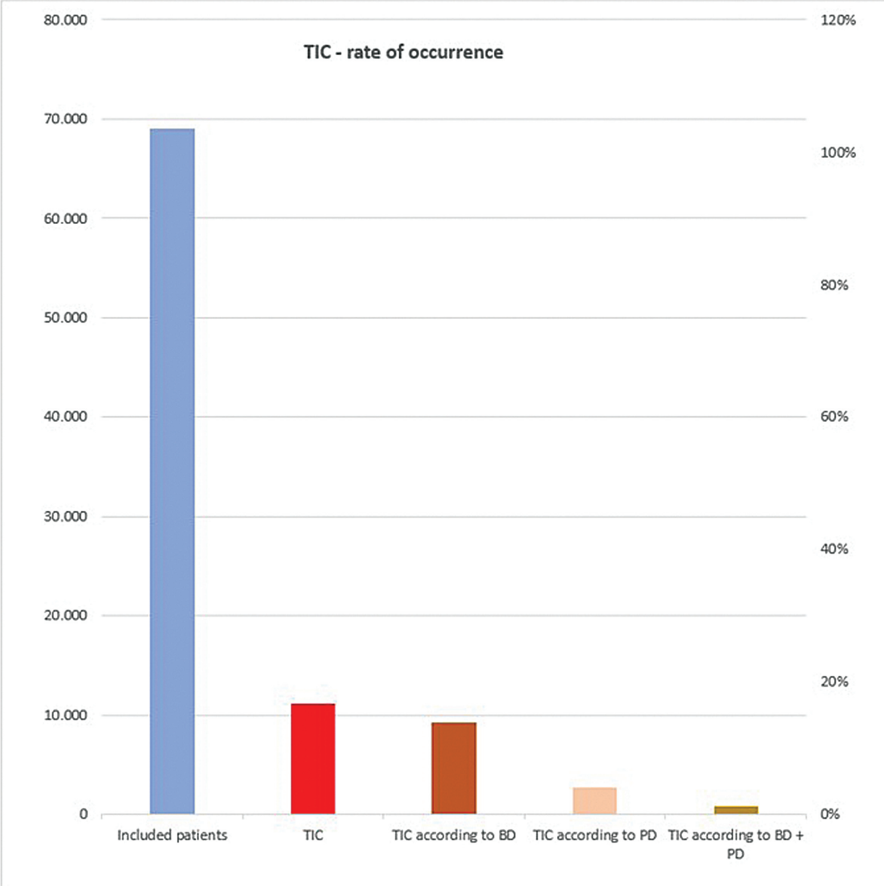

Fig. 1 Rate of occurrence of TIC in total and with regard to the different used definitions. TIC, trauma-induced coagulopathy.

aPTT (–0.373). The correlation of Hb and BE with ROTEM parameters was not clinically relevant with values <0.10. When considering only patients with an ISS ≥16, the correlation increased. Hb/BE with Quick's value (0.434/0.311) and with aPTT (–0.339/– 0.403). The correlation of Hb/BE with ROTEM parameters also increased, but still showed no clinical relevance.

3. Step

Association between Hb and BE and the Rate of TIC

We compared different Hb/BE values with the frequency of any of the above-mentioned coagulopathies. With a decrease in Hb and BE, the frequency of coagulopathy was constantly increasing as shown in ►**Fig. 2**. ►**Fig. 3** summarizes the frequency of TIC depending on admission Hb and BE. As one can see, low Hb and BE values are associated with a high risk of TIC. In trauma patients with an admission Hb <9 g/dL and a BE ≤ – 6 mmol/L, the probability of a TIC at hospital admission is more than 50% and with an Hb <8 g/dL, the majority of patients have a detectible TIC. On the other hand, a decrease in Hb and BE resulted in an almost linear increase in the probability of transfusion requirement. The probability of a transfusion increases from 2% in patients with an admission Hb of 9 g/dL to almost 80% in patients with an admission Hb ≤5 g/dL. Likewise, the transfusion probability increases in patients with an admission BE of 0 mmol/L from about 12% to over 70% in patients with admission BE of –15 mmol/L.

The above-mentioned associations strongly suggest that an Hb below 8g/dL in combination with a BE below –6 mmol/L should be interpreted as a strong warning sign regarding TIC.

Clinical Factors Associated with TIC

The following clinical conditions listed in ►**Table 2** were associated with a TIC: GCS ≤ 8, shock (SBP ≤ 90 mmHg) on the scene or at hospital admission, the need of prehospital volume resuscitation of more than 1,000 mL, serious injuries (Abbreviated Injury Scale ≥ 3) to the head and/or the thorax and/or the abdomen and/or the extremities/pelvis. In other words, the majority of severely injured patients in shock with the need of forced prehospital volume resuscitation present with proven TIC at hospital admission.

Discussion

The study demonstrates that the number of trauma patients with a detectable TIC at hospital admission is below 20% and has therefore decreased considerably over the last decade. An older study within the TR-DGU found one-third of all admitted patients with established coagulopathy, but employed a different coagulopathy definition.[14] The data of the current study suggest that initial Hb/BE levels have relevance beyond

Table 2 Comparison between patients with and without coagulopathy

Parameter	Without coagulopathy ($N = 57,871$)	With coagulopathy ($N = 11,125$)	p-Value[a]
Age (years)	53.5 ± 20.5	58.2 ± 23.1	<0.001
Male sex	41,298 (71.4%)	7,920 (71.2%)	<0.001
ISS (points) reflecting *injury severity*	20.3 ± 10.2	28.3 ± 14.9	<0.001
GCS on scene (points)	12.5 ± 3.9	9.7 ± 5.0	<0.001
Unconscious (GCS ≤ 8)	4,505 (7.8%)	1,751 (15.5%)	<0.001
Head injury AIS ≥ 3	6,202 (10.7%)	2,012 (18.1%)	<0.001
SBP on scene (mmHg)	135 ± 29	122 ± 43	<0.001
SBP on admission (mm Hg)	135 ± 29	119 ± 38	<0.001
Shock on admission (SBP ≤ 90 mmHg) (n, %)	3,519 (6.4%)	2,469 (23.6%)	<0.001
Prehospital volume resuscitation (mL)	667 ± 532	861 ± 777	<0.001
HR on scene (1/min)	89 ± 21	92 ± 31	<0.001
HR at admission (1/min)	88 ± 20	94 ± 28	<0.001
SpO_2 (%)	97 ± 5	95 ± 9	<0.001
Admission Hb (g/dL)	13.2 ± 1.9	11.2 ± 2.8	<0,001
Admission BE (mmol)	−1.3 ± 3.8	−4.8 ± 7.0	<0.001
Quick's value (%)	92 ± 14	52 ± 23	<0,001
INR	1.06 ± 0.10	1.83 ± 1.06	<0.001
aPTT (s)	26.2 ± 4.1	44.8 ± 28.6	<0.001
Platelet count (Gpt/L)	231 ± 76	188 ± 88	<0.001
Expected mortality based on RISC II (%)	8.7	35.5	<0.001

Abbreviations: aPTT, activated partial thromboplastin time; BE, base excess; GCS, Glasgow Coma Scale; Hb, hemoglobin; HR, heart rate; INR, international normalized ratio; ISS, Injury Severity Score; Quick, prothrombin time in %; RISC II, Revised Injury Severity Classification II; SBP, systolic blood pressure; SpO_2, oxygen saturation.
Note: Parameters printed in italics are clinically more relevant in the opinion of the authors than the others.
[a]Chi-squared test or *t*-test as appropriate.

Table 3 Pearson's or Spearman's correlation coefficient respectively between Hb/BE and different clotting studies as appropriate

Parameter (*n* of sample size)	Hb	BE
Quick's value (68.291)	0.415[a]	0.291[b]
INR (68.936)	−0.284[b]	−0.228[b]
aPTT (66.720)	−0.320[b]	−0.373[b]
Fibrinogen (g/dL) (13.698)	0.220[b]	0.201[b]
Platelet count (67.702)	0.208[b]	0.092
ROTEM CT Extem (2.651)	0.084	−0.073
ROTEM A 10 Fibtem (2.651)	−0.014	−0.003
ROTEM MCF Extem (2.651)	0.048	0.032

Abbreviations: A 10 Fibtem, clot amplitude at 10 minutes in the platelet-inhibited test; aPTT, activated partial thromboplastin time; BE, base excess; CT Extem, clotting time of the extrinsic coagulation system; Hb, hemoglobin; INR, international normalized ratio; MCF Extem, maximum clot firmness of the extrinsic coagulation system; Quick, prothrombin time in %.
Note: The correlation between Hb and BE was 0.299.
[a]Good correlation.
[b]Moderate correlation.

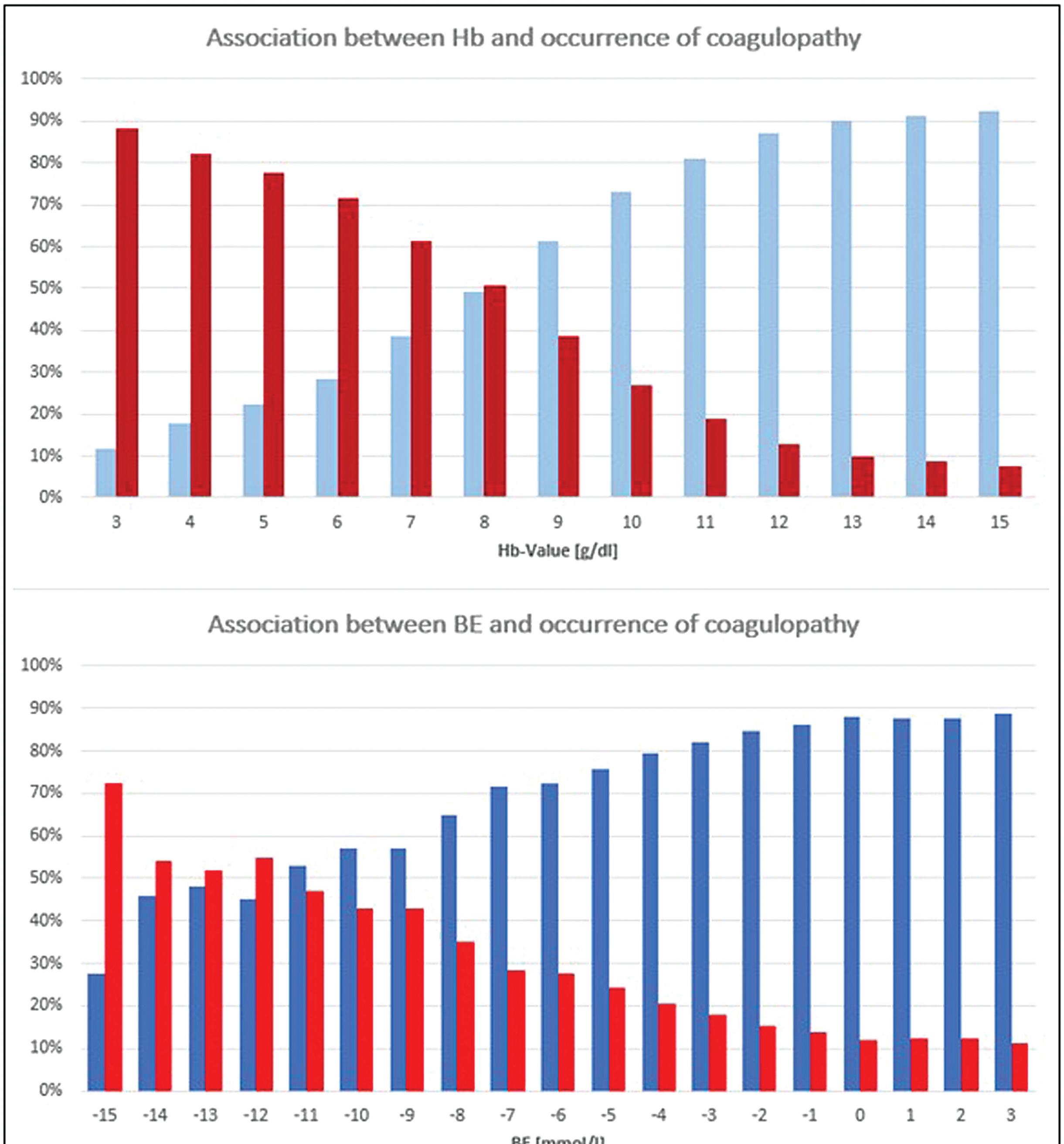

Fig. 2 Association between Hb/BE and the rate of occurrence of coagulopathy. Blue columns present percentage of no coagulopathy and red columns present percentage of coagulopathy. With decreasing Hb and BE values, the percentage of coagulopathy is increases. BE, base excess; Hb, hemoglobin.

their role as an indicator of anemia, shock, persistent bleeding, tissue damage, and poor outcome.[3,15–18] We found relevant correlations between Hb/BE levels and standard clotting tests, and were able to show that the probability of a TIC increases with a decrease in Hb/BE at hospital admission. These results support known pathways of TIC generation: relevant trauma impact, impaired tissue perfusion indicated by shock, and the probability of TIC development in patients with shock.[2,19] The above-mentioned clinical factors associated with TIC underline what has been stated. Due to the fact that viscoelastic coagulation tests are not yet widespread in German Trauma centers, these tests were only employed in less than 10% of trauma patients in the study cohort. This finding is in accordance with a current survey among German trauma centers, which stated that almost 50% of trauma centers do not have a viscoelastic coagulation test available.[20]

Interestingly, in contrast to the standard coagulation test, no clinically relevant correlation was found between Hb/BE and important ROTEM parameters. This might be explained by the fact that viscoelastic tests do not just quantify the beginning of the coagulation pathway like the investigated

Hb in g/dl \ BE in mmol/l	0	-1	-2	-3	-4	-5	-6	-7	-8	-9	-10	mean
5	50%	73%	57%	61%	91%	64%	100%	91%	85%	77%	64%	74%
6	47%	58%	44%	67%	68%	71%	83%	67%	85%	74%	92%	69%
7	38%	55%	55%	44%	59%	71%	71%	59%	60%	71%	67%	59%
8	43%	37%	51%	43%	50%	52%	50%	55%	54%	54%	57%	50%
9	26%	30%	30%	40%	32%	38%	38%	44%	55%	45%	64%	40%
10	21%	21%	21%	25%	27%	30%	26%	35%	31%	42%	46%	29%
11	14%	15%	15%	17%	21%	20%	23%	26%	26%	30%	30%	22%
12	10%	11%	12%	13%	15%	17%	16%	15%	19%	25%	23%	16%
13	9%	9%	9%	11%	11%	13%	15%	15%	14%	21%	23%	14%
14	7%	8%	9%	8%	10%	11%	12%	14%	14%	25%	25%	13%
15	7%	7%	7%	9%	8%	10%	14%	12%	10%	19%	13%	10%
mean	25%	29%	28%	31%	36%	36%	41%	39%	41%	44%	46%	

Fig. 3 The graph illustrates the frequency of coagulopathy in dependence on different Hb/BE values at hospital admission. For example, in trauma patients presenting with admission Hb of 8 g/dL and BE of −6 mmol/L, 50% have an evident coagulopathy, and in trauma patients with admission Hb of 11 g/dL and BE of −2 mmol/L, only 15% have an evident coagulopathy. BE, base excess; Hb, hemoglobin.

standard clotting test, but measure additional clot formation, clot firmness, and fibrinolysis. A weak correlation between standard coagulation tests and viscoelastic tests is regularly described in the literature and might be one reason for missing clinically relevant correlation between Hb/BE and ROTEM values.[21,22] Standard coagulation tests only measure the beginning of the coagulation process and have, at best, a weak conclusive power concerning impairment of coagulation by hemorrhage, but the majority of clinicians use it to detect TIC and to guide therapy.[6,13] An interesting aspect of our data is the fact that if viscoelastic tests were used, in almost 40% of patients, TIC was detected. This implies that, e.g., ROTEM is mainly used in patients with suspected TIC and not as a general screening tool. Current guidelines recommend the use of viscoelastic tests but our data show that many trauma centers do not stick to these recommendations.[5,6,8,9,23,24] Of course, there are many possible reasons regarding the fairly low usage of viscoelastic tests including the high costs. The complex knowledge necessary to sufficiently interpret the graphs and the lack of evidence from large randomized controlled multicenter trials regarding survival benefit may only be some reasons for our results. On the other hand, there is increasing evidence from smaller randomized controlled trials and meta-analysis that viscoelastic testing and goal-directed therapy might have a survival benefit in traumatic bleeding.[25–29] The current German trauma guideline and "The European guideline on management of major bleeding and coagulopathy following trauma" recommend the early use of viscoelastic tests in the trauma bay.[5,9]

The association of Hb and coagulation tests is further supported by several studies involving multiple trauma patients that found strong correlations of Hb, BE, and ISS with plasma fibrinogen, a key parameter in hemostasis and almost all coagulation factors.[11,30–35] A current study from the TR-DGU showed that trauma patients with moderate (Hb 7–8 g/dL) to severe anemia (Hb < 7 g/dL) needed more therapeutic interventions addressing TCI in the ED: 21–33% fresh frozen plasma, 12–18% prothrombin complex concentrate, 26–33% fibrinogen, 18–25% tranexamic acid, 7–12% platelet transfusion, supporting the data of our study.[36] Our data also revealed significant correlations between BE and PT, as well as BE and aPTT, supporting previous studies, in which BE was found to be closely associated with PT and impaired coagulation.[34,35,37–39] We observed, however, weaker correlations for Hb and standard clotting tests than described in earlier studies.[11,32] A reason for the observed weaker correlation could be the increasing use of oral anticoagulation drugs (e.g., factor X antagonists and oral thrombin inhibitors) due to current guidelines and the lower severity of injury in the current study, with less prehospital fluid given.[11,31,40] An older study had shown a better correlation between Hb and TIC in more severely injured patients with an ISS >25.[11] Additionally, BE levels may be influenced by the aggressiveness of prehospital therapy to compensate for base deficits (fluid resuscitation using balanced crystalloids and mechanical ventilation) and prehospital time. Accordingly, shock may be present in slightly abnormal or even normal BE. On the other hand, the mean occurrence of a TIC in only ≈50% of patients with a BE of −10 mmol/L in our study seems to indicate TIC occurrence in strongly acidotic patients. To our understanding, this underlines the fact that TIC is a multifactorial process and acidosis is just one part of the complex process. Acidosis per se has negative effects on coagulation due to the pH-dependent activity of some coagulation factors, but according to our data it seems less pronounced than one would expect. As shown in ►Fig. 3, the interpretation of BE in context with Hb is much more instructive than a single BE.

The results of this study suggest that the combination of clinical presentation (severely injured, continuing C-problem) and BGA can be a tool to estimate the critical condition of trauma patients. ►Fig. 3 could be used as a pretest probability tool for advanced coagulation diagnostics and as an indicator for the need of early coagulation support. Hb and BE together provide valuable information on trauma pathophysiology that is accessible within the first minutes after ED arrival. Clinical appearance together with a BGA-oriented algorithm for early coagulation therapy may be more effective than the blind administration of coagulation substances or waiting for coagulation test results.[1,41,42] This may be particularly relevant for hospitals with no access to viscoelastic POC devices in the ED or in rural or remote areas. In a setting without a POC device, an early coagulation therapy, in severely injured hemodynamic unstable patients, driven by the Hb and BE values from the initial BGA as described, can be very helpful.[43,44] The trauma team caring for the severely injured patient should be aware of the valuable information of a BGA and the clinical impression of the patient. This awareness can help to anticipate TIC in an early stage, initiate early therapy, and may help to save the patient's life.

Limitations

This study has several limitations we would like to address. Due to the fact that the study is registry-based and because of the large sample sizes, the statistical effects may produce significance levels that may not necessarily reflect clinically relevant conditions. Therefore, our results have to be interpreted cautiously and only with regard to the individual circumstances of a trauma patient. Data were missing in a number of patients. The participating hospitals use their own laboratory standard and testing reagents, which may result in relevant differences in standard coagulation test values.[45] All investigated standard coagulation tests and ROTEM were originally developed for purposes other than TIC detection, and currently no single parameter exists to detect TIC. The fact that fluid resuscitation volumes recorded in the TR-DGU decreased over the years due to the implementation of German trauma guidelines has to be considered as a possible confounder in this database analysis.[1] Another important limitation of this study is that patients receiving oral anticoagulation agents like warfarin or NOACs before injury were not excluded from the analysis. Last but not least, the role of the platelets and possible disturbances of the platelet function due to trauma were not investigated, because the TR-DGU does not include platelet function tests. It is known that disturbances of platelet function are detectable in almost one-fourth of trauma patients at hospital admission.[33]

Conclusions

Almost one-sixth of trauma patients in this study present with a TIC at hospital admission, and in patients with an admission Hb < 8 g/dL and BE < −6 mmol/L the majority (>60%) have a detectible TIC. Patients with coagulopathy according to ROTEM and those fulfilling the coagulopathy definition according to standard coagulation tests had a high transfusion rate of 50%. Trauma bay BGA samples of a large number of trauma patients showed relevant correlations between Hb/BE levels and standard coagulation tests. The combined closer inspection of Hb/BE and the clinical presentation of the patient are able to predict TIC in the majority of trauma patients. The prediction of TCI by the mentioned conditions can help guide initial advanced clotting diagnostics and clotting therapy in the first minutes of admission, if no viscoelastic POC devices are immediately available. Future studies may determine whether clinical presentation/BGA-oriented coagulation therapy is an appropriate tool for improving outcomes after major trauma.

Conflict of Interest

The authors declare that they have no conflict of interest.

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