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The effect of FFP:RBC ratio on morbidity and mortality in trauma patients based on transfusion prediction score

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Abstract

Background and Objectives—The empiric use of a high plasma to packed red-blood-cell [fresh frozen plasma:red-blood-cells (FFP:RBC)] ratio in trauma resuscitation for patients with massive bleeding has become well accepted without clear or objective indications. Increased plasma transfusion is associated with worse outcome in some patient populations. While previous studies analyse only patients who received a massive transfusion, this study analyses those that are at risk to receive a massive transfusion, based on the trauma-associated severe haemorrhage (TASH) score, to objectively determine which patients after severe trauma would benefit or have increased complications by the use of a high FFP:RBC ratio.

Methods—Multicentre retrospective study from the Trauma Registry of the German Trauma Society. Multivariate logistic regression and statistical risk adjustments utilized in analyses.

Results—A high ratio of FFP:RBC in the ≥15 TASH group was independently associated with survival, with an odds ratio of 2.5 (1.6–4.0), while the <15 TASH group was associated with increased multi-organ failure, 47% vs. 38%, (P <0.005).

Conclusions—A predictive model of massive transfusion upon admission might be able to rapidly identify which severe trauma patients would benefit or have increased complications from the immediate application of a high ratio of FFP:RBCs. This study helps to identify the appropriate population for a prospective, interventional trial.

Keywords

blood component transfusion; resuscitation; wounds and injuries

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Conflict of interest We report no conflicts of interest. This is an unfunded study.

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Introduction

Traumatic injury is the leading cause of mortality and morbidity for patients 1–59 years of age throughout the world, and road traffic fatalities are the leading cause of death for ages 5–30 in developed countries [1]. While traumatic brain injury is the most common primary mechanism of death, haemorrhage remains the primary preventable cause of death for patients presenting with severe trauma [2–4]. Twenty-five per cent of patients with traumatic injury upon admission present with coagulopathy. This has recently been described as trauma-induced coagulopathy and has been demonstrated to increase the risk of haemorrhage and death in this population [5–8]. This coagulopathy is complex and multifactorial: induced by tissue factor activation, endothelial injury, ischaemia, inflammation, and exacerbated by factor consumption, fibrinolysis, hypocalcaemia, haemodilution, hypothermia and acidosis [5–7]. The concept of haemostatic resuscitation, which includes the early use of plasma, has been developed to prevent death from haemorrhage for patients with life-threatening bleeding from traumatic injury [9,10]. Most traumatic deaths from haemorrhage occur within the first several hours of admission [11–14], and patients with severe internal bleeding may not initially be recognized to be at risk for massive bleeding, coagulopathy and shock. Contrarily, inappropriate transfusion of plasma in non-bleeding patients can lead to increased infections rates or lung injury [15–18]. As a result, early identification of patients who might benefit or be harmed from the use of haemostatic resuscitation principles or increased plasma is critical in order to attempt to prevent death from haemorrhage and decrease the risks associated with increased plasma transfusion.

The trauma associated severe haemorrhage (TASH) score was developed and validated in 1993–2006 [19]. This score utilizes seven independent variables (systolic blood pressure, haemoglobin, intra-abdominal fluid, long bone and/or pelvic fracture, heart rate, base excess and gender) to determine an individual's risk of life-threatening haemorrhage and need for massive transfusion (MT) after severe trauma. The TASH score has been validated on a similar population of over 6000 data sets and can simply be determined <15 min after arrival [19]. While there have been several other predictive algorithms developed with area under the receiver operating characteristic curve (AUC) ranging from 0.78 to 0.84 [20–23], the TASH score has reported to have an AUC of 0.88 [19].

While previous studies evaluated the relationship between blood product ratios and mortality for patients with MT, our aim in this study was to determine if a prediction model could be utilized to rapidly determine upon admission which patients might have a survival benefit with the use of a high fresh frozen plasma:red-blood-cells (FFP:RBC) resuscitation approach and which patients may have increased risk of multi-organ failure (MOF) and other morbidities.

Materials and methods

This study is a retrospective analysis of a prospective multi-centre database: the Trauma Registry of the *Deutsche Gesellschaft für Unfallchirurgie*, German Trauma Society (TR-DGU) [24]. Currently, there are 145 centres affiliated with the registry, mostly from Germany (n = 128) of which 100 are actively contributing data into the database. The data analysis for this study comprised data that was collected and entered into the database between 2002 and 2007. Each affiliated centre utilizes a standardized electronic data entry system that includes detailed information on demographics, laboratory and clinical data. The TRDGU is approved by the review board of the German Trauma Society. The Children's Hospital, Boston, internal review board approved this study.

All primary admissions (no transfers) with an injury severity score (ISS) ≥9, who received at least one blood transfusion and were at least 16 years of age, were included in this study. To minimize survivorship bias, deaths within 60 min of admission to the emergency department (ED) were excluded, and the amount and ratio of blood products transfused were calculated from the products used in the ED and/or operation room (OR) only, not including intensive care unit (ICU). Blood products transfused in this database are recorded according to location transfused and not by the time from admission. To focus on the initial resuscitation, a MT was defined as receiving ≥10 units of RBCs within in the ED and/or OR. We defined a high FFP:RBC ratio as receiving above a 1:2 ratio of FFP:RBCs. Our primary outcome measure was in-hospital mortality. Secondary outcome measures included 6-, 24-hour and 30-day mortality, ventilator-free days, hospital-free days, ICU-free days, sepsis, and MOF (sequential organ failure assessment score 3–4). Ventilator- and hospital-free days were calculated based out of 30 days.

The TASH-score[19] is based on the following point system: systolic blood pressure (<100 mmHg = 4 pts, <120 mmHg = 1 pt), haemoglobin (<7 g/dl = 8 pts, <9 g/dl = 6 pts, <10 g/dl = 4 pts, <11 g/dl = 3 pts, and <12 g/dl = 2 pts), intra-abdominal fluid or abdominal abbreviated injury scale (AIS) ≥3 (3 pts), complex long bone and/or pelvic fractures (AIS 3/4 = 3 pts and AIS 5 = 6 pts), heart rate (>120 = 2 pts), base deficit (≥10 m_M = 4 pts, ≥6 m_M = 3 pts, and ≥2 m_M = 1 pt) and gender (male = 1 pt) [19].

In order to determine above what TASH score a high or low ratio was associated with mortality, we calculated the mortality at increasing TASH scores. We arbitrarily divided the population, a priori, into six groups: TASH score 0–8 (<10% risk of MT), 9–10 (10–15% risk), 11–12 (16–25% risk), 13–14 (26–39% risk), 15–16 (40–54% risk), and >16 (>54% risk). We chose not to further subdivide the population so as not to introduce bias from small groups and multiple comparisons. We hypothesized that there would be a point at which there would be a significant (P <0.05) improvement in survival when evaluating a high FFP:RBC ratio at increasing TASH score groups. When this was determined, we used this score as the cut-off and compared patients with high or low TASH scores to patients who received a high (>1:2) or low (≤1:2) ratio of FFP:RBC (Fig. 1). A univariate analysis was conducted to compare baseline characteristics and outcomes between these four groups. Unadjusted comparisons were made within either the high or low TASH score groups. Data is presented as mean (±SD). The *t*-test and chi-squared test, as appropriate, were utilized for these univariate analyses.

In order to adjust for a combination of proven prognostic factors, the revised injury severity classification (RISC) score was calculated for the study groups and presented as a standard mortality ratio (SMR) with 95% confidence interval. The RISC score [25] is a validated prognostic index combining 10 different factors that have been shown to have a profound impact on outcome after trauma, including age, ISS, presence of head and limb injury, presence of cardiorespiratory arrest and bleeding signs, Glasgow Coma Scale, coagulation parameters partial thromboplastin time and Quick % (prothrombin time expressed as a percentage) and base excess. The RISC score and other confounding variables were incorporated into a multivariate logistic regression for both survival and MOF in the high- and low-TASH-score groups respectively. The selection of variables that were placed into the regression analyses were based upon significant associations measured upon univariate analysis with survival or MOF. We also incorporated variables associated with survival or organ failure that had been previously published to include the RISC score [25], the year of treatment [26], multi-slice computed tomography [25], the presence of pre-existing medical conditions [27], the use of vasopressors, early emergency operative intervention and FFP:RBC ratio [11]. SPSS v15.0 (SPSS, Chicago, IL, USA) was utilized for all analyses.

Results

A total of 2474 primary admissions entered into the TRDGU between 2002 and 2007 were identified and included in this study (Fig. 1). 1729 (70%) patients were male, the average age was 43 (±19) years, and 93.2% were blunt injuries. The overall mean ISS was 34 (±15.4), with an overall mortality of 24.5%.

Figure 2 depicts the in-hospital mortality based on transfusion of a high or low FFP:RBC ratio within different TASH-score groups. Within the patient group with a TASH score of 15–16 (40–54% predictive of MT), those who received a high FFP:RBC ratio had a relative in-hospital mortality reduction of 42.5% ($P = 0.009$). As described in our methods, we then divided patients based on a TASH score of ≥15 ($n = 659$), the more severely injured group, at increased risk for MT, and patients with a TASH score of <15 ($n = 1815$), the less injured group, at decreased risk for MT (Fig. 1).

TASH ≥15 patients

For these 659 patients with a TASH score ≥15, the mean ISS was 42 (±15), and the overall in-hospital mortality was 39.5% (260/659). In-hospital mortality was 34.8% for the high-ratio group, compared to 47.7% in the low-ratio group (Table 2) ($P < 0.0005$). The incidence of sepsis and MOF were similar between groups, as well as ICU-free and ventilator-free days.

The mean time of transfusions within emergency room (ER) and/or OR until ICU admission was less than 5 h, or 278 min (±118), and the mean FFP:RBC ratio was 1:0.95 (±2) for the high-ratio group, compared to 1:5.6 (±5) for the low-ratio group (Table 2). Baseline characteristics were similar between ratio groups, with the exception of femur fractures, which were more common in the high FFP:RBC ratio group (Table 1). Of note, both groups had similar admission haemoglobin concentrations, degree of coagulopathy (as measured by partial thromboplastin time and Quick %), degree of shock as measured by base excess, as well as ISS and AIS scores. Each group was also similar in severity of injury as measured by RISC score. The high FFP:RBC did experience a longer time total ER and OR time, experienced slightly more operative procedures, and had rFVIIa administered more often (Tables 1 and 2). Though the high FFP:RBC group had a higher incidence of MT, they experienced decreased mortality. This benefit in mortality was primarily in the first 24 h, with a precipitous drop in the first 6 h, as noted on the Kaplan–Meier survival curve (Fig. 3). The observed mortality was less than predicted for patients transfused a high compared to low FFP:RBC ratio (SMR 0.76 compared to 1.02) ($P < 0.005$) (Table 2). The multivariate logistic regression analysis (Table 3) indicated that a high (>1:2) FFP:RBC ratio is independently associated with survival with an odds ratio of 2.50 (1.56–4.00), ($P = 0.001$).

TASH <15 patients

For these 1815 patients with a TASH score <15, the mean ISS was 31 (±14), and the overall mortality was 19.1% (347/1815). The high- and low-ratio groups were similar in baseline demographics, were similar in severity of injury as measured by RISC score; however, the high-plasma group was more coagulopathic and spent slightly less time in the ED (Table 1). As in the ≥15 TASH group, there was a higher incidence of MT in the high-plasma group, and the mean FFP:RBC ratio was 1:0.83 (±1.25) for the high-ratio group compared to 1:10 (±5) for the low- ratio group. The overall in-hospital mortality was not statistically different, 18.2% for the high-ratio group and 20.1% for the low-ratio group (Table 4). The observed mortality was less than predicted for patients transfused a high FFP:RBC ratio, SMR 0.86, though not statistically different than the low FFP:RBC ratio group, with an SMR of 1.02 (Table 4). In the univariate or unadjusted analysis, the morbidities measured were increased

in the high ratio compared to low-ratio group. Hospital and intensive care unit length of stay were longer, and ICU-free days were decreased (10.9 compared to 12.4 days), respectively (P <0.003). Additionally, in the unadjusted analysis when the high-to-low-ratio groups were compared, the incidence of MOF was higher (47.1% vs. 38.2%) (P <0.0005) and there were decreased ventilator-free days in the high-ratio group (14.9 compared to 16.1 days), respectively, (P <0.05). When adjusted for in multivariate logistic regression, RISC score, vasopressor use, IV fluids and emergent operative interventions remained associated with MOF, and a high ratio of FFP:RBC was no longer associated with organ failure (Table 5).

Discussion

Our results demonstrate that a high FFP:RBC ratio of >1:2 (mean 1:0.95), transfused on average <5 h from admission, is independently associated with improved survival in trauma patients that have a TASH score of ≥15. All previous studies on this subject have evaluated those who have already received a massive transfusion [11,28–35]. This is the first published study that evaluates if a predictive model for MT can determine which patients might benefit from a more balanced FFP:RBC transfusion strategy and which may not. We have therefore shown that by utilizing the TASH score for rapid identification of those at risk for MT (<15 min from admission), there is an association with survival when using a high FFP:RBC transfusion strategy. This concept is critical, given that the theoretical benefit of a more balanced FFP:RBC transfusion strategy comes only when it is applied quickly in order to prevent early death from haemorrhage. Conversely, we report no survival benefit and a possible association with increased organ failure and decreased ventilator-free days with the use of a high FFP:RBC ratio for patients with a TASH score <15. This further emphasizes the importance of applying this transfusion strategy appropriately in order to improve outcomes while minimizing adverse events. Recently, an abstract presented at the 2008 American Association for the Surgery of Trauma conference performed a similar analysis. In this abstract where 50% prediction of MT was arbitrarily used to define study groups, they reported improved survival for those at high risk of MT transfused a high FFP:RBC ratio [36]. We instead analysed multiple TASH scores to determine above which cut point a MT prediction score would be associated with improved survival. Our analysis suggests that a TASH score of 15 or greater, which is associated with a MT prediction of 40%, was associated with improved survival.

In the years following WWII, blood banking became more complex as blood fractionation techniques were advanced. Over time, transfusion practice shifted from utilizing whole blood to blood components in order to improve resource allocation [37]. This transition was done without any clinical evidence comparing the safety or efficacy of the two practices for patients requiring MT. Until very recently, trauma resuscitation transfusion protocols empirically called for a ratio of one unit FFP for every 4–10 units of RBC [38,39], and for the past 25 years Advance Trauma Life Support training (ATLS) has recommended transfusing FFP only after coagulopathy was recognized on laboratory analysis, a practice which is based on 18 MT trauma patients [40]. Recent US Military and multi-centre civilian retrospective data indicate an association between the transfusion of a higher ratio of FFP:RBC with reduced mortality [11,29–33,35,41]. In addition to the haemostatic benefit of FFP replacing coagulation factors that are consumed with traumatic haemorrhage, there is some preliminary evidence that plasma may also contribute to endothelial repair mechanisms [28,42], which could possibly be another mechanism of the benefit of FFP.

In the early 1980s, Lucas and Ledgerwood [43] first noted that decreased plasma transfusion exacerbated coagulopathy in trauma patients. Several studies of trauma patients in the late 1990s reported that survivors received more FFP relative to RBC compared to non-survivors [44–46]. Additionally, computer modelling of uncontrolled haemorrhage has recommended

an FFP:RBC ratio of 2:3 [47]. Recently, there are ten studies examining survival based on the FFP:RBC ratio in massive transfusion in trauma [11,29–35,48]. Eight of these studies demonstrated an association between survival and the transfusion of an increased ratio of FFP:RBC [11,28–31,33,35,48]. Regarding the other two, Kashuk *et al.* [28,32] found a benefit for those in the ≥1:2 group, but not for those getting 1:1; however, this group only had 11 patients. Snyder *et al.* [34] also found a benefit, though this benefit lost significance when placed in the regression analysis. However, this study was underpowered (n = 134 with 67 deaths) to perform the regression analysis with the number of variables utilized (10–15), so it is difficult to draw a definitive conclusion.

Though our study has the advantage of analysing patients at risk for massive transfusion from a prospectively collected database, it still contains the same limitations inherent in retrospective analyses. When applying blood product ratios retrospectively to trauma patients, two main sources of bias are survival bias and catch-up bias. To reduce survival bias, deaths within 60 min were excluded. This should assure that all patients had adequate time to receive FFP, but may not completely eliminate the survival bias. Although one may also argue that within this group are the ideal patients we would like to study, such as patients who should have received FFP up front, yet haemorrhaged to death when they perhaps otherwise would have been saved. While previous studies calculate blood product ratios over the first 6–24 h, our mean time from ED to ICU was <5 h (mean 278 min), with the majority <7 h. Additionally, transfusions were not counted after admission to the ICU. This drastically reduces the `catch-up' bias, where survivors get transfused FFP later in the course of the day after the initial resuscitation and surgical control of major bleeding in the operating room.

Interestingly, patients who were <40% predicted to receive a MT, and who received a high ratio of FFP:RBC, had increased adverse events, to include MOF, decreased ventilator-free and ICU-free days. Increased morbidity from FFP has previously been reported extensively in non-bleeding patients [15,18,49]. Side effects include allergic reactions, rarely anaphylaxis, and transfusion-associated acute lung injury (TRALI) [15]. Classically, TRALI describes pulmonary oedema and hypoxia that occurs after blood product transfusion likely mediated by the transfer of anti-neutrophil antibodies [50,51]. Recently, a `delayed TRALI syndrome' has been described associated with trauma and MT [50]. The aetiology is poorly defined, but could be related to the decreased ventilator-free days we observed in the high-ratio group for those not predicted to need MT. We also noted an independent association of increased crystalloid resuscitation with death that might also account for the decreased ventilator-free days. Given the recent emphasis of the `1:1 FFP:RBC' transfusion ratio within the trauma community, it is critical that this strategy is applied only to those patients who may benefit, given the risks outlined earlier.

Prospective, randomized trials that study outcomes related to the use of plasma, platelets and RBCs for patients with severe traumatic injury are needed. As a hypothesis-generating study, our analysis helps identify which population, upon admission to the ED, might benefit from a more balanced FFP:RBC transfusion protocol. If our results are validated, the TASH predictive model of MT could be used in prospective studies to determine inclusion criteria for blood product ratio studies in patients with severe traumatic injury. In addition to survival benefits, one would also be able to discern whether a more balanced FFP:RBC ratio would decrease overall RBC utilization and the need for a MT. Two recent studies indicate that the use of a massive transfusion protocol with a 1:1 strategy decreases overall RBC utilization and can improve survival [52,53]. Additional study is needed regarding platelet transfusion in patients predicted to need MT. A prospective cohort study in 10 trauma centres in the US has begun that will evaluate both FFP and platelet to RBC ratios.

This study demonstrates that a high FFP:RBC ratio (mean 1:0.95), may improve survival for trauma patients who are at least at a 40% risk of receiving a massive transfusion by a TASH score predictive model. This study also indicates that a high FFP:RBC ratio does not improve mortality and may cause harm for those at lower risk for a massive transfusion. Our results, if validated, may be used to help identify the appropriate population for the prospective study of FFP:RBC ratios for patients with severe traumatic injury.

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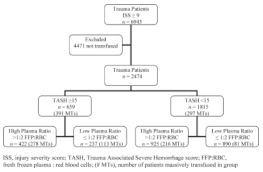
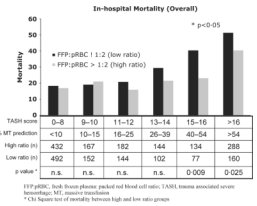


Fig. 1.

Flow chart of patients analysed. ISS, injury severity score; TASH, trauma associated severe haemorrhage score; FFP:RBC, fresh frozen plasma : red-blood-cells; (# MTs), number of patients massively transfused in group.



TASH score	0–8	9–10	11–12	13–14	15–16	>16
% MT prediction	<10	10–15	16–25	26–39	40–54	>54
High ratio (n)	432	167	182	144	134	288
Low ratio (n)	492	152	144	102	77	160
p value *	n.s.	n.s.	n.s.	n.s.	0·009	0·025

FFP:pRBC, fresh frozen plasma: packed red blood cell ratio; TASH, trauma associated severe haemorrhage; MT, massive transfusion
* Chi Square test of mortality between high and low ratio groups

Fig. 2.

Mortality based on high and low FFP:RBC ratio and prediction of massive transfusion based on TASH score. FFP:pRBC, fresh frozen plasma:packed red-blood-cell ratio; TASH, trauma associated severe haemorrhage; MT, massive transfusion. *Chi-squared test of mortality between high- and low-ratio groups.

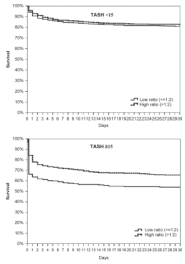


Fig. 3.
Kaplan-Meier curves for 30 day survival for TASH score groups <15 and ≤15.

Table 1

Basic characteristics, injury pattern, physiological state at scene and upon emergency department arrival for patients above and below 40% risk of needing massive transfusion

	TASH ≥ 15		**TASH < 15**	
	High plasma FFP:pRBC > 1:2	**Low plasma FFP:pRBC ≤ 1:2**	**High plasma FFP:pRBC > 1:2**	**Low plasma FFP:pRBC ≤ 1:2**
N (total)	422	237	925	890
Sex				
Male (*n*; %)	291 (69)	152 (64.1)	679 (73.4)	607 (68.2)
Female (*n*; %)	131 (31)	85 (35.9)	246 (26.6)	283 (31.8)
Age (years; mean ± SD)	41 (18)	43 (19)	42 (19)	46 (20)
Trauma mechanism				
Blunt (*n*; %)	390 (92.4)	215 (90.7)	871 (94.2)	831 (93.4)
Penetrating (*n*; %)	32 (7.6)	22 (9.3)	54 (5.8)	59 (6.6)
Predicted mortality rate based upon RISC score (%)	45.9	46.9	21.2	19.7
Injury severity score/ISS (points; mean ± SD)	42 (15)	42 (15)	32 (14)	29 (14)
AIS head/neck (points; mean ± SD)	2.1 (2.1)	2.0 (2.0)	2.4 (2.1)	2.2 (2.1)
AIS thorax (points; mean ± SD)	3.1 (1.6)	3.2 (1.8)	2.4 (1.9)	2.3 (1.9)
AIS abdomen (points; mean ± SD)	2.6 (1.7)	2.5 (1.8)	1.3 (1.7)	1.0 (1.5)
AIS extremities (points; mean ± SD)	3.4 (1.3)	3.2 (1.5)	2.3 (1.4)	2.3 (1.4)
Pelvic fracture (*n*; %)	219 (51.9)	115 (48.5)	262 (28.3)	241 (27.1)
Femur fracture (n; %)	**271 (64.3)** *	**121 (51)** *	280 (30.3)	282 (31.7)
FAST exam (*n*; %)	375 (93.1)	204 (91.5)	816 (92.9)	767 (92.5)
Glasgow coma scale at scene (points; mean ± SD)	9 (5)	9 (5)	10 (5)	10 (5)
BP systolic. at scene (mmHg; mean ± SD)	89 (32)	84 (32)	112 (33)	114 (32)
Heart rate at scene (bpm; mean ± SD)	106 (30)	103 (32)	98 (25)	95 (23)
IV fluids pre-hospital (litres; mean ± SD)	2.2 (1.1)	2.2 (1.4)	1.7 (1.0)	1.7 (1.1)
Time pre-hospital (minutes; mean ± SD)	78 (47)	74 (41)	77 (48)	74 (38)
SBP at ER (mmHg; mean ± SD)	85 (27)	82 (27)	120 (27)	119 (27)
Heart rate at ER (bpm; mean ± SD)	103 (29)	105 (28)	93 (22)	91 (20)
Temperature (°C; mean ± SD)	34.9 (1.6)	35.3 (1.6)	35.7 (1.4)	35.9 (1.2)
Haemoglobin (g/dl; mean ± SD)	7.3 (2.1)	7.2 (2.2)	10.6 (2.4)	10.6 (2.4)
Platelets (per ml; mean ± SD)	153.5 (88.8)	154.3 (69.8)	192.9 (75.5)	198.5 (76.8)
WBC (per nl; mean ± SD)	11.3 (6.3)	12.1 (6.2)	12.7 (5.9)	12.1 (5.5)
Quick (%; mean ± SD)	48 (20)	50 (22)	**68 (21)** *	**75 (21)** *
PTT (seconds; mean ± SD)	58.7 (34.1)	63.4 (40.0)	36.9 (17.1)	35.7 (18.9)
Base Excess (mM; mean ± SD)	−8.9 (5.8)	−9.4 (6.3)	−3.7 (3.9)	−3.5 (3.9)
TASH score (points; mean ± SD)	18.4 (2.8)	18.5 (3.1)	8.5 (3.6)	8.0 (3.4)
Time in ER (minutes; mean ± SD)	69 (42)	70 (41)	**77 (44)** *	**83 (48)** *
Time ER arrival to ICU (minutes; mean ± SD)	300 (119) *	236 (117) *	302 (125) *	258 (127) *

AIS, abbreviated injury scale; SBP, systolic blood pressure; bpm, beats per minute; ER, emergency room; FAST, focused assessment with sonography for trauma; ICU, intensive care unit; IV, intravenous; LOS, length of stay; n.s., non-significant; OR, operating room; PTT, partial thromboplastin time; TASH, trauma-associated severe haemorrhage score; SD, standard deviation; WBC, white-blood-cells.

* Pair of high- and low-ratio values are statistically different ($P < 0.05$).

Table 2

Blood products, procedures and outcomes for patients with at least a TASH Score of 15

	High plasma FFP:pRBC > 1:2	Low plasma FFP:pRBC ≤ 1:2	*P*-value
N (total)	422	237	
Massive transfusion (n; %)	**278 (65.9)**	**113 (47.7)**	**<0.005**
FFP:RBC transfusion ratio (mean ± SD, and median)	**1.05 (0.5), 1**	**0.19 (0.2), 1**	**<0.005**
pRBC transfusions/units (mean ± SD)	**16.1 (12.9)**	**12.4 (12.1)**	**<0.005**
FFP transfusions/units (mean ± SD)	**15.4 (12.2)**	**3.2 (4.9)**	**<0.005**
Platelet transfusions/units (n; mean ± SD)	**1.4 (3.1)**	**0.8 (2.6)**	**<0.005**
Pre-hospital crystalloids (mls; mean ± SD)	1298 (779)	1365 (1017)	n.s.
Pre-hospital colloids (mls; mean ± SD)	827 (606)	782 (643)	n.s.
In-hospital crystalloids (mls; mean ± SD)	**3481 (2722)**	**3093 (2588)**	**<0.005**
In-hospital colloids (mls; mean ± SD)	**1788 (1587)**	**1542 (1380)**	**<0.005**
Fibrinogen concentrates* (*n*; %)	**99/239 (41.1)**	50/131 (38.2)	n.s.
rFVIIa administration* (n; %)	**30/213 (14.1)**	**6/99 (6.1)**	**<0.05**
Emergency operative intervention (*n*; %)	101 (23.9)	56 (23.6)	n.s.
Number of operative procedures (mean ± SD)	**8 (6)**	**6 (6)**	**<0.005**
Multi-slice computed tomography (*n*; %)	228 (54)	114 (50.9)	n.s.
Vasopressor use (*n*; %)	321 (76.1)	173 (73.3)	n.s.
Sepsis (*n*; %)	109 (28.9)	40 (23.4)	n.s.
Single organ failure (*n*; %)	287 (76.9)	145 (83.3)	n.s.
Multiple organ failure (*n*, %)	236 (63.3)	118 (67.8)	n.s.
Ventilator-free days (days; mean ± SD)	9.5 (10.9)	8.4 (10.9)	n.s.
ICU LOS (days; mean ± SD)	**18.9 (22.3)**	**14 (18.1)**	**<0.005**
In-hospital LOS (days; mean ± SD)	**38.6 (42.5)**	**28 (33.2)**	**<0.005**
ICU free days (days; mean ± SD)	6.3 (8.4)	6.1 (9.0)	n.s.
6-hour mortality (n; %)	**52 (12.3)**	**77 (32.5)**	**<0.0005**
24-hour mortality (n; %)	**86 (20.4)**	**83 (35.1)**	**<0.0005**
30-day mortality (n; %)	**145 (34.4)**	**109 (46.1)**	**<0.005**
Time to death (days; mean (±SD) , median)	4.43 (9.8), 1	3.1 (7.6), 0	n.s.
In-hospital mortality overall (n; %)	**147 (34.8)**	**113 (47.7)**	**<0.005**
Standard mortality ratio [95% CI]	**0.76 [0.66–0.86]**	**1.02 [0.88–1.15]**	**<0.005**

FFP, fresh frozen plasma; RBC, red-blood-cell unit; SD, standard deviation; ICU, intensive care unit; LOS, length of stay; CI, confidence interval.

*Fibrinogen and rVIIa administration is documented in the Trauma Registry-Deutsche Gesellschaft für Unfallchirurgie (TR-DGU) only as of 2005.
Bold values are significant ($P < 0.05$).

Table 3

Multivariate logistic regression analysis of variables to determine independent associations with survival in patients with a TASH ≥ 15 or ≥40% predicted to have massive transfusion (*n* = 557 complete datasets)

	Regression coefficient	Odds ratio (95% CI)	*P*-value
RISC score (25) (coefficient)[a]	−0.8360	0.43 (0.35–0.50)	0.001
Emergency operative intervention	−0.4670	0.63 (0.38–1.03)	0.045
FFP:RBC (>1:2) (high plasma ratio)	0.915	2.50 (1.56–4.00)	0.001

[a]Per point increase in revised injury severity classification (RISC) score; the RISC score is a prognostic index combining 10 different factors, including age, new ISS, presence of head and limb injury, presence of cardiorespiratory arrest and bleeding signs, Glasgow Coma Scale, coagulation parameters and base excess.

Table 4

Blood products, procedures and outcomes for patients with TASH score <15

	High plasma FFP:pRBC > 1:2	**Low plasma FFP:pRBC ≤ 1:2**	***P*-value**
N (total)	925	890	
Massive Transfusion (n; %)	216 (23.4)	81 (9.1)	<0.05
FFP:RBC transfusion ratio (mean ± SD, and median)	1.2 (0.8), 1	0.1 (0.2), 0	<0.005
pRBC transfusions/units (mean ± SD)	6.9 (7.1)	4.6 (4.3)	<0.005
FFP transfusions/units (mean ± SD)	7.6 (6.8)	0.8 (1.8)	<0.005
Platelet transfusions/units (n; mean ± SD)	0.4 (1.2)	0.1 (0.5)	<0.005
Pre-hospital crystalloids (mls; mean ± SD)	1135 (750)	1096 (830)	n.s.
Pre-hospital colloids (mls; mean ± SD)	574 (513)	513 (527)	n.s.
In-hospital crystalloids (mls; mean ± SD)	3438 (2437)	2756 (1999)	<0.005
In-hospital colloids (mls; mean ± SD)	1361 (1045)	1019 (841)	<0.005
Fibrinogen concentrates* (*n*; %)	111/525 (19.1)	75/494 (15.2)	n.s.
rFVIIa administration* (*n*; %) 14	14/486 (2.9)	10/454 (2.2)	n.s.
Emergency operative intervention (*n*; %)	92 (10.2)	55 (6.6)	n.s.
Number of operative procedures (mean ± SD)	6 (5)	5 (4)	n.s.
Multi-slice computed tomography (n; %)	432 (46.7)	357 (41.1)	<0.05
Vasopressor use (n; %)	449 (53.9)	376 (41.4)	<0.05
Sepsis (*n*; %)	144 (16.7)	133 (16.2)	n.s.
Single organ failure (n; %)	551 (65.2)	481 (58.6)	<0.05
Multiple organ failure (n, %)	398 (47.1)	314 (38.2)	<0.0005
Ventilator-free days (days; mean ± SD)	14.9 (11.5)	16.1 (12)	<0.05
ICU LOS (days; mean ± SD)	17 (15.5)	14.6 (14.8)	<0.005
In-hospital LOS (days; mean ± SD)	35.5 (32.7)	31.6 (27.8)	<0.05
ICU free days (days; mean ± SD)	10.9 (10.1)	12.4 (11)	<0.005
6-h mortality (*n* ;%)	34 (3.7)	42 (4.7)	n.s.
24-h mortality (*n*; %)	61 (6.6)	72 (8.1)	n.s.
30-day mortality (*n*; %)	161 (17.4)	171 (19.2)	n.s.
Time to death (days; mean ± SD, and median)	6.9 (13.8), 3	6.7 (11.9), 2	n.s.
In-hospital mortality overall (*n*; %)	168 (18.2)	179 (20.1)	n.s.
Standard mortality ratio [95% CI]	0.86 [0.74–0.98]	1.02 [0.89–1.16]	n.s.

FFP, fresh frozen plasma; RBC, red-blood-cell unit; SD, standard deviation; ICU, intensive care unit; LOS, length of stay; CI, confidence interval.

*Fibrinogen and rVIIa administration is documented in the Trauma Registry-Deutsche Gesellschaft fü Unfallchirurgie (TR-DGU) only as of 2005.
Bold values are significant ($P < 0.05$).

Table 5

Multivariate logistic regression analysis of variables to determine independent associations with the development of multi-organ failure in surviving patients with TASH < 15 (*n* = 1242 complete datasets)

	Regression coefficient	Odds ratio (95% CI)	*P*-value
RISC score (25) (coefficient)[a]	0.331	1.39 (1.27–1.52)	0.001
Vasopressors	0.916	2.49 (1.94–3.22)	0.001
Intravenous crystalloids/colloids (total)	0.082	1.08 (1.03–1.14)	0.001
Emergency operative interventions	0.591	1.81 (1.14–2.87)	0.012

[a]Per point increase in revised injury severity classification (RISC) score; the RISC score is a prognostic index combining 10 different factors, including age, new ISS, presence of head and limb injury, presence of cardiorespiratory arrest and bleeding signs, Glasgow Coma Scale, coagulation parameters and base excess.