Massive Transfusion: The Revised Assessment of Bleeding and Transfusion (RABT) Score

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Abstract

Background Massive transfusion (MT) is a lifesaving treatment for trauma patients with hemorrhagic shock, assessed by Assessment of Blood Consumption (ABC) Score based on mechanism of injury, systolic blood pressure (SBP), tachycardia, and FAST exam. The aim of this study was to assess the performance of ABC score by replacing hypotension and tachycardia; with Shock Index (SI) > 1.0 and including pelvic fractures.

Methods We performed a 2-year (2014–2015) analysis of all high-level trauma activations and excluded patients dead on arrival. The ABC score was calculated using the 4-point score [blunt (0)/penetrating trauma (1), HR $\geq$ 120 (1), SBP $\leq$ 90 mmHg (1), and FAST positive (1)]. The Revised Assessment of Bleeding and Transfusion (RABT) score also included 4 points, calculated by replacing HR and SBP with SI > 1.0 and including pelvic fracture. AUROC compared performances of the two scores.

Results A total of 380 patients were included. The overall MT was 27%. Patients receiving MT had higher median ABC scores [1.1 (0–2) vs. 1 (0–2), $p = 0.15$] and RABT scores [2 (1–3) vs. 1 (0–2), $p < 0.001$]. The RABT score had better discriminative power (AUROC = 0.828) compared to ABC score (AUROC = 0.617) for predicting the need for MT. Cutoff of RABT score ≥ 2 had a sensitivity of 84% and specificity of 77% for predicting need for MT compared to ABC score with 39% sensitivity and 72% specificity.

Conclusion Replacement of hypotension and tachycardia with a SI > 1.0 and inclusion of pelvic fracture enhanced discrimination of ABC score for predicting the need for MT. The current ABC score would benefit from revision to more appropriately identify patients requiring MT.

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Introduction

Trauma is one of the leading causes of morbidity and mortality in the USA [1], and post-traumatic hemorrhage (exsanguination) is second leading cause of mortality after trauma [2, 3]. Furthermore, over 20–40% of trauma deaths that occur after hospital admission usually involve massive hemorrhage, which is potentially preventable [4]. Hemorrhage management has changed significantly over the last two decades. Now, prompt hemorrhage control, along with adequate resuscitation, is a key component of early trauma care. Additionally, there has been a more recent change from the aggressive to the limited use of crystalloid fluids for the resuscitation of exsanguination. In fact, in such cases, there has been a paradigm shift from the use of crystalloids altogether to blood products [5, 6]. Indeed, as observed in the Pragmatic, Randomized Optimal Platelet and Plasma Ratios (PROPPR) trial, administration of blood products (in a 1:1:1 ratio of plasma, platelet, and red blood cells) within 24 h improved hemostasis control and reduced the number of deaths due to exsanguination [7].

A massive transfusion (MT) is defined as a transfusion of ≥ 10 packed red blood cells (PRBC) units within the first 24 h of injury [8]. It occurs in about 3–5% of all civilian and 8–10% of all military trauma cases [6, 9]. While an MT addresses the rapid blood loss and coagulopathy associated with trauma, the optimal timing of the initiation of balanced resuscitation also greatly improves outcomes [10–12]. Several investigators have developed systems based on physiological, hemodynamic stability, laboratory, and mechanism parameters that can reliably predict when to activate a MT protocol (MTP) [10, 13–19]. These scoring systems are based on retrospective and prospective analyses of patients who received an MT. However, they are not rooted in real-time application and, most often, simplified versions are plagued by the risk of under triage or over triage for the activation of an MTP.

According to the literature, the most common scoring systems are the Assessment of Blood Consumption (ABC) Score [14]. The ABC score includes an SBP < 90 mm Hg, a heart rate (HR) ≥ 120 beats per minute (bpm), a positive focused assessment for the sonography of trauma (FAST) exam, and a penetrating mechanism of injury (MOI) [14]. The aim of our study was to compare the Revised Assessment of Bleeding and Transfusion (RABT) score with the ABC score. We hypothesized that the RABT score

would have a higher sensitivity and specificity for the activation of an MTP than the ABC score.

Methods

Setting

We performed a retrospective analysis of all high-level trauma activations for a 2-year period (2014–2015) in our trauma registry at Banner University Medical Center-Tucson (BUMCT) in Arizona. As the only Level-1 Trauma Center in southern Arizona (verified by the American College of Surgeons and the State of Arizona), BUMCT treats more than 5000 patients each year. This project was approved by the Institutional Review Board (IRB) of the University of Arizona.

Inclusion and exclusion criteria

We included all high-level trauma activation patients age ≥ 18 years who were predicted to receive blood transfusions and excluded all those transferred from other facilities, dead on arrival, who sustained burns or had missing data.

Data points

We abstracted the following data points from the BUMCT trauma registry: demographics (age, gender, race, and ethnicity); vitals on presentation [heart rate (HR), systolic blood pressure (SBP), respiratory rate, temperature, and Glasgow Coma Scale (GCS)]; MOI, FAST result; pelvic fracture; hospital length of stay (LOS); intensive care unit (ICU) LOS and ventilator days; and, in-hospital mortality and discharge disposition. We abstracted patients' injury characteristics via the Injury Severity Score (ISS) and the Abbreviated Injury Scale (AIS) Score. An MT was defined as a transfusion of > 10 units of packed red blood cells (pRBC) within the first 24 h of admission [11]. The Shock Index (SI) was calculated as a ratio of HR to SBP ($SI = HR/SBP$). Patients were stratified into two groups: those who received an MT (MT) and those who did not (No MT).

RABT score

The RABT score consists of four (dichotomous) components that are readily obtainable in a typical trauma bay for acutely injured patients. The presence of any one component contributes one point to the total score, which ranges from zero to four. The RABT components are as follows:

- Positive FAST (1 = yes, 0 = no)

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- SI > 1 (1 = yes, 0 = no)
- Presence of a pelvic fracture (1 = yes, 0 = no)
- A penetrating MOI (1 = yes, 0 = no)

Each variable if present was given a score of one, with a range from zero to four.

Statistical analysis

We performed descriptive statistics. Data are reported as mean $\pm$ standard deviation (SD) for continuous descriptive variables, median (range) for ordinal descriptive variables, and as proportions for categorical variables. We used a logistic regression model for an MT to determine independent predictors. To assess the association between each variable and the binary outcomes, we performed a univariate analysis. Variables with a significant ($p < 0.2$) association on the univariate analysis were then used in a multivariate logistic regression model after controlling for demographics, and injury severity. The model fit was assessed by the Hosmer–Lemeshow test. In the logistic regression model, the Hosmer–Lemeshow test exceeded 0.05 and the tolerance was greater than 0.1 for all independent variables with a variance inflation factor of less than 10.0. The predictive capacity of the RABT score for an MT was then assessed using a receiver operator characteristic (ROC) curve analysis. Optimum cutoff values were determined on the ROC curve using the Youden Index. We performed a Chi-square test for categorical variables as well as a Student's t test and a Mann–Whitney U test to assess the difference between two continuous variables. For data analysis, we used the statistical package for social sciences software (SPSS, V24; IBM Inc. Chicago, IL, USA). A p value < 0.05 was considered statistically significant.

Results

We included a total of 380 patients in the analysis. The mean age was 42.9 ± 20 , and 72.1% were males. The median ISS was 23 (13–34), the mean SBP was 121 ± 31 , and the mean HR was 109 ± 28 . The MOI was blunt in 66.9% patients. Overall, 26.8% of the patients received an MT, while the mortality rate was 25.3%.

The demographics and injury parameters of the two groups are shown in Table 1. Patients who received an MT were more likely to have a higher HR ($p < 0.001$), a lower GCS ($p = 0.019$), a higher ISS ($p < 0.001$), and a higher mortality rate ($p < 0.001$). There was no difference in the median ($p = 0.10$) and mean ($p = 0.1$) ABC scores between the two groups, while patients who received an

MT had a higher mean ($p < 0.001$) and median ($p < 0.001$) RABT score.

The RABT score was created using a multivariate logistic regression model. All of the four components of the RABT score independently predicted an MT: a positive FAST with an OR of 2.5 (1.5–3.4), an SI > 1 with an OR of 8.9 (7.5–11.3), a pelvic fracture with an OR of 4.4 (3.7–5.8], and a penetrating MOI with an OR of 3.1 (2.6–3.8).

Clinical characteristics and outcomes in relation to the RABT score are summarized in Table 2. An MT was received in 1.1% (1/88) of patients with a RABT score of zero, 10.5% (15/142) with a score of 1; 53.4% (71/133) with a score of 2; 85.7% (12/14) with a score of 3; and 100% (3/3) with a score of 4. Clinical characteristics and outcomes in relation to the ABC score are summarized in Table 3. An MT was received in 21.9% (21/96) of patients with an ABC score of 0; 29.5% (49/166) with a score of 1; 31% (31/100) with a score of 1; 61% (11/18) with a score of 3; and 100% (2/2) with a score of 4.

On performing an ROC analysis, the RABT score had better discriminative power (AUROC = 0.828, 95% CI = 0.782–0.873, $p < 0.001$) compared to the ABC score (AUROC = 0.617, 95% CI = 0.551–0.68, $p < 0.001$) for predicting the need for an MT (Fig. 1). For the RABT score, the ROC curve analysis revealed an optimal cutoff RABT score ≥ 2 (using the Youden Index) that corresponds to a sensitivity of 84% and a specificity of 77% for predicting the need for an MT; in contrast to the ABC score with 39% sensitivity and 72% specificity. The sensitivity, specificity, NPV and PPV of the RABT and ABC scores are listed in Table 4. Patients who received an MT were more likely to have an ABC or a RABT score ≥ 2 ($p < 0.001$) compared to those patients who did not. Furthermore, 84.3% of patients who received MT had a RABT score ≥ 2 , but only 41.2% had an ABC score of ≥ 2 ($p < 0.001$).

Table 5 summarizes the false negatives using the RABT score and a cutoff of two. There were no significant differences between the age, gender, race, and ISS between patients with RABT score < 2 and ≥ 2 . Patients who were false negatives were more likely to have blunt mechanism of injury (100 vs. 70.6%, $p < 0.001$).

Using an RABT score cutoff of 2 points (RABT Score ≥ 2), 64 patients were defined as false positives, i.e., were predicted to receive MT and did not receive it. When compared with the remaining of the patients, they were more likely to be younger ($p = 0.015$), males ($p = 0.01$) and had a SI > 1 ($p = 0.021$).

Table 1 Demographics and injury parameters of the two groups

Characteristics	No MT (<i>n</i> = 278)	MT (<i>n</i> = 102)	<i>p</i>
Age, year, mean $\pm$ SD	42.5 $\pm$ 20.6	44.0 $\pm$ 20.3	0.52
Male, % (<i>n</i>)	71.9% (200)	72.5 (74)	0.90
White, % (<i>n</i>)	81.3% (226)	76.5% (78)	0.02
Penetrating MOI, % (<i>n</i>)	34.5% (96)	29.4% (30)	0.28
Vital parameters			
ED SBP, mean $\pm$ SD	121.5 $\pm$ 32	120.6 $\pm$ 28.5	0.80
ED HR, mean $\pm$ SD	104.5 $\pm$ 28.5	124 $\pm$ 24.5	<0.001
Injury severity and pattern			
GCS, median (IQR)	14 (3–15)	11 (3–15)	0.019
ISS, median (IQR)	18 (10–29)	34 (22–43)	<0.001
ABC score			
Mean $\pm$ SD	1.1 $\pm$ 0.63	1.23 $\pm$ 0.83	0.10
Median (IQR)	1 (0–2)	1 (0–2)	0.15
RABT score			
Mean $\pm$ SD	1.1 $\pm$ 0.79	1.98 $\pm$ 0.60	<0.001
Median (IQR)	1 (0–2)	2 (1–3)	<0.001
Mortality, % (<i>n</i>)	16.5% (46)	49% (50)	<0.001

MT massive transfusion, ISS Injury Severity Score, ED Emergency Department, SBP systolic blood pressure, HR heart rate, GCS Glasgow Coma Scale

Table 2 Clinical characteristics and outcomes by RABT score

Variable	0 (<i>n</i> = 88)	1 (<i>n</i> = 142)	2 (<i>n</i> = 133)	3 (<i>n</i> = 14)	4 (<i>n</i> = 3)
Penetrating MOI, % (<i>n</i>)	0	35.6% (50)	48.1% (64)	78.6% (11)	100% (3)
Positive FAST,% (<i>n</i>)	0	17.8% (26)	36.8 (50)	95.7% (12)	100% (3)
SI > 1, % (<i>n</i>)	0	37.3% (52)	81.2% (108)	100% (14)	100% (3)
Pelvic fracture, % (<i>n</i>)	0	9.6% (14)	33.1% (44)	35.7% (5)	100% (3)
MT, % (<i>n</i>)	1.1% (1)	10.5% (15)	53.4% (71)	85.7% (12)	100% (3)
Mortality, % (<i>n</i>)	25% (22)	22.5% (32)	28.5 (38)	21.4 (3)	33.3% (1)

MOI mechanism of injury, FAST focused assessment with sonography in trauma, SI Shock Index, MT massive transfusion

Table 3 Clinical characteristics and outcomes by ABC score

Variable	0 (<i>n</i> = 96)	1 (<i>n</i> = 166)	2 (<i>n</i> = 100)	3 (<i>n</i> = 18)	4 (<i>n</i> = 2)
Penetrating MOI, % (<i>n</i>)	0	34% (56)	58% (58)	66% (12)	100% (2)
Positive FAST,% (<i>n</i>)	0	15% (23)	55% (55)	61% (11)	100% (2)
HR $\geq$ 120 bpm	0	26% (45)	50% (50)	88% (16)	100% (2)
SBP $\leq$ 90 mm Hg	0	24% (42)	37% (37)	83% (15)	100% (2)
MT, % (<i>n</i>)	21.9% (21)	29.5% (49)	31% (31)	61% (11)	100% (2)
Mortality, % (<i>n</i>)	19.8% (19)	23% (31)	30% (30)	38.8% (7)	100% (2)

MOI mechanism of injury, FAST focused assessment with sonography in trauma, SI Shock Index, MT massive transfusion

Discussion

Hemorrhagic shock remains one of the leading causes of death within the first 24 h of injury, despite the paradigm shift in resuscitation techniques. Along with traumatic

exsanguination, hemorrhagic shock contributes to a mortality rate greater than 50% within the first 24 h after an injury; and more than 80% within the operating room [3, 20, 21]. While only a small subset of the trauma population has a significant hemorrhage requiring an MTP,

Fig. 1 Area under the ROC curve for RABT and ABC score

they have a very high mortality rate and consume two-thirds of the total number of blood transfusions received by all trauma patients [22]. Nonetheless, early identification of patients with a significant hemorrhage who will likely require a massive transfusion as well as timely activation of an MTP can lead to improve outcomes. Likewise, blood is a precious resource and should only be utilized in patients who really need it. In our analysis, we have devised a scoring system based on patient initial characteristics that can be easily obtained in the trauma bay, which can predict MT.

In order to rapidly identify patients who will require an MT, several scoring criteria have been proposed. One is the Trauma Associated Severe Hemorrhage (TASH) Score derived from German Trauma Registry data [15]. It is, however, limited because it has laboratory parameters and requires the ISS for the calculation of the score. Another scoring system was developed by McLaughlin et al. [10] using data from the Joint Theater Trauma Registry (JTTR) maintained at the US Army Institute of Surgical Research. The McLaughlin score, however, also relies on laboratory tests (i.e., arterial blood gas and hematocrit), which are not

readily available to clinicians in the trauma bay. One of the most recent and more widely used scoring system for MTP activation is the ABC score [11]. Although this is a simple score comprising a penetrating mechanism of injury, a positive FAST, arrival SBP, and arrival HR, it has questionable sensitivity and specificity.

In contrast, the RABT score is as simple as the ABC score and does not require any of the laboratory parameters required for the calculation of the TASH, CITT and McLaughlin scores. The RABT score substitutes the HR and the SBP required for the ABC score with the SI and the presence of a pelvic fracture. The SI, which has been studied extensively, has better predictive power compared to HR or SBP alone [23, 24]. It also correlates with hospital resource use, number of blood products received, and mortality after trauma. Moreover, the addition of a pelvic fracture further increased the discriminative power of the RABT score because such a fracture is associated with extensive bleeding into the pelvic cavity, which is relatively difficult to control and has been shown to be associated with increased mortality due to hemorrhage [25–27]. While the ABC score is widely used in clinical settings, our analysis shows that its sensitivity and specificity for predicting an MT were poor. In contrast, the discriminative power of the RABT score to predict an MT was better than the ABC score. Both the sensitivity and the specificity of the RABT score for predicting an MT was higher than the ABC score at each point. In fact, in the analysis by Nunez et al. 33.3% of the patients who had an ABC score of 1 or less and received MT had a pelvic fracture, which could have been predicted by the RABT score [11].

In our analysis, all four variables (i.e., the SI, a pelvic fracture, a penetrating mechanism of injury, and a positive FAST) independently predicted massive transfusion. Isolated vital parameters such as heart rate and systolic blood pressure have been shown unreliable in the assessment of hemorrhagic shock [28–30]. Their ratio defined by SI has been emphasized to serve as a capable measure for unstable hemodynamics. SI has been used to risk stratify patients for transfusion requirement and outcomes [31]. As

Table 4 Sensitivity, specificity, NPV, and PPV of RABT and ABC score

Cutoff point	Sensitivity		Specificity		NPV		PPV	
	RABT	ABC	RABT	ABC	RABT	ABC	RABT	ABC
≥1	99.1	82	31.2	28	99	78	35	33
≥2	84	39	77	72	93	73	57	37
≥3	15.3	11	99.2	97	76	72	88	65
≥4	3	2	100	100	73	70	100	100

NPV negative predictive value, PPV positive predictive value, RABT Revised Assessment of Bleeding and Transfusion Score, ABC Assessment of Blood Consumption Score

Table 5 False negatives: patients who received a massive transfusion but did not have an RABT score of ≥ 2

S. no.	Sex	Age	MOI	SI	FAST	Pelvic Fx	24-h Products	Death	Injuries
1	M	32	Blunt	0.98	0	0	10 RBCs 8 Platelets 9 Plasma	No	Femur, humerus, and radius fracture, and splenic injury
2	M	49	Blunt	0.93	1	0	12 RBC 9 Platelets 10 Plasma	No	Small bowel degloving injury, multiple rib fractures
3	F	42	Blunt	1.8	0	0	35 RBC 18 Platelets 25 Plasma	Yes	Bilateral rib fractures, traumatic aortic rupture
4	M	62	Blunt	1.45	0	0	17 RBC 12 platelets 12 Plasma	Yes	Lower extremity and bilateral femur fractures
5	M	48	Blunt	0.89	1	0	16 RBC 9 Platelets 5 Plasma	No	Multiple spine injury, liver laceration
6	M	31	Blunt	1.3	0	0	13 RBC 6 Platelets 5 Plasma	No	Crush injury, femoral fracture, abdominal bruises
7	F	60	Blunt	0.91	1	0	19 RBC 9 Platelets 7 Plasma	Yes	Multiple rib and spine fracture, small bowel traumatic injury
8	M	38	Blunt	0.98	0	1	11 RBC 8 Platelets 9 Plasma	Yes	Pelvic fracture, femur fracture
9	M	39	Blunt	0.93	1	0	13 RBC 5 Platelets 8 Plasma	No	Tibial–fibular and femur neck fractures, multiple rib fractures
10	M	37	Blunt	0.88	1	0	10 RBC 2 Platelets 2 Plasma	No	Bilateral femoral neck, rib fractures, traumatic liver injury
11	M	42	Blunt	2.2	0	1	21 RBC 15 Platelets 10 Plasma	Yes	Multiple rib and pelvic fractures, bilateral Femoral fractures
12	M	41	Blunt	2.1	0	0	31 RBC 27 Platelets 19 Plasma	No	Traumatic aortic root injury
13	F	43	Blunt	0.96	0	1	12 RBC 6 Platelets 9 Plasma	No	Pelvic and femoral fracture, traumatic brain injury
14	M	56	Blunt	1.41	0	0	25 RBC 16 Platelets 19 Plasma	Yes	Multiple rib fractures, bilateral hemothoraces
15	F	24	Blunt	1.23	0	0	17 RBC 12 Platelets 10 Plasma	No	Crush injury, multiple rib fractures, hemothorax

Table 5 continued

S. no.	Sex	Age	MOI	SI	FAST	Pelvic Fx	24-h Products	Death	Injuries
16	F	41	Blunt	0.97	1		12 RBC 7 Platelets 10 Plasma	Yes	Abdominal vascular injury, splenic laceration

MOI mechanism of injury, SI Shock Index

expected, the SI was the strongest independent predictor of a massive transfusion. Vandromme et al. [31] concluded that increasing the SI by two decimals above 0.9 resulted in an incremental higher risk for massive transfusion. Similarly, Rao et al. [32] compared the discriminatory power of SBP and SI for prediction of massive transfusion. They concluded that SI had a better discriminatory power compared to SBP alone. Mutschler et al. [28] analyzed over 21,000 trauma patients and concluded that SI maybe used to assess the presence of hypovolemic shock and the need for massive transfusion. Clearly, substituting HR and SBP with the SI and the presence of a pelvic fracture increases the predictive capacity of the ABC score. Moreover, Schroll et al. [33] recently analyzed 645 patients with complete data and demonstrated that ARUOC of SI for predicting MT was 0.83 compared to 0.74 for ABC score. The sensitivity of ABC score ≥ 2 in their analysis was 47% (95% CI 29.8–64.9%), which is similar to our reports.

Despite these findings, there are several limitations in this study. First, as a retrospective database study, it may lead to error caused by confounding variables and bias for patients. We have evaluated the RABT score in massively injured patients with high trauma activation. Using a selective patient population can decrease the generalizability of this score. We have excluded patients with missing data, which might have caused a bias. However, only 11 patients were excluded because of missing data, so the risk of bias is pretty low. The results of the FAST depend on the operator and the RABT accuracy indirectly depends on the accurate application and interpretation of the FAST. The RABT score has not been validated in a prospective manner, and we are currently involved in a multi-institutional study to validate the scoring system and plan to apply it prospectively following the validation study.

Conclusion

The replacement of hypotension and tachycardia with a Shock Index as well as the inclusion of a pelvic fracture enhanced the discrimination of an ABC score for predicting the need for an MT. The standard criteria underlying an ABC score should be revised to more appropriately identify patients requiring an MT. RABT score can be calculated on admission and requires no laboratory testing. A multicenter validation of the score is currently underway.

Compliance with ethical standards

Conflict of interest The author declares that they have no conflict of interest.

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