Early Prediction of Massive Transfusion in Trauma: Simple as ABC (Assessment of Blood Consumption)?

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Background: Massive transfusion (MT) occurs in about 3% of civilian and 8% of military trauma patients. Although many centers have implemented MT protocols, most do not have a standardized initiation policy. The purpose of this study was to validate previously described MT scoring systems and compare these to a simplified nonlaboratory dependent scoring system (Assessment of Blood Consumption [ABC] score).

Methods: Retrospective cohort of all level I adult trauma patients transported directly from the scene (July 2005 to June 2006). Trauma-Associated Severe Hemorrhage (TASH) and McLaughlin scores calculated according to published methods. ABC score was assigned based on four nonweighted parameters: penetrating mechanism, positive focused assessment sonography for trauma, arrival systolic blood pressure of 90 mm Hg or less, and arrival heart rate ≥120 bpm. Area under the receiver operating characteristic curve (AUROC) used to compare scoring systems.

Results: Five hundred ninety-six patients were available for analysis; and the overall MT rate of 12.4%. Patients receiving MT had higher TASH (median, 6 vs. 13; $p < 0.001$), McLaughlin (median, 2.4 vs. 3.4; $p < 0.001$) and ABC (median, 1 vs. 2; $p < 0.001$) scores. TASH (AUROC = 0.842), McLaughlin (AUROC = 0.846), and ABC (AUROC = 0.842) scores were all good predictors of MT, and the difference between the scores was not statistically significant. ABC score of 2 or greater was 75% sensitive and 86% specific for predicting MT (correctly classified 85%).

Conclusions: The ABC score, which uses nonlaboratory, nonweighted parameters, is a simple and accurate in identifying patients who will require MT as compared with those previously published scores.

Key Words: Hemorrhage, Trauma, Massive transfusion, Prediction, Scoring systems.

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Massive transfusion (MT) occurs in 3% to 5% of all civilian and 8% to 10% of all military trauma patients.[1,2] Exsanguinating hemorrhage is the most common cause of mortality in the first hour of arrival to a trauma center and accounts for almost 50% of deaths in the first 24 hours.[3–5] Of these patients, 25% to 40% will be coagulopathic at admission to the trauma center.[6,7] This coagulopathy has also been associated with an increase in mortality and early correction of this coagulopathy could reduce blood product usage and mortality.[8,9]

Damage control resuscitation actively addresses the issues of rapid blood loss and trauma-associated coagulopathy through a MT protocol with predefined blood component ratios.[2,9,10] Many authors have demonstrated that providing blood products in an organized and predefined fashion is associated with improved survival in severely injured trauma patients.[9,11,12] Other benefits of this organized delivery of blood products is the reduction in provider to provider variability, ease of use, and helps facilitate compliance from ancillary staff who are needed to carry out the MT protocol.[11]

Although many centers have implemented MT protocols, most do not have a standardized initiation policy.[11] Currently, the activation of such protocols is clearly provider dependent and great variability exists even among high-volume centers. In addition, the full survival benefit of these higher blood component ratios seems to be related to early activation of these protocols. If an easy to use scoring system could be used to help guide the activation of a MT protocol, this could help providers of all experience levels know when it is likely the patient will require MT.[9] Although several other scoring systems have been proposed to predict the need for MT, these scores require laboratory data, injury severity scores, and significant mathematical computations.[13–15] Our purpose was to validate these previously described MT scoring systems in a civilian population, and to compare these scores with a simplified, nonlaboratory-dependent scoring system (Assessment of Blood Consumption [ABC] score).

PATIENTS AND METHODS

Setting

Vanderbilt University Medical Center (VUMC) is a state level I trauma center that provides trauma care for ~65,000 square miles of the southeastern United States. The trauma

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center evaluates ~3,000 acutely injured patients annually, with >900 being admitted to the trauma intensive care unit (ICU). Approximately 750 of these patients require mechanical ventilation for >24 hours. The 14-bed trauma ICU is located within a 31-bed trauma unit. The non-ICU beds include a 7-bed acute admission area and a 10-bed subacute care unit.

Data Sources

The VUMC Division of Trauma has participated in the Trauma Registry of the American College of Surgeons since 1986. Demographic, clinical, and injury-related data on all patients admitted to VUMC for trauma or burns are entered into the database, which is maintained locally and shared quarterly with the National Trauma Data Bank after deidentification. Among the >300 parameters currently captured via retrospective chart review are patient's demographics, injuries, diseases, operative procedures, hospital disposition, complications, and length of stay at various levels of care, costs, and resource utilization.

Study Population

The Vanderbilt University Institutional Review Board approved this study. We conducted a retrospective review of our institution's Trauma Registry of the American College of Surgeons database for all patients admitted to our trauma service between July 1, 2005 and June 30, 2006. The study population was made up of all patients who were level I (major) trauma activations, were transferred directly from the scene, and received any blood transfusion during their hospitalization. Patients transferred from other facilities, who were level II (minor) trauma activations, or who died within 30 minutes of arrival were excluded. MT was defined as the transfusion of 10 units or more of packed red blood cells (PRBC) in the first 24 hours after admission.

Protocol Activation

On arrival of a severely injured patient, the attending trauma surgeon determines whether the patient (based on physiology or injury complex) will likely warrant a Blood Bank response beyond routine. The attending will notify Blood Bank and activate the "Trauma Exsanguination Policy (TEP)." The attending supplies the Blood Bank technician with the following information: attending name, patient's sex and medical record, "Stat" name, and the operating room (OR) location, including room number, where blood products are to be delivered. A type and screen is sent immediately to the Blood Bank through pneumatic tube system. On receipt of phone notification of TEP (by trauma attending only), the Blood Bank prepares and dispenses the following blood products as part of the initial response: 10 units of nonirradiated, uncrossed PRBC, 6 units of AB-negative plasma, and 2 units of single-donor platelets. The Blood Bank then notifies the trauma team that initial response products are en route and ascertains whether the TEP should continue or cease. If they are told to continue, the next round of products will be prepared. If the protocol is to continue the following products will be delivered as soon as they are prepared: six units of nonirradiated PRBC, four units of thawed plasma, and one unit of single-donor platelets. This cycle of dispensing follow-up products continues until terminated by the attending trauma surgeon in the OR. For each new cycle of products generated, the Blood Bank contacts the OR room to notify them that the next round of products are en route and get decision on whether or not to continue protocol.

Scoring Systems

Trauma-Associated Severe Hemorrhage

The Trauma-Associated Severe Hemorrhage (TASH) scoring system uses seven independent variables to identify patients who will require a MT. The variables are weighted and make the scoring system somewhat cumbersome. These include blood pressure, gender, hemoglobin, focused assessment for the sonography of trauma (FAST), pulse, base excess, and extremity or pelvic fractures. There are 16 total scores that need to be memorized to calculate the score. Possible range of scores is from 0 to 28. The authors proposed an added worksheet to help calculate the score for all trauma patients.[15] The probability for mass transfusion associated with the TASH score points was calculated by the following logistic function:

$$p = 1/[1 + \exp(4.9 - 0.3 \times \text{TASH})]$$

McLaughlin Score

This scoring system consists of four dichotomous components that require both physical components and laboratory results. The components were not weighted and were simple to identify as yes or no. If one variable was present a 20% incidence of MT was present if all four variable were present there was an 80% chance of MT. The variables were heart rate (HR) >105 bpm, systolic blood pressure (SBP) <110 mm Hg, pH <7.25, and hematocrit <32%. This system still requires laboratory usage and time.[13] Variables are assigned values of either 0 or 1 based on whether or not the value is classed as predictive. The final predictive equation is:

$$\log(p/[1 - p]) = 1.576 + (0.825 \times \text{SBP}) + (0.826 \times \text{HR}) + (1.044 \times \text{Hct}) + (0.462 \times \text{pH})$$

ABC Score Development

All TEP activations undergo review by a multidisciplinary performance improvement (PI) committee for compliance and need for "real-time" protocol adjustments. Educational conferences, Grand Rounds presentations, and individual provider education have been performed on a quarterly basis since its implementation. Seven primary protocol components are evaluated for compliance: type and screen sent from emergency department (ED), activation of protocol in ED, activation by trauma attending, administration of 2:3 plasma to RBC, administration of 1:5 platelets to RBC, protocol discontinuation upon leaving OR, and proper product handling to avoid wasted products. Patients are grouped according to full compliance or noncompliance (at least one protocol violation). ED activation of the protocol has been demonstrated through the PI process to be a consistent independent predictor of 24-hour and 30-day survival.

Through a structured, aggressive educational process, each of the PI measures demonstrated a significant improvement in compliance during the study period with the exception of ED activation of the protocol. In light of this, we set out to create a scoring system to rapidly identify patients who would require a MT with objective data available to the trauma surgeon immediately after arrival. There was a consistent pattern of early and late activations by faculty. Faculty who were noted to uniformly activate the protocol early were queried independently for their clinical criteria for activation. The "early activation" faculty were consistent in their responses: tachycardia, hypotension, positive fluid on ultrasound, and penetrating mechanism of injury.

ABC Score

The ABC score consists of four dichotomous components that are available at the bedside of the acutely injured patient early in the assessment phase. The presence of any one component contributes one point to the total score, for a possible range of scores from zero to four. The parameters include

- Penetrating mechanism (0 = no, 1 = yes)
- ED SBP of 90 mm Hg or less (0 = no, 1 = yes)
- ED HR of 120 bpm or greater (0 = no, 1 = yes)
- Positive FAST (0 = no, 1 = yes)

Statistical Analysis

Previously developed scores (TASH and McLaughlin) were calculated for each patient according to their published definitions, and the ABC score was calculated based on the above definition. To determine whether this simplified score could be improved on, logistic regression coefficients were used for weighting. The ability of these scores to predict MT was estimated by the area under the receiver operating characteristic curve (AUROC).

RESULTS

A total of 596 patients were included in the cohort. The overall MT rate was 12.7% (n = 76), and the overall mortality rate was 18.1% (n = 108). Table 1 summarizes the demographic and clinical characteristics of patients by MT group. Patients receiving MT had higher injury severity scores (ISSs) and more severe physiologic derangements as manifest by lower ED SBP, higher ED HR, and lower ED GCS. Patients in the MT group also had higher TASH, McLaughlin, and ABC scores.

Table 1 Demographic and Clinical Characteristics of Patients by MT Status

	No MT (n = 510)	MT (n = 76)	*p*
Age (yr)	48 ± 24	40 ± 18	0.06
Males, n (%)	357 (69)	54 (73)	0.43
Blunt mechanism, n (%)	432 (83)	53 (72)	0.02
ISS, median (25th, 75th IQR)	22 (10, 34)	34 (22, 41)	<0.001
ED systolic blood pressure (mm Hg), mean ± SD	121 ± 33	89 ± 34	<0.001
ED heart rate (beats/min), mean ± SD	95 ± 26	111 ± 28	<0.001
ED GCS, mean ± SD	11.5 ± 5.1	9.0 ± 5.5	<0.001
TASH, mean ± SD	6.3 ± 4.4	13.4 ± 5.6	<0.001
Mortality, n (%)	75 (14%)	33 (45%)	<0.001

MT, massive transfusion; ISS, injury severity scores; IQR, interquartile range; ED, emergency department; SD, standard deviation; GCS, Glasgow coma scale; TASH, Trauma Associated Severity of Hemorrhage.

The ABC score was created by our institution's trauma faculty based on their clinical experience of appropriate activation of the trauma center's protocol. Multiple logistic regression modeling evaluated the four components. FAST had an odds ratio for predicting MT of 8.2 ($p < 0.001$, CI 4.34–5.30). HR of 90 bpm or greater (odds ratio 3.9, $p < 0.001$, CI 2.00–6.85) and SBP of 90 mm Hg or less (odds ratio 13.0, $p < 0.001$, CI 6.93–24.52) were both significantly associated with predicting MT. Although much less significant, penetrating mechanism carried an odds ratio of 1.9 in predicting MT ($p = 0.02$, CI 1.15–3.44).

Table 2 summarizes the clinical characteristics and outcomes by ABC score. Three hundred nine (52%) patients did not meet any ABC criteria. These patients had an overall MT rate of 2% (n = 8). One ABC parameter was present in 177 (30%) patients. These patients had an overall MT rate of 12%. Two or more MT parameters were present in 110 patients, and among these patients, 44 (40%) required MT. The sensitivity, specificity, and percent correctly classified for ABC score is shown in Table 3. On the basis of the sensitivity and specificity provided at a score of 2, this was chosen as the "cutpoint" for declaring need for MT.

Table 2 Clinical Characteristics and Outcomes by ABC Score

	0	1	2	3	4
Patients, n	292	167	91	31	5
Penetrating, n (%)	0	41 (25)	40 (44)	21 (68)	100
Positive FAST, n (%)	0	34 (20)	50 (55)	21 (68)	100
HR ≥120, n (%)	0	48 (28)	40 (44)	24 (77)	100
SBP ≤90, n (%)	0	44 (26)	52 (57)	27 (87)	100
Massive transfusion, n (%)	4 (1)	16 (10)	37 (41)	15 (48)	5 (100)
Mortality, n (%)	29 (10)	34 (20)	26 (29)	9 (29)	1 (20)

FAST, focused assessment of the sonography of trauma; HR, heart rate; SBP, systolic blood pressure.

Table 3 Sensitivity, Specificity, and Percent Correctly Classified for ABC Score Cutpoints

Cutpoint	Sensitivity (%)	Specificity (%)	Correctly Classified (%)
≥0	100	0	13
≥1	95	56	61
≥2	75	86	84
≥3	25	97	87
≥4	6	100	88

Figure 1 displays the MT rate by ABC score. As the score increase above 2, the likelihood of requiring MT increases from 10% to 40%. A score of four of four translated to a 100% chance of MT. Figure 2 depicts the contributions of the four parameters to the distribution of ABC scores.

There were a total of 19 false negatives using the ABC score and a cutoff of two points (ABC <2 and received a MT) (Table 4). This group of patients was similar to the remaining population with respect to age, sex, race, ISS, pH, hematocrit, and TASH and McLaughlin scores. Although they were similar with respect to the presence of femur and pelvic fractures, patients who were false positives were more likely to have sustained a blunt mechanism of injury (100% vs. 77%, $p = 0.03$) and to have received PRBC in the trauma bay (75% vs. 28%, $p < 0.001$).

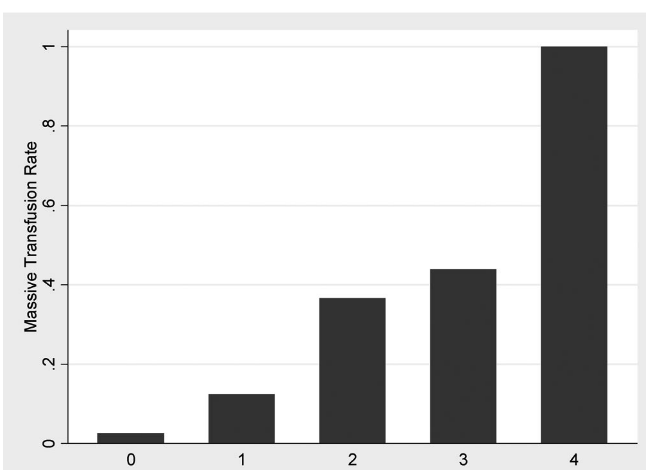

Fig. 1. *Rate of massive transfusion by ABC score.*

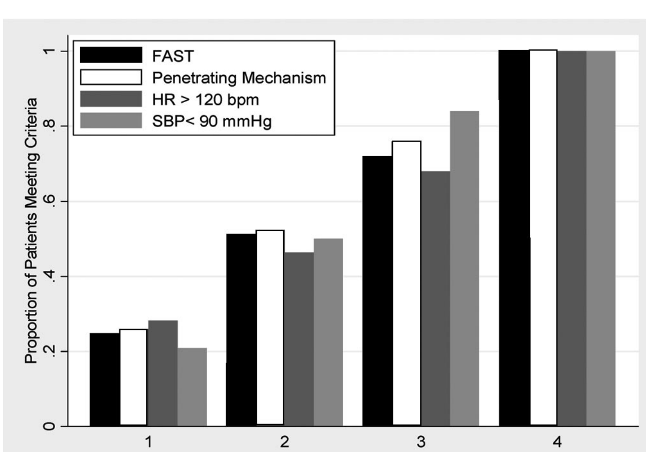

Fig. 2. *Individual contributions of each component of the ABC score.*

Seventy patients were defined as false positives using an ABC score cutoff of 2 points (ABC >2 and did not receive MT). This group of patients was similar to the remaining population with respect to race, ISS, pH, and hematocrit. When compared with other patients, these patients were more likely to be male (87% vs. 67%, $p < 0.001$), younger (34.5 vs. 43.7 years, $p < 0.001$), and to have sustained penetrating injury (63% vs. 13%, $p < 0.001$). Though the groups were similar with respect to their McLaughlin score, the false-positive patients had higher TASH scores (10.2 vs. 6.9, $p < 0.001$).

Comparison of Scores

Figure 3 compares the ROC curves for the ABC, TASH and McLaughlin scores. ABC had the highest overall accuracy by AUROC (0.859). The TASH score had intermediate accuracy (AUROC = 0.842), whereas the McLaughlin score has the lowest predictive ability (AUROC = 0.767). However, the difference in the predictive ability between the TASH and ABC scores was not statistically significant.

DISCUSSION

Although MT affects a relatively small subset of trauma patients, mortality from hemorrhage in this population occurs early (first 6 hours after arrival) and occurs often (40%).[1–3,5,12,14,16–18] This cohort of trauma patients has a mortality rate of 40% to 60% and consumes >70% of the total blood transfused to trauma patients.[19] To address these issues, many centers are attempting to find the best way to rapidly identify patients who will require a MT and several scoring systems have been proposed. Yucel et al.[15] developed a complex system from data extracted from the German trauma registry. This scoring system has multiple-weighted variables that require not only physical examination findings, but injury severity score assessment, laboratory data, and diagnostic imaging capabilities for calculation of the score.[13] McLaughlin et al.[13] looked at military casualties from the current conflict in Iraq using data from the Joint Trauma Theater Registry. Their scoring system is simple to remember and use but still requires physical examination findings and laboratory data.[13] Our goal was to develop a system that was extremely easy to use and remember. It only requires data that will be obtained in the trauma resuscitation area and requires no laboratory usage. We applied our score retrospectively to a high-risk group of adult trauma patients. Our score was just as accurate as previously described scores but was much simpler to apply in real time.

To compare our score with the previously described scoring systems we retrospectively applied all three scoring systems to our high-risk cohort of adult trauma patients. The AUROC was calculated for each scoring system as it was

Table 4 ABC Score False-Negatives: Patients Who Received a Massive Transfusion but Did Not Have an ABC Score of ≥2

	Sex	Age	Mechanism	HR	SBP	FAST	24-h Products	ED RBC	Death	Injuries
1	M	34	Blunt	130	150	Negative	10 U RBC 4 U plasma 12 pack platelets	No	No	Tibia-fibula, ulna, radius, scapula, rib, and humerus fractures
2	F	83	Blunt	63	0	Negative	11 U RBC 12 U plasma 0 platelets	Yes	Yes	Bilateral rib fractures and bilateral hemothoraces
3	M	44	Blunt	81	100	Positive	15 U RBC 4 U plasma 12 pack platelets	No	No	Abdominal vascular injury, multiple facial fractures
4	M	45	Blunt	105	88	Negative	15 U RBC 12 plasma 8 pack platelets	Yes	No	Pelvic and femur fracture, renal injury, mesenteric hematoma
5	M	50	Blunt	115	60	Negative	50 U RBC 32 U plasma 32 pack platelets	Yes	Yes	Crush injury, multiple rib, thoracic spine, and pelvic fractures
6	F	61	Blunt	110	70	Negative	18 U RBC 20 plasma 17 pack platelets	Yes	No	Multiple rib and spine fractures, and bilateral hemothoraces
7	M	50	Blunt	108	70	Negative	12 U RBC 10 U plasma 5 pack platelets	Yes	No	Pelvic, femur, and tibia-fibula fracture, large scalp laceration
8	M	27	Blunt	40	140	Positive	17 U RBC 12 U plasma 12 pack platelets	No	No	Multiple rib, lumbar spine, and pelvic fractures, liver injury
9	M	56	Blunt	87	72	Negative	12 U RBC 10 U plasma 4 pack platelets	Yes	No	Pelvic, scapula, humerus, bilateral ankle and tibial plateau fractures
10	M	73	Blunt	80	50	Negative	31 U RBC 18 U plasma 29 pack platelets	Yes	Yes	Traumatic upper extremity amputation, bilateral femur fractures
11	F	48	Blunt	103	80	Negative	12 U RBC 4 plasma 5 pack platelets	Yes	No	Inferior vena cava injury, bilateral hemothoraces
12	M	48	Blunt	118	50	Negative	21 U RBC 15 U plasma 5 pack platelets	Yes	Yes	Multiple rib, face, and femur fractures, brain injury, hemothorax
13	F	31	Blunt	123	132	Negative	10 U RBC 4 U plasma 0 platelets	Yes	No	Bilateral femur, femoral neck, and tibia-fibula fractures
14	M	40	Blunt	141	100	Negative	14 U RBC 0 plasma 0 platelets	Yes	Yes	Traumatic aortic rupture, bilateral hemothoraces, mesenteric injury
15	M	20	Blunt	80	134	Negative	11 U RBC 4 U plasma 0 platelets	No	No	Femur, humerus, and patellar fractures, brachial artery transection
16	M	55	Blunt	108	90	Negative	10 U RBC 7 U plasma 0 platelets	Yes	No	Multiple rib fractures, bilateral hemothoraces
17	M	62	Blunt	109	108	Negative	19 U RBC 18 U plasma 21 pack platelets	Yes	No	Pelvic, femoral shaft, and femoral neck fractures, and brain injury
18	F	20	Blunt	143	150	Negative	46 U RBC 37 U plasma 35 pack platelets	Yes	Yes	Traumatic aorta injury, splenic injury, bilateral rib fractures, hemothoraces
19	F	50	Blunt	85	116	Negative	12 U RBC 12 U plasma 0 platelets	No	No	Traumatic abdominal wall hernia, rib fractures, colon and small bowel injuries

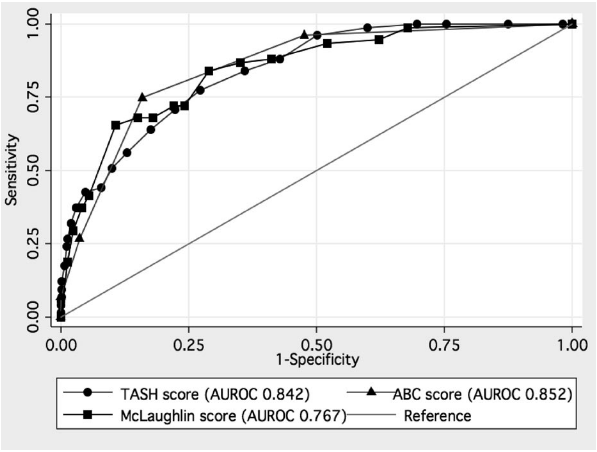

Fig. 3. *AUROC for the three scoring systems.*

applied to our cohort. All three scoring systems were capable predictors of MT. The differences between the three scores were not statistically significant. An ABC score of 2 or greater was 75% sensitive and 86% specific (correctly classified 85%). In our analysis, the predictive ability of the ABC score could be marginally improved with the addition of weighting or additional variables, but not without sacrificing its ease of use and ability to be calculated without laboratory results.

The major advantage of the ABC score is its simplicity. It requires only remembering four values; each value is a yes or no. The values are all equally weighted and require no calculating. The values are obtained rapidly in the trauma bay with the initial vitals and completion of a FAST examination. It is realistic to complete the ABC evaluation in the first few minutes after arrival to the trauma resuscitation area. In most busy trauma centers, it will take this amount of time just to obtain blood samples. Obviously, there will be more time wasted waiting for the lab values. It is our contention this severely limits the other scoring systems because accurate and rapid identification of patients who require a MT is our goal. Every delay in the severely injured patient is more likely to effect there outcome. It has been proposed that early activation of a MT protocol is beneficial as compared with later activations. This may prevent or begin quickly correcting the acute coagulopathy of trauma.[10,13]

Despite these promising findings, there are several important limitations. The first and most important limitation is current study's hypothesis is based on the following assumptions: (1) that MT protocols are associated with a reduction in mortality and (2) that early activation of these protocols is associated with a further reduction in mortality. Although there has been no prospective randomized trial to demonstrate benefit of a MT protocol, several authors and institutions have published results from retrospective cohorts demonstrating improved survival after protocol implementation.[9,12,21] However, O'Keeffe et al.[22] found no difference in difference in survival with the implementation of a MT protocol. These authors did, thought, note a significant reduction in overall blood product use and hospital costs with protocol use. To address the second assumption, we recently evaluated risk factors and system errors associated with mortality within our MT protocol. The only independent predictor risk for improved survival was early (ED) protocol activation.[23] These findings reinforce the need for early utilization of institutional transfusion protocols.

In addition to these limitations, our results are based on (1) a retrospective application of a scoring system, (2) in a single population of patients, and (3) the score has not been applied in a prospective manner. We are currently involved in a multi-institutional validation of this scoring system and plan to apply it prospectively following this multicenter validation. Second, we evaluated these scores in a high-risk patient population—major trauma activations, transported directly from the scene, and who received at least one unit of PRBC during their hospitalization. Using this inclusion criteria increases the rate of MT while limiting the overall sample size required, and is the same inclusion criteria used in major clinical trials of MT.[13] It is uncertain how these scores would apply to a similar population of "all comers" but this is currently being evaluated. However, these patients are very unlikely to require MT and in whom a scoring system would provide little more than clinical acumen. Third, FAST is highly operator dependent, and its accuracy (and thus, the accuracy of the ABC score) depends on its reliable and accurate application.[24,25]

CONCLUSIONS

MT protocols and higher ratios of blood components appear to be associated with improved survival in patients with exsanguinating hemorrhage.[9] The earlier these protocols are instituted, the higher the chances for survival. Unfortunately, most trauma centers rely on clinical judgment alone to institute MT. The ability to assign objective data to the acutely injured can help improve the uniformity of damage control hematology and protocol activation. Scoring systems are not meant to replace clinical judgment but to augment decision making. Our scoring systems greatest strength is that it is easy to use and remember. The ABC method requires no laboratory testing and uses only that data available during the primary survey (hence, ABC) so the final score is quickly obtained. Although this simplified scoring system allows for rapid activation of MT protocols, it has not been validated. A multicenter validation of the score is currently underway.

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