Title

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Journal

Journal of Trauma and Acute Care Surgery, 80(3)

ISSN

2163-0755

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Publication Date

2016-03-01

DOI

10.1097/ta.0000000000000914

Peer reviewed

HHS Public Access

Author manuscript

J Trauma Acute Care Surg. Author manuscript; available in PMC 2017 March 01.

Published in final edited form as:

J Trauma Acute Care Surg. 2016 March ; 80(3): 450–456. doi:10.1097/TA.0000000000000914.

THE MASSIVE TRANSFUSION SCORE AS A DECISION AID FOR RESUSCITATION: LEARNING WHEN TO TURN THE MASSIVE TRANSFUSION PROTOCOL ON AND OFF

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Abstract

Introduction—Prior work proposed a massive transfusion score [MTS] calculated from values obtained in the emergency department to predict likelihood of MT (massive transfusion). We hypothesized the MTS could be utilized at hour 6 to differentiate who continues to require balanced resuscitation in hour 7–24 and to predict death at 28 days.

Methods—We prospectively enrolled patients in whom the MT protocol (MTP) was initiated from 2005 to 2011. Data including timing of blood products were determined at hour 0, 6, 12, and 24. For each patient, transfusion needs were defined based upon either an inappropriately low hemoglobin response to transfusion or a hemoglobin decrease of > 1gm/dL if no transfusion. Timing and cause of death were utilized to account for survivor bias. Multivariate logistic regression was utilized to determine independent predictors of outcome.

Results—190 MTP activations were included and by hour 6, 61% required >=10 units of PRBCs. Calculated at initial presentation, a Revised MTS (SBP<90mmHg, BD>=−6, Temp<35.5 C, INR>1.5, Hgb <11g/dL) was superior to the original MTS (including HR>=120bpm, FAST status, mechanism) or the ABC score for predicting MT (AUC MT at 6 hours 0.68, 95% CI 0.57–

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Presented in part at the American Association for the Surgery of Trauma Annual Meeting in San Francisco, CA, September 2013

Level of Evidence: Prognostic, level 3

Author contributions:
Literature search – Callcut, Robinson, Cohen
Study design – Callcut, Robinson, Cohen
Data collection – Cripps, Conroy, Nelson
Data analysis – Callcut, Cohen
Data interpretation – Callcut, Cohen
Writing – Callcut, Cohen
Critical revision – Cripps, Conroy, Nelson, Robinson, Cohen

0.79; at 24 hour 0.72, 0.61–0.83; p<0.05); p<0.05). For those alive at hour 6, the Revised MTS was predictive of future PRBC need (AUC 0.87) in hour 7 to 12, 24-hour mortality (AUC 0.95), and 28-day mortality (AUC 0.77). For each additional positive trigger of the MTS at hour 6, the odds of death at 24 hours and 28 days was substantially increased (24 hours OR 4.6, 95% CI 2.3–9.3; 28 days OR 2.2, 95% CI 1.5–3.2, p<0.0001).

Conclusion—Early end points of resuscitation adopted from the components of the Revised MTS are predictive of on-going transfusion. Failure to normalize these components by hour 6 portends a particularly poor prognosis.

Keywords

massive transfusion protocol; massive transfusion score (MTS); trauma transfusion triggers

INTRODUCTION

Although progress has been made in improving early identification of those likely to receive a massive transfusion [MT], prediction scores have been based upon total transfusion volumes received and not necessarily what patients required(1–3). The vast majority of these scores, including the Trauma Associated Severe Hemorrhage [TASH] Score, and the Assessment of Blood Consumption [ABC] Score were developed prior to the modern era of balanced resuscitation and the impact of this treatment on the validity of these scores is unknown(4–6). A new prediction score, the MT Score [Original MTS, Table 1] was recently developed in a multicenter cohort of patients treated under balanced resuscitation protocols [MTP](1). This score is calculated from values obtained in the emergency department to predict likelihood of MT at 24 hours and the proposed score has not been validated. This study attempts to validate the MTS calculated at presentation for need for massive transfusion by 6 and 24 hours.

Although the MTS may be helpful to predict patients that require early initiation of balanced resuscitation, the components of the score may also have utility for targets of end points of resuscitation. To date studies have focused on a single assessment of the need for MTP initiation (ABC, TASH)(4, 6, 7) with far less attention to understanding when to terminate the MTP. This fixed time point does not examine the dynamic need of on-going transfusion over the course of a patient's evolving clinical picture and provides no guidance when to end such resuscitation. To address this, we hypothesized that the components of this score could be utilized as end points of resuscitation summed into a MTS score calculated at hour 6 to differentiate who continues to require balanced resuscitation in hour 7–24 and to predict death at 28 days.

METHODS

Study Subjects

We prospectively enrolled 190 patients in whom the massive transfusion protocol (MTP) was initiated over a 6 year period. MTP was activated based upon clinician gestalt. All patients in whom the MTP was activated were followed in systematic fashion throughout the first 96 hours of hospitalization. Hemodynamic, laboratory, and intervention parameters

such as timing and type of blood products were determined at defined intervals including hour 0, 3, 6, 12, and 24. No changes to transfusion practice or the MTP was undertaken during the time interval of the study.

Determining Need for Transfusion and Massive Transfusion

For each patient, the need for on-going transfusion during a given time interval was defined based upon either an inappropriately low response to transfusion (< 0.7gm/dL increase in hemoglobin per unit of packed red blood cells received), a hemoglobin decrease of > 2gm/dL if no transfusion was received and the subsequent hemoglobin was <9 g/dL, or an absolute hemoglobin <8 g/dL. The definition of inappropriate response to transfusion was adapted from Lee et al. who demonstrated an expected rise in hemoglobin level of between 0.7 g/dL to 1.5 g/dL for each unit transfused in patients receiving transfusion for primarily active bleeding indications(8). Massive transfusion was defined as requiring >10 units of packed red blood cells (PRBCs) in the given time interval. Need for MT was assessed at both 6 and 24 hours. To account for survival bias, timing and cause of death were utilized. Those dying of hemorrhagic deaths prior to 6 hours or 24 hours were assumed to have required MT if they died prior to receiving >10 units of PRBCs in the relevant time interval[1]. Cause of death was adjudicated real-time by attending surgeons blinded to the on-going study.

Massive Transfusion Score (MTS) and Revised MTS

Recently published work by members from our group proposed a score that could be applied early in the emergency department (ED) course of a patient to predict likelihood of massive transfusion and this score is known as the Massive Transfusion Score (MTS)(1) [Table 1]. The score was developed in a multicenter prospective observational study and consisted of components from the Assessment of Blood Consumption (ABC) score(5) and the Cincinnati individual transfusion trigger (CITT)(2) study [Table 1]. Prior work found that the score performed best when the individual components were equally weighted with a value of 1 point for each component met(2).

The trigger threshold and components of each score are listed in Table 1. The ABC score included systolic blood pressure (SBP)<90 mmHg, heart rate (HR)>=120 beats per minute (bpm), positive FAST, and a penetrating mechanism of injury(5). The Cincinnati triggers included SBP<90mm Hg, base deficit (BD)>=6, temperature <35.5 degrees Celsius, international normalized ratio (INR)>1.5, and hemoglobin (Hgb)<11 g/dL(2). The original MTS excluded temperature due to a high frequency of temperatures missing in the previous prospective cohort used to develop the score(1, 2). The remaining combined ABC components plus the Cincinnati trigger values became known as the original MTS [Table 1]. This current study investigates the predictive ability of the Original MTS to a Revised MTS (SBP<90mmHg, BD>=6, Temp<35.5 °C, INR>1.5, Hgb <11g/dL). The Revised MTS [Table 1] reflects the original 5 components of the Cincinnati Individual Transfusion Trigger (CITT) including temperature summed into a singular score. In addition, both the original MTS and revised MTS were compared with the ABC scores to predict need for MT at 6 and 24 hours. Multivariate logistic regression controlling for interaction between variables was

utilized to determine independent predictors of outcomes of interest and Receiver Operator Curves (AUROC) were calculated to determine model fit.

6 hour Revised MTS to predict on-going transfusion needs

For each patient still alive at 6 hours, the value of each component of the Revised MTS was collected at hour 6. A total score was calculated assigning one point for each component in which the value measured met or exceeded each trigger threshold (range 0 points if no trigger met up to 5 points if all triggers met). The performance of the Revised MTS score at hour 6 was then compared against a model using the components of the score as continuous variables to predict future blood product needs. Need for transfusion was determined by the definition described above(8). Given need for transfusion is a derived definition, sensitivity analysis was also performed using actual units transfused in each time interval.

6 hour & 3 hour Revised MTS to predict 24 hour and 30 day mortality

For those patients in the cohort still alive at 6 hours, the revised MTS obtained from vital sign and lab values at hour 6 was also investigated to determine if it could predict mortality at 24 hours and 28 days. Receiver operator curves were utilized to determine the MTS predictive ability. Multivariate logistic regression accounting for interaction was utilized to investigate the predictive ability of individual triggers to predict death. A similar analysis was done with a 3 hour Revised MTS for patients alive at 3 hours. The shorter time interval of 3 hours was selected due to recent data suggested that the majority of patients who are substantially bleeding receive the largest component of their transfusion volumes by hour 3 and most hemorrhagic deaths occur in less than 3 hours(3, 9). Recently, there have been on-going discussions sponsored by the FDA that traumatic hemorrhage studies include a 3 hour end-point evaluation(3).

Statistical Analysis

Data are presented as mean (standard deviation), median (interquartile range), or percentage; univariate and group comparisons were made using 2 tailed Student's t test or one-way analysis of variance for normally distributed data, Wilcoxon rank sum for skewed data, and Fisher's exact test for proportions. For each model, goodness of fit was tested using the Hosmer-Lemeshow (HL) method and discrimination reported as Area under Receiver Operating Characteristic curves (AUROC). Statistical significance was determined at alpha <0.05. All data were analyzed using SPSS version 18.0.

RESULTS

During the study interval, 190 MTP activations occurred. The median patient age was 33 years (23–50 years). At 6 hours, 79% (153/190) of patients were still alive. The overall 28 day mortality was 38% (73/190) including 54 (28%) patients who died in the first 24 hours. Although 74% of all deaths occurred in the first 24 hours, 50% (27/54 deaths) of these early deaths occurred within 3 hours. The median length of stay was 9 days (IQR 2–29), ICU days 4 (1–14), and ventilator free days 6 (0–25). Blunt mechanism was present in 49% (94/190). There was no difference in early mortality (<24 hours) by mechanism (blunt 28%, penetrating 29%, p=0.81).

The median Injury Severity Score (ISS) was 26 (IQR 17–35) including 51/190 whom suffered a traumatic brain injury (TBI). The TBI patients included 10 patients with a head AIS (abbreviated injury score) of 4 and 21 with a head AIS of 5. There was no difference in the distribution of mortality across head AIS groups at 6 or 24 hours (p=.81, p=.38, respectfully). At presentation, patients were generally cold (temperature 35.7°C), acidotic (pH 7.25), borderline hypotensive (systolic blood pressure 100 mmHg), and with median hemoglobin of 11.7 g/dL [Table 2]. At 6 hours, patients were more anemic (hemoglobin 10.9 g/dL) with unchanged INR values (median 1.3) [Table 2].

The median PRBC received in 24 hours was 12 units (IQR 7–18), plasma 10 units (5–16), platelets 1 unit (0–2), and crystalloid 7420 mLs (5335–12113mLs) [Table 3]. In the first 6 hours of care, 6 patients received no PRBCs, 19 received no plasma, and 92 received no platelets. Most patients required a massive transfusion by hour 6. Using actual transfusion data and not controlling for survivor bias, at 6 hours, the massive transfusion threshold was reached by 107 (56%) of the patients; this is in comparison to 115 (61%) reaching the massive transfusion threshold when survivor bias was accounted for [Table 2]. Likewise, by 24 hours, 71% of the cohort met the threshold for massive transfusion with and without survivor bias accounted for.

Revised MTS and Predicting Need for Massive Transfusion

Using baseline values obtained in the emergency room, an original MTS, revised MTS, and ABC score were calculated for all trauma patients were the data was complete. Although the Revised MTS outperformed the ABC score for predicting need of a MT at 24 hours [Table 4], none of the models had good performance for predicting either 24 hour or 6 hour massive transfusion needs. The Hosmer-Lemeshow (HL) test for goodness of fit indicated adequate fit for each model (p>0.59 for all).

A comparison of the patients with and without missing data at time zero was performed. There was no statistical difference in any baseline demographic variables including age, ISS, mechanism, 6 hour, 24 hour, or 28 day mortality. There was no difference in crystalloid use, PRBCs, plasma, or platelets in any time interval. Sensitivity analysis also revealed no statistical differences between model performance in those with and without missing data for prediction of massive transfusion by 24 hours (AUROC MT at 24 hours for those with complete data Revised MTS 0.72, 95% CI, 0.61–0.83 versus 0.77, 0.67–0.87 in missing data; Original MTS complete data 0.60, 0.47–0.72, missing data 0.71, 0.59–0.83). The results for predicting MT in the first 6 hours were similar (AUROC Revised MTS complete data 0.68, 0.57–0.79; missing data 0.73, 0.63–0.84; original MTS complete data 0.60, 0.48–0.72; missing data 0.74, 0.64–0.84).

For each additional point on the Revised MTS, the median number of overall PRBCs received increased [Table 5]. For those meeting MT thresholds by hour 24, the median Revised MTS was 2 compared with a 1 for those not reaching MT thresholds (p<0.001). More specifically, 82% of those with a Revised MTS>=2 at time zero received a MT by 24 hours. Likewise, 68% of the cohort with a Revised MTS>=2 required MT by hour 6, and the median Revised MTS was also 2 compared with 1 for those not needing MT by hour 6 (p=0.002). If one were to activate the MTP based upon a MTS>=2 at time zero, the

sensitivity is 70%, specificity 67%, and accuracy 69% [Table 5]. In contrast, if one were to activate the MTP based upon a MTS>=1, the sensitivity rises substantially (93%) but with a significant specificity loss (20%). Similarly for predicting MT by hour 6, a MTS>=2 at time zero would give a sensitivity of 71%, specificity 57%, PPV 68%, and NPV 60%; for a MTS>=1, sensitivity would be 91%, specificity 14%, PPV 58%, and NPV 55%.

6 Hour individual MTS components as end points of resuscitation

For those still alive at 6 hours, the model containing the components of the Revised MTS was assessed to predict future packed red blood cell needs. The model was highly predictive for future PRBC need in hour 7 to 12 (AUROC 0.87, 0.80–0.94). SBP, hemoglobin, and base deficit remained independent predictors of need of further transfusion in hours 7 to 12 on multivariate analysis [Table 6]. The 6 hour Revised MTS model containing individual trigger values was less predictive of PRBC need in hour 13 to 24 (AUROC 0.74, 0.64–0.85). However, the 6 hour hemoglobin value remained predictive of PRBC transfusion needs in hour 13 to 24 on multivariate analysis (p=0.001) [Table 6]. Sensitivity analysis found a similar result for the predictive model for future PRBC received in hour 7 to 12 (AUROC 0.80, 0.72 – 0.89) and hour 13 to 24 (AUROC 0.79, 0.69–0.88).

Using a MTS from hour 6 values to predict future blood product needs

To simplify the use of the MTS as a potential endpoint of resuscitation, a Revised MTS was calculated for each patient still alive at 6 hours (MTS_{6hour}). Each trigger point was determined based upon the pre-specified value cut-offs of the Revised MTS using the 6 hour value (SBP<90mmHg, BD>=6, Temp<35.5 °C, INR>1.5, Hgb <11g/dL) [Table 1]. The MTS_{6hour} was predictive of hour 7 to 12 PRBC needs (AUROC 0.78, 0.69–0.87; HL p=0.17). For each additional positive trigger at 6 hours, patients were nearly 3-fold more likely to need subsequent transfusion in hour 7 to 12 (OR 2.74, 95% CI 1.65–4.55, p<0.001). The MTS_{6hour} did not perform as well for predicting transfusion needs in hour 13 to 24 (AUROC 0.69, 0.57–0.82; OR 1.89, 1.23–2.93, p=0.004; HL p=0.32). Although the absolute number of units received in the subsequent hours were low [Table 2], 42% received at least 1 unit of blood in hour 7 to 12 and 38% in hours 13 to 24. For those receiving blood products in hours 7 to 12 and 13 to 24, the range of PRBCs received was 1 to 30 units and 1 to 21 units, respectfully.

MTS_{6hour} Predicts 24 hour and 28 day mortality

The Revised MTS_{6hour} was highly predictive of subsequent 24 hour mortality (n=115; AUC 0.95, 0.91–0.99; HL p=0.29). Failure to normalize the parameters of the Revised MTS_{6hour} portended a particularly poor 24 hour prognosis (OR death at 24 hours 4.6, 95% CI 2.3–9.3). Although the Revised MTS_{6hour} was not as predictive for 28 day mortality (n=137, AUROC 0.77, 0.67–0.88; HL 0.80), for each additional positive trigger at hour 6, the odds of death for trauma patients at 28 days increased 2-fold (OR 2.2, 95 % CI 1.5–3.2, p<0.0001). A 3 hour MTS was also investigated and it performed similarly for prediction of 24 hour (AUROC 0.86, 0.78–0.94) and 28 day mortality (0.76, 0.67–0.85). For each additional positive trigger at hour 4, the odds of death for trauma patients at 28 days also increased 2-fold (OR 2.3, 95% CI 1.5–3.6, p<0.0001).

DISCUSSION

For hemorrhaging patients, earlier initiation of massive transfusion protocols [MTP] have been linked to improved survival(1, 2, 10, 11). Significant attention in recent years has been focused on rapidly identify those needing the MTP(1, 2, 5–7, 12–14). Many scoring systems for predicting massive transfusion (traditionally defined by >=10 units of PRBCs in 24 hours) have been investigated with several reporting high fidelity prediction(4, 7, 13, 14); however, they are not widely used in practice. The most promising score (TASH) requires cumbersome calculations potentially limiting its use in the chaotic trauma bay(7). As a result, MTP initiation continues to be largely based upon clinical gestalt which itself has recently been shown to be only slightly better than a simple flip of a coin(15). In fact, amongst the scores tested in recent work by Pommerening et al. in a similar trauma cohort, gestalt was no better than the ABC score and inferior to the TASH score(15).

In an effort to refine the scores for simplicity of use and applicability in the era of balanced resuscitation, our group recently published a new score, the MT Score [MTS] which was developed in a multicenter prospective cohort of patients treated with balanced resuscitation. The present study attempts to validate the utility of this proposed score and compares its performance to the most widely used simple score, the ABC score. In the present study, the Revised MTS which eliminates all the unique components of the ABC score (FAST, heart rate, penetrating mechanism) outperforms the ABC score in trauma patients.

This finding is not unexpected for several reasons. First, the interpretation of FAST positivity is user dependent(16–18) and both the ABC score and the original MTS have FAST as a variable. Therefore, the inclusion of it in a scoring system will result in prediction that reflects the differences in FAST sensitivity and specificity at individual institutions. Second, heart rate has been explored with conflicting results(1, 2, 4, 19). Within a narrow age range, heart rate is helpful; however, when applied to a large spectrum of patients of variable ages and pre-existing states of health, the sensitivity and specificity appears to decline. For example, in a predominantly elderly group with a high prevalence of beta blockade use, heart rate will neither be sensitive nor specific for indicating hemorrhage(20, 21). Third, penetrating trauma as a variable alone is quite predictive of MT, however, when utilized in combination with the other components of the Revised MTS, the overall model performance is essentially unchanged. Thus, penetrating trauma acts as a surrogate marker that is fully captured by the other components of the score.

It is important to highlight that none of the scores examined predict MT as well as they have in historic data that predated balanced resuscitation strategies and overall they have relatively poor performance. This is not surprising. Multiple studies have shown an overall decrease in the total blood products utilized with balanced resuscitation(22, 23) and therefore, one would expect a decline in model prediction if MT is used as the outcome metric. This does not imply these scores are not useful. MT is probably no longer the proper metric to predict given the effect balanced resuscitation has had on blood needs. Rather, figuring out who is bleeding rapidly and turning on the MTP early is the key. In assessing scores that are easy and quick to calculate in the trauma bay, although limited, the Revised MTS appears to be the best performer for this to date.

Given the improvement in mortality shown in prior work with early activation of the MTP in hemorrhage patients, the score might actual be useful using a threshold MTS to initiate MTP. The threshold would ideally be one that predicts all patients needing MT and misses none, while minimizing unnecessary activations. Similar to our previous work deriving the MTS(1), the current study again found the median score of those requiring MT was 2 compared with a median of 1 for those not requiring MT. For each additional point on the Revised MTS, the median number of overall PRBCs also rose proportionally. This confirms that the Revised MTS has reasonable discrimination between those needed traditional MT volumes defined as 10 units of PRBCs in 24 hours or 6 hours. Thus, in the case of the Revised MTS, a threshold score of 1 or more to activate the MTP would result in a very high sensitivity (few false negatives), but also frequent activation that may not be necessary. The trade-off for unnecessary MTP activation is a potential strain on institutional resources. If the threshold was increased to a MTS>=2, the accuracy remains unchanged due to the improvement true positive rate, however, the sensitivity decreases reflecting more false negatives. These false negatives could translate to potentially missed or delayed activations if the decision to activate the MTP was based solely on the MTS.

In reality, the best utility of the MTS may be as an adjunct to clinical gestalt to help identify patients that we may otherwise not be predicted to substantial blood resuscitation. In a recent study, the patients most likely to be missed by gestalt alone or by the ABC score were those suffering pelvic bleeding(15). Our study is limited in its ability to distinguish between differing types of abdominal and pelvic hemorrhage due to the manner in which the data was collected. In addition, the dataset investigated in this analysis includes only those patients in whom the clinician provider activated the massive transfusion protocol. Therefore, we cannot definitively establish if a particular MTS cut-off would be better at identifying occult hemorrhages in all comer trauma patients compared with prior scores and this should be investigated in future study.

Recent hemorrhage research has focused on newer metrics, like CAT [Critical Administration Threshold], as a marker of rapid bleeding and future studies should also attempt to correlate massive transfusion scores to such measures(24). The more rapidly bleeding patients are likely to have more physiologic derangement and prediction scores including physiologic criteria like the MTS theoretically will probably perform better for predicting CAT positivity. Our dataset was not collected in a manner to allow us to calculate the CAT and therefore, we cannot evaluate the Revised MTS for prediction of CAT positivity as the outcome metric.

The scores that predated the MTS were developed from retrospective data utilizing total transfusion volumes received and not necessarily what patients required. The subtle but relevant difference between what is *received* and what is *needed* highlights the difficulty in knowing what the proper end point of balanced resuscitation is. For example, is it anatomic hemorrhage control, a stable hematocrit value, or hemodynamic stability? Currently, there is no standard accepted method for assessing the optimum timing of when a MTP should be terminated.

The present study is the first to investigate utilizing a MTS calculated at subsequent time points to predict on-going transfusion needs. In other words, the MTS may provide a common method for assessing the end point of active MTP resuscitation. Recent data has demonstrated that most hemorrhaging trauma patients require the predominant proportion of their blood products by hour 6 and therefore, patients were reassessed at 6 hours to determine if they had continued on- going transfusion needs. The Revised MTS_{6hour} was predictive of future transfusion needs with it being most useful for the immediate next 6 hour interval (post trauma hours 7 to 12). This suggests the MTS utility extends beyond just knowing when to turn on the MTP in the trauma bay. Those who normalized Revised MTS components by hour 6 were unlikely to require any further blood products in the first 24 hours of care. The Revised MTS is an additional adjunct to clinical gestalt to assist providers in knowing when to turn balanced resuscitation or the MTP off.

Perhaps most surprising, not only does the Revised MTS predict transfusion needs, but it was also extremely predictive of both short-term and long-term mortality. Failure to normalize the Revised MTS components (or achieve a MTS of zero) by hour 3 or 6 conferred a particularly poor prognosis. Failure to achieve normalization of the MTS components likely reflects both non-modifiable patient/injury factors, and modifiable provider/institutional factors. Thus, aiming to achieve a 6 hour MTS of zero may be an important potential future quality metric for trauma center performance.

CONCLUSIONS

Since the incorporation of balanced resuscitation strategies into clinical practice, the currently investigated massive transfusion prediction scores all have relative poor predictive performance for estimating need for traditional massive transfusion volumes. However, the Revised MTS is a better predictor of MT than the ABC score, and a powerful predictor of mortality. Failure to normalize the MTS components by hour 6 portends a poor prognosis and also predicts on-going transfusion needs after hour 6.

Acknowledgments

Funding: Dr. Callcut is funded by National Center for Advancing Translational Sciences of the NIH under Award Number KL2TR000143.

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Table 1

Transfusion Score Components and Trigger Cut-Off Values

	TASH	ABC (ED 1st value)	CITT (ED 1st value)	Original MTS (ED 1st value)	Revised MTS (ED 1st value)	MTS_{3hour} (at 3 hours)	MTS_{6hour} (at 6 hours)
SBP (mm Hg)	<100 = 4 pts 100 to <120 =1 point	<90	<90	<90	<90	<90	<90
HR (bpm)	>120 = 3 pts	>=120		>=120			
Positive FAST	included (3 pts)	included		included			
Penetrating Mechanism		included		included			
Base Deficit (mmol/L)	6 to 10 = 4 pts 2 to 6 = 3 pts < 2 = 1 point		>=6	>=6	>=6	>=6	>=6
INR			> 1.5	> 1.5	> 1.5	> 1.5	> 1.5
Hemoglobin (g/dL)	<7 = 8 pts 7 to <9 = 6 pts 9 to <10 = 4 pts 10 to <11 = 3 pts 11 to <12 = 2 pts		< 11	< 11	< 11	< 11	< 11
Temperature (°C)			<35.5		<35.5	<35.5	<35.5
Long Bone Fracture or Complex Pelvis Fracture	included (AIS 3/4=3 pts AIS 5=6 pts)						
Male	included (1 point)						

TASH: Trauma Associated Severe Hemorrhage, ABC: Assessment of Blood Consumption; CITT: Cincinnati Individual Transfusion Triggers, MTS: Massive transfusion score, ED: emergency department, SBP: systolic blood pressure, mmHg: millimeters of mercury, HR: heart rate, FAST: focused abdominal sonography for trauma, mmol/L: millimol per liter, INR: international normalized ratio, g/dL: grams/deciliter, C: degrees Celsius

Table 2

Vital Sign, Laboratory, and Transfusion Parameters on Emergency Department Presentation and at 6 hours in Trauma Patients

	ED value		6 hour	
	n	Median	n	Median
HR (bpm)	185	106 (83–129)	133	92 (82–108)
SBP (mmHg)	186	100 (80–128)	134	124 (107–145)
Temperature (°C)	109	35.7 (35.2–36.4)	129	36.7 (35.7–37.3)
INR	167	1.3 (1.1–1.6)	127	1.3 (1.2–1.4)
pH	169	7.25 (7.09–7.32)	128	7.39 (7.32–7.43)
Base Excess	166	−8.6 (−5.4 to −14.6)	127	−1.7 (−6.8 to 1.8)
Hemoglobin (g/dL)	178	11.7 (10.2–13.3)	134	10.9 (9.7–12.2)
Platelet	177	248 (190–316)	131	109 (82–154)
Plasma:PRBC, all			189	0.68 (0.43–0.91)
Plasma:PRBC, alive at 6 hours			152	0.75 (0.50–0.96)
% MT			189	61%

ED: emergency department, n= number of patients, HR: heart rate, bpm: beats per minute, SBP: systolic blood pressure, mmHg: millimeters of mercury, C: degrees Celsius, INR: international normalized ratio, g/dL: grams/deciliter, PRBC: packed red blood cells; MT: massive transfusion

Table 3

Timing & Quantity of Transfusion of Crystalloid and Blood Products in Trauma Patients

Median (IQR)	**0–6 hr (n=190)**	**7–12 hr (n=160)**	**13–24 hr (n=152)**	**24 hr total**
Crystalloid (mLs)	4000 (2500–6100)	974 (625–1707)	1675 (1174–2880)	7420 (5335–12113)
PRBC (units)	10 (6–19)	0 (0–2)	0 (0–2)	12 (7–18)
Plasma (units)	8 (4–15)	0 (0–1)	0 (0–0)	10 (5–16)
Platelet (units)	1 (0–2)	0 (0–1)	0 (0–0)	1 (0–2)

IQR: interquartile range, n: number of patients, mLs: milliliters, PRBC: packed red blood cells

Table 4

Comparison of the ABC Score, Original MTS, and Revised MTS at time zero for prediction of Massive Transfusion in Trauma Patients*

Model	n	Need for MT by 6 hours				Need for MT by 24 hours			
		OR MT (95% CI)	AUC (95% CI)	p-value	HL	OR MT	AUC (95% CI)	p-value	HL
Revised MTS	97	1.8 (1.2–2.6)	0.68 (0.57–0.79)	**0.003**	p=0.59	2.2 (1.4–3.3)	0.72 (0.61–0.83)	**0.001**	p=0.62
Original MTS	83	1.3 (0.9–1.7)	0.60 (0.48–0.72)	0.154	p=0.57	1.3 (0.9–1.7)	0.60 (0.47–0.72)	0.146	p=0.83
ABC Score	189	1.3 (1.0–1.8)	0.58 (0.50–0.67)	0.051	p=0.88	1.0 (0.8–1.4)	0.51 (0.42–0.60)	0.799	p=0.83

*accounting for hemorrhagic deaths within the interval time period; Hosmer-Lemeshow (HL) goodness of fit performed for each model

MTS: Massive transfusion score, ABC: Assessment of blood consumption score, n: number of patients, OR: odds ratio, MT: massive transfusion, AUC: area under the curve, CI: confidence interval; HL: Hosmer-Lemeshow goodness of fit

Table 5

Revised MTS at time zero and prediction of future blood product needs

Revised MTS	Median units PRBCs 0 to 6 hours*	Median units PRBCs 0 to 24 hours**	Prediction of MT*** at 24 hours			
				MTS>=1	MTS>=2	MTS>=3
0	8	7	Sensitivity	93%	70%	40%
1	8	12	Specificity	20%	67%	87%
2	10	13	PPV	72%	83%	87%
3	13	14	NPV	55%	50%	39%
4	22	19	Accuracy	70%	69%	55%
5	23	27				

* p=0.001

** p=0.02

*** analysis accounting for hemorrhagic deaths within the interval time period

MTS: Massive transfusion score, PRBC: packed red blood cells, PPV: positive predictive value, NPV: negative predictive value

Table 6

The $MTS_{6\ hour}$ Trigger Variables Individual Utility of Prediction of Further Transfusion Needs 92/153 79/146 hr 12

MT Trigger Value at hour 6	Adjusted Likelihood of PRBC Transfusion in Hour 7 to 12 (n=92)			Adjusted Likelihood of PRBC Transfusion in Hour 13 to 24 (n=79)		
	OR	95% CI	p-value	OR	95% CI	p-value
INR (for each increase of 0.5 units)	1.5	0.4–5.3	0.505	0.9	0.8–1.2	0.318
SBP (for each 10 mm Hg decrease)	**1.4**	**1.1–1.8**	**0.008**	1.0	0.8–1.3	0.763
Hgb (for each 1g/dL decrease)	**1.8**	**1.1–2.5**	**<0.001**	**1.9**	**1.3–2.7**	**0.001**
Base Deficit (for each 2 unit increase)	**1.2**	**1.0–1.6**	**0.046**	1.1	0.9–1.4	0.364
Temperature (for each 0.5 °C decrease)	1.2	0.9–1.6	0.126	1.1	0.9–1.4	0.499

MT: massive transfusion, INR: international normalized ratio, SBP: systolic blood pressure, Hg: millimeters of mercury, C: degrees Celsius, PRBC: packed red blood cells, OR: odds ratio, MT: massive transfusion, CI: confidence interval