The American Journal of Surgery 218 (2019) 1195–1200

Contents lists available at ScienceDirect

The American Journal of Surgery

journal homepage: www.americanjournalofsurgery.com

The Extremity/Mechanism/Shock Index/GCS (EMS-G) score: A novel pre-hospital scoring system for early and appropriate MTP activation

Alexandra Kovar [a], Heather Carmichael [a], Robert C. McIntyre Jr. [a], Jacob Mago [b], Alicia Heelan Gladden [a], Erik D. Peltz [a], Franklin L. Wright [a, *]

[a] Division of GI, Trauma, and Endocrine Surgery, Department of Surgery, University of Colorado Anschutz Medical Campus, Aurora, CO, USA
[b] University of Colorado School of Medicine, Aurora, CO, USA

ARTICLE INFO

Article history:
Received 14 March 2019
Received in revised form
1 July 2019
Accepted 16 August 2019

Keywords:
Pre-hospital
Massive transfusion
Trauma

ABSTRACT

Background: Numerous in-hospital scoring systems to activate massive transfusion protocols (MTP) have been proposed; however, to date, pre-hospital scoring systems have not been robustly validated. Many trauma centers do not have blood or pre-thawed plasma available in the trauma bay, leading to delays in balanced transfusion. This study aims to assess pre-hospital injury and physiologic parameters to develop a pre-hospital scoring system predictive of need for massive transfusion (MT) prior to patient arrival.

Methods: A retrospective review of all adult full and partial trauma team activations from July 2014–July 2018 from an urban level 2 trauma center was performed utilizing our trauma registry. Stepwise logistic regression analysis was performed to develop a new scoring system, with point totals assigned proportional to the odds ratios of requiring MT for each variable. Internal validation of the EMS-G score was performed using a subset of the data which was not utilized for development of the scoring system, and sensitivity and specificity were compared to previously validated in-hospital scoring systems applied in the pre-hospital setting.

Results: 763 patients were included with 94 patients (12.3%) receiving early MT, defined as 4 units pRBC in 4 h or ED death. In-hospital models for predicting MT such as Assessment of Blood Consumption (ABC) or Shock Index (SI) have sensitivities and specificities of 46/85% and 94/79% respectively for early MTP utilization based on pre-hospital data. Pre-hospital variables found to be predictive of MT were used to develop the EMS-G (Extremity, Mechanism, Shock Index, GCS) score. This system assigns obvious extremity injury–1-point, penetrating mechanism –2 points, shock index $\geq$0.9–2 points, GCS $\leq$8–3 points. A score of 3 or greater was chosen to maximize sensitivity and specificity for pre-hospital MT activation. EMS-G score based on pre-hospital report is 89% sensitive, 84% specific, with a PPV of 44% and NPV of 98% for early MT. Using this system, 25% of full and partial trauma team activations met criteria for pre-hospital MTP activation.

Conclusion: The EMS-G Score has increased sensitivity and specificity compared to the ABC Score in the pre-hospital setting and appears more appropriate than shock index alone at predicting massive transfusion. This scoring system allows trauma centers to activate MTP prior to patient arrival to ensure early and appropriate blood product administration without blood product wastage.

Introduction

The most common causes of death in the trauma population are hemorrhagic shock and traumatic brain injury.[1,2] The greatest risk for mortality due to uncontrolled hemorrhage occurs within the first hour of trauma, therefore, prompt recognition of the exsanguinating patient and delivery of massive transfusion products while working to establish hemorrhage control, are paramount in improving outcomes.[3] To prevent hemodilution and correct coagulopathy in the exsanguinating patient, massive transfusion protocols assist in expediting the delivery of appropriate blood products.[4,5] These protocols, once activated by a physician, allow for the quick mobilization and transfusion of packed red cells,

* Corresponding author. Division of GI, Trauma, and Endocrine Surgery, Department of Surgery, University of Colorado Anschutz Medical Campus, 12631 E. 17th Ave, C313, Aurora, CO, 80045, USA.
E-mail address: Franklin.Wright@cuanschutz.edu (F.L. Wright).

https://doi.org/10.1016/j.amjsurg.2019.08.019
0002-9610/

plasma, and platelets with improved outcomes.[6]

Although the majority of trauma centers throughout the United States have established Massive Transfusion Protocols (MTP), there is significant variation in how these protocols are activated.[7] In response, a number of scoring systems have been developed to guide clinical decision making on the appropriate activation of MTP. The Assessment of Blood Consumption (ABC) score is a validated in-hospital system based on 4 clinical variables: heart rate greater than 120 bpm, systolic blood pressure less than 90 mmHg, a positive Focused Assessment with Sonography for Trauma (FAST) exam, and evidence of a penetrating injury.[8] Although this scoring system has a negative predictive value of less than 5%, ACS TQIP guidelines indicate that the ABC score overestimates the need for massive transfusion by nearly 50%.[3] Additionally, Motameni et al. demonstrated that clinical judgment was more sensitive than the ABC score, but advocated that the combination of the ABC score and clinical acumen decreases blood product waste while activating MTP in a timely fashion.[9]

Numerous studies have identified blood products as independent predictors of mortality, ICU admission, hospital length of stay, and the development of multiple organ failure in critically injured patients.[10,11] Resource utilization of unnecessary MTP activation also creates a strain on health care systems.[12] Findings such as these underlie the crucial nature of a scoring system which is not only able to recognize the exsanguinating patient, but also accurately identifies those patients without a need for massive transfusion (MT).

The expeditious and appropriate activation of MT improves mortality, overall outcomes, and reduces unnecessary healthcare costs. The purpose of this study is to create a pre-hospital scoring system that has potential to minimize time to infusion of MT to patients in hemorrhagic shock and reduce overutilization of MTP activation. This study also aims to internally validate this score and compare its performance to the ABC Score and Shock Index (SI) in accurately identifying patients in hemorrhagic shock.

Methods

A retrospective review of the trauma registry from the University of Colorado Hospital (UCH), an urban and academic level 2 trauma center, during the 4-year period between August 2014 and July 2018, was performed. This registry captures all adult full and partial trauma team activation criteria. The trauma registry records data such as demographics, trauma mechanism, clinical outcome measures, and procedures performed during the admission. For the purposes of this analysis, we included all adult patients ($\geq$18 years) who met partial or full trauma team activation criteria. Partial and full trauma team activation criteria include physiologic, mechanistic, and anatomic factors. We excluded all transfers, readmissions, and patients with thermal injury. Patients who were missing pre-hospital vital signs were also excluded.

The primary outcome variable was need for early massive transfusion, defined as requiring >4 units of packed red blood cells (pRBCs) within 4 h of arrival[13,14] to the hospital or death in the Emergency Department. This definition of MT was chosen for its demonstration of clinically significant bleeding with acute need for rapidly available blood products. Although this definition is focused on pRBC transfusion, the goal for massive transfusion delivery in trauma patients at our institution uses alternating pRBC and fresh frozen plasma (FFP) with delivery of a platelet apheresis unit after 5 units of pRBCs and 5 units of FFP have been given. Patients who died in the Emergency Department were included in the massive transfusion cohort. Since the majority of early trauma deaths are due to exsanguination, these patients have a high probability of requiring transfusions, had they survived. Pre-hospital and demographic variables assessed for potential inclusion in the predictive model included age, sex, race/ethnicity, blunt versus penetrating mechanism, presence of penetrating torso trauma, obvious lower extremity injury, pre-hospital heart rate (HR), pre-hospital systolic blood pressure (SBP), pre-hospital Glasgow Coma Scale (GCS), pre-hospital shock index (SI), and transport time. Obvious lower extremity injury was defined as an Abbreviated Injury Scale (AIS) score $\geq$3; after reviewing the injury patterns that meet this cutoff, these injuries should be recognizable and reportable by EMS personnel (Table 1).

The EMS-G Score was then compared to the ABC Score and SI in the ability to accurately predict MT need in the same patient population.[15,16] The ABC Score was chosen due to its adoption by the American College of Surgeons trauma guidelines and pervasive use to activate massive transfusion.[3] SI is another scoring tool used for identification of the need for MT in trauma patients and has been compared to the ABC Score in the in-hospital setting.[17,18] Depending on the study, this tool has a reported sensitivity and specificity of 53–85% and 64–86%, respectively.[19,20] Due to its ease of use, applicability in the pre-hospital setting, and comparison to other scoring systems in the literature, the authors sought to evaluate whether the accuracy of SI could be improved upon by comparing to ABC and with incorporation of other variables as previously discussed.

Statistical analysis

Continuous variables (SBP, GCS, HR, SI) were dichotomized using a receiver operator curve (ROC) analysis with an optimal cut-point chosen using a Youden index. Models were developed using a training set involving 70% of the data. Multivariable, stepwise logistic regression analysis was performed to develop the scoring system. Point totals for the scoring system were assigned proportionate to the odds ratios of requiring massive transfusion (MT) for each variable. Internal testing of the EMS-G score with evaluation of sensitivity and specificity of the scoring system with different cutoffs was analyzed using the 30% of data retained for this purpose. This 30% of data was not used to create the EMS-G model. An optimal cut-point was again chosen using a Youden index. The ability of the EMS-G score to predict need for MT was estimated using the AUROC curve and compared to other scoring systems previously described in the literature.

Results

There were 791 partial and full trauma team activation patients who were included in the analysis; 27 patients were missing pre-hospital vital sign data; thus 764 patients (295 full trauma team activations, 469 partial trauma team activations) were included in the multivariable analysis (Fig. 1). Ninety-four (12.3%) met the definition of early massive transfusion; of these, 48 patients (6.3%) received at least 4 units of blood in 4 h and 46 patients (6.0%) died in the Emergency Department prior to transfusion of at least 4 units. Of the patients requiring MT, 90 were full trauma team activations and 4 were partial trauma team activations. The patient characteristics of studied population can be found in Table 2. Clinical variables that could be reliably assessed in the pre-hospital setting were analyzed using univariate analysis (Table 3).

It was determined that penetrating mechanism, elevated SI $\geq$ 0.9 or SBP 0 mmHg, GCS $\leq$8, and presence of an obvious lower extremity injury were associated with high odds ratios for prediction of MT. Systolic blood pressure of 0 mmHg was added to the SI $\geq$ 0.9 to capture patients with pre-hospital arrest, who would otherwise have a SI of 0/0 and would therefore not meet criteria. Penetrating mechanism had an OR 10.69, Elevated SI OR 9.97, GCS

Table 1
Injury patterns for lower extremity AIS ≥3.

1. Amputation at least below knee, at or above ankle	1. Sciatic nerve laceration
2. Compartment syndrome with muscle loss	2. Open femur fx
3. Crush injury below knee, at or above ankle	3. Open tibia fx
4. Degloving, entire extremity	4. Open bimalleolar fx
5. Penetrating injury with >20% blood volume loss	5. Open pelvic ring
6. Any femoral artery injury, major femoral vein injury/popliteal A&V/, other named arteries and veins	6. Incomplete disruption of posterior arch
	7. Complete disruption of posterior arch and pelvic floor
	8. Open acetabular fx

Fx = Fracture, A&V = artery and vein.

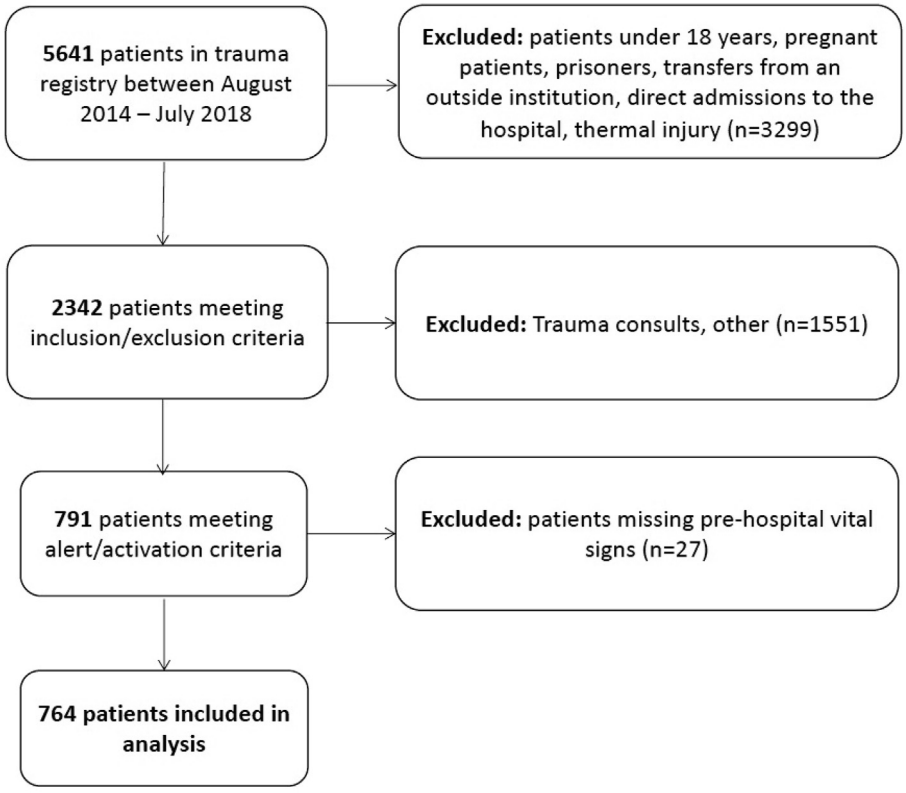

Fig. 1. Flow diagram of patient population included for analysis.

≤8 OR 34.48, and obvious lower extremity injury had an OR 4.72 (Table 4). Using this logistic regression model, the Extremity Mechanism Shock Index- GCS (EMS-G) Score was developed. Similar odds ratios, sensitivities, and specificities for the EMS-G score were found when excluding patients who died in the trauma bay.

In the pre-hospital setting, a patient with an obvious lower extremity injury or pelvic injury receives 1-point, penetrating mechanism receives 2 points, SI ≥ 0.9 or SBP of 0 mmHg receives 2 points, and GCS ≤8 receives 3 points. If a patient has 3 points or greater in the pre-hospital setting, he is EMS-G positive and the MTP will be activated. Sensitivity analysis and 95% confidence intervals (in parenthesis) were analyzed. This scoring system has a sensitivity of 89% (72–90%), specificity of 84% (78–89%), a positive predictive value (PPV) of 44% (35–80%), and a negative predictive value (NPV) of 98% (94–99%). In order to maximize the sensitivity and negative predictive value of this scoring system, we also analyzed a cut-point of 2 points or greater. This resulted in a sensitivity of 96% (82–100%), specificity of 66% (59–72%), a PPV of 28% (23–94%), and an NPV of 99% (96%–99%). The distribution of EMS-G scores in patients who did and did not receive MTP are demonstrated in Fig. 2. Overall, twenty-five percent of partial and full trauma team activations would have had MTP activated using the EMS-G score with a cut-point of 3. Of partial trauma team activations, 5.6% (8/143) would have MTP activated and of full trauma team activations 57.6% (49/85) would have MTP activated under this protocol.

Table 4 compares the results of the ABC score, shock index, and the EMS-G score (at cut-points of both 2 and 3) applied in the pre-hospital setting and each of their abilities to predict MTP. The EMS-G score with a cut-off of 3 points has a sensitivity of 89% compared to 46% and 85% in the ABC and SI scores, respectively. Table 5 compares the AUROC curves for the EMS-G score, SI, and ABC score in the study population. The EMS-G scoring system with a 3-point cut-off outperforms the other scoring systems with an AUROC of 0.866 (see Table 6).

Discussion

The EMS-G Score is a pre-hospital scoring system that accurately and reliably predicts patients in hemorrhagic shock to allow immediate blood product availability upon arrival to the trauma

Table 2
Patient demographics.

Patient Variable	
Age in years, median [IQR]	41 [28,57]
Male Sex, n (%)	549 (72.0)
Race, n (%)	
White	545 (71.4)
Black	161 (21.1)
Other	57 (7.5)
Hispanic Ethnicity, n (%)	226 (29.6)
Blunt Mechanism, n (%)	608 (79.7)
Pre-Hospital SBP, median [IQR]	130 [106,148]
Pre-Hospital HR, median [IQR]	94 [80,110]
Pre-Hospital GCS, median [IQR]	15 [13,15]
ISS	11 [5,22]

IQR = Interquartile range, SBP = Systolic Blood Pressure, HR = Heart Rate, GCS = Glasgow Coma Score, ISS = Injury Severity Score.

center. This is especially important for trauma centers that do not have immediate access to blood products in the trauma bay such as a stocked and maintained blood refrigeration unit with pRBCs and FFP thawed and ready to transfuse. Utilizing a scoring system based upon pre-hospital patient factors like vitals, GCS, mechanism, and injury pattern allows trauma centers to prepare blood products prior to patient arrival to ensure timely and balanced resuscitation.

The PROMMTT trial concluded that inadequate transfusion of plasma and platelets in the first 6 h was associated with increased mortality in the substantially bleeding trauma patient.[21] Furthermore, the PROPPR trial demonstrated early and balanced resuscitation was associated with improved mortality in the first 24 h.[22] Holcomb et al. stated that the most common cause of death in the first 24 h was exsanguination occurring within 96–106 min.[22] The EMS-G score can be utilized to activate MTP prior to patient arrival to a trauma center, thereby decreasing the time to first blood product administration. This improvement in early and appropriate blood product transfusions decreases patient mortality.[6]

The Assessment of Blood Consumption (ABC) score was designed as an in-hospital scoring system with multicenter validation to predict need for massive transfusion in the trauma population utilizing the dichotomous variables of penetrating mechanism, SBP < 90 mmHg, HR > 120 bpm, and positive FAST.[16] Nunez et al. showed that an ABC score of 2 or greater is 75% sensitive and 86% specific for need for massive transfusion, defined as 10 or more units of pRBCs in the first 24 h of arrival.[8] In comparison, the EMS-G score of 3 developed in this study has a sensitivity of 89% and a specificity of 84% for predicting transfusion requirements in a more acute time frame using variables that can be reliably

Table 4
Final multivariable logistic regression model used to develop the EMS-G scoring system.

	Odds ratio	95% CI	P-value
(Intercept)	0	0,0.01	<0.001
Penetrating mechanism	10.69	4.24,26.92	<0.001
Elevated shock index (≥0.9)	9.97	4.27,23.31	<0.001
GCS ≤8	34.48	13.75,86.45	<0.001
Lower Extremity Injury	4.72	1.78,12.52	<0.001

AUROC: 0.919.

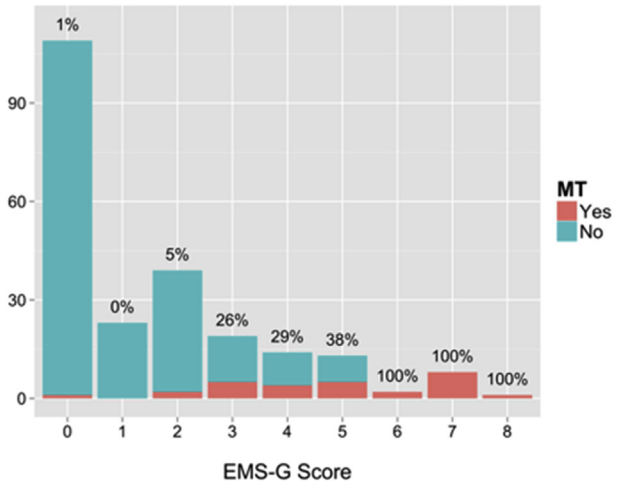

Fig. 2. Distribution of EMS-G Scores in the test population (n = 228). The percentage of patients with each score who received MT is demonstrated above each bar.

communicated from the scene and does not rely of the FAST exam, an operator dependent study which is not widely available in the prehospital setting.

Prior to the development of the EMS-G scoring system, our institution applied the ABC score to pre-hospital reports from EMS excluding FAST. A score of 2 or greater was still used to activate MTP despite the lack of availability of the FAST exam. While an EMS-G score cut-off of ≥2 points leads to maximal sensitivity and an exceedingly high negative predictive value, this comes with a trade-off in specificity. In our patient population, this cut-off would have led to a high over-triage rate for MTP activation, with 42% of our test cohort meeting the cut-off for this lower point criteria. Based on these data, the cut-off of ≥3 points appears to be a better

Table 3
Univariate analysis of variables and cut-points considered for use in a pre-hospital scoring system. ABC – Acute Blood Consumption.

	No MT	MT	p-value
N	670	94	
Under 40 years old (%)	321 (47.9)	60 (63.8)	0.005
Male sex(%)	471 (70.3)	79 (84.0)	0.008
ABC criteria – Penetrating mechanism (%)	103 (15.4)	52 (55.3)	<0.001
ABC modified criteria – Penetrating torso trauma (%)	50 (7.5)	33 (35.1)	<0.001
ABC criteria – HR over 120 bpm (%)	109 (16.3)	16 (17.0)	0.976
ABC modified criteria – HR under 60 or over 130 (%)	39 (5.8)	56 (59.6)	<0.001
ABC criteria – SBP less than 90 mmHg (%)	58 (8.7)	71 (75.5)	<0.001
ABC modified criteria – SBP under 100 mmHg (%)	79 (11.8)	73 (77.7)	<0.001
Age modified SBP – SBP under 100 mmHg if age less than 65, SBP under 110 if age greater 65 or older	91 (13.6)	74 (78.7)	<0.001
Elevated shock index, greater than 0.9 or SBP of 0 (%)	139 (20.7)	80 (85.1)	<0.001
Glasgow coma scale - 8 or less (%)	47 (7.0)	63 (67.0)	<0.001
Obvious lower extremity fracture – AIS ≥3 (%)	108 (16.1)	25 (26.6)	0.018

AIS – Abbreviated Injury Scale.
SBP – systolic blood pressure.
HR – heart rate.

Table 5
Comparison of EMS-G to other scoring systems.

	EMS-G score(≥3 points)	EMS-G(≥2 points)	Pre-hospital ABC score (≥2 points)	Shock Index
Sensitivity (95% CI)	89% (72–98%)	96% (82–100%)	46% (27–66%)	85% (78–92%)
Specificity (95% CI)	84% (78–89%)	65% (59–72%)	94% (89–96%)	79% (76–82%)
PPV (95% CI)	44% (35–80%)	28% (23–94%)	50% (26–69%)	37% (32–52%)
NPV (95% CI)	98% (94–99%)	99% (96–99%)	93% (85–96%)	97% (96–98%)
MTP Activation Rate	25%	42%	11%	29%

CI = Confidence Interval, PPV = positive predictive value, NPV = negative predictive value, MTP = massive transfusion protocol.

Table 6
Comparison of scoring systems by AUROC.

Scoring System	ROC Area	95% CI
EMS-G (3 pts)	0.866	0.803–0.930
EMS-G (2 pts)	0.81	0.762–0.858
SI	0.822	0.782–0.861
ABC	0.827	0.786–0868

overall predictive score although this will need to be validated with a larger data set. Additionally, in trauma centers with lower MTP utilization or those with local factors which may contribute to a substantial delay in obtaining blood products, the more sensitive cut-off of 2 may be more appropriate.

The major strength of the EMS-G score is the ability to utilize strictly pre-hospital variables to appropriately risk stratify trauma patients with significant hemorrhage while maximizing the balance of sensitivity and specificity. Its ease of use by triaging personnel at the trauma center and focused reporting by EMS allow for clear communication of severity injury prior to patient arrival. Our blood bank colleagues have not found an increase in blood product waste with the utilization of pre-hospital MT activation. High institutional blood product usage allows for redistribution of unused products throughout the hospital. In other institutions who do not have a high blood product use, limiting MT activation to 1–2 units of pRBC and FFP would allow for immediate blood product availability with less risk waste.

Development of scoring systems to predict patient outcomes requires a careful balancing of specificity and sensitivity. Higher sensitivity and higher NPV will result in less "missed" early MT activations with potential morbidity and mortality from uncorrected hemorrhagic shock. Higher specificity and higher PPV will result in less potential over-activation of MT and possible blood product waste. The NPV and PPV depend on the prevalence of hemorrhage in the trauma populations seen at a given institution. In the study population the EMS-G score, compared to pre-hospital ABC and SI, had higher sensitivity and NPV rates at 89% and 98%, respectively.

The limitations of this study include its retrospective design, development and application to a single institution's patient population and lack of prospective application. The use of extremity AIS ≥3 as a proxy for the clinical assessment of an "obvious" injured extremity is a limitation; therefore, prospective validation will be required. Small patient population and percentage of patients requiring MT are additional limitations. Lastly, using an alternative definition for MT, 4 units of pRBCs in 4 h, instead of the traditional definition, 10 units of pRBCS in 24 h, can be viewed as a limitation; however, the authors feel this is the most clinically relevant definition to the exsanguinating trauma patient.[23] Uncontrolled hemorrhage and coagulopathy associated with trauma often result in death within the first few hours. Investigations have changed the focus from Massive Transfusion within 10 or 24 h to an earlier time point (3–4 h). The conventional definition of 10 units pRBC in 24 h does not account for the patients who die within hours of arrival but have not yet received 10 units or the survivor bias of the patient who receives 10 units over 24 h due without serious injury.[25]

We know from the PROMPT and PROPPR trials, that early death from hemorrhage occurred at a median time of 2.6 and 2.3 h, respectively(21, 22). The FDA recommended the "time to hemostasis" to be within 4 h of the administration of prothrombin complex concentrate in its phase 3 trial.[22,24] With such evidence, the authors feel the definition of MT as 4 units pRBC within 4 h of arrival decreases the survivor bias and more accurately identifies patients in hemorrhagic shock. In our study population, 48 patients required MT. Of those 48 patients, only 20 patients (41.7%) ended up receiving 10 units in 24 h. Blood product resuscitation is critically important during the golden hour, and using a definition of 4 units of pRBCs in 4 h identifies those patients in hemorrhagic shock where timely activation of MTP is essential. Validation of this association will require evaluation utilizing a larger patient population and prospective data collection.

The EMS-G score is a valid and reliable pre-hospital scoring system to assess and risk stratify trauma patients for hemorrhage, the most common cause of death in the first 24 h. The literature shows early and balanced resuscitation with blood products improves mortality in the exsanguinating patient.[14, 15] In conclusion, the EMS-G score allows trauma centers to accurately activate massive transfusion prior to patient arrival for expeditious delivery of blood products in the most tenuous population.

Conclusion

The EMS-G Score is a reliable pre-hospital scoring system that accurately predicts patients who will require MTP based upon variables easily communicated from the field to trauma triage personnel. The EMS-G Score performed better than ABC and SI applied in the pre-hospital setting for predicting MTP in this study population.

Conflicts of interest

The authors did not receive any funding for this study. None of the authors has a financial interest in any of the products, devices, or drugs mentioned in this manuscript.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.amjsurg.2019.08.019.

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