ORIGINAL ARTICLE

Development of Prehospital Factors for Predicting Massive Blood Transfusion in Trauma Patients

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Background: Massive blood loss is the primary cause of immediate death in trauma patients. In prehospital care, where laboratory and investigation resources are limited, a massive blood transfusion (MBT) scoring system could activate blood bank preparation of blood components and facilitate EMS decision-making regarding the appropriate trauma center destination. This is particularly significant in urban environments where motor vehicle accidents are highly prevalent.

Materials and Methods: A retrospective cohort study was conducted using data from prehospital trauma patients. Predictive parameters, including vital signs, mechanism of injury, and serious injury body parts, were analyzed, and the significant parameters identified by a multivariable analysis were used to develop a clinical scoring system. Discrimination was evaluated by the area under the receiver operating characteristic (AuROC) curve, calibration was demonstrated with the Hosmer-Lemeshow goodness of fit test, and internal validation was performed.

Results: Among 511 trauma patients, 72 (14.1%) received MBT. The prehospital factors that significantly predicted massive MBT included hypotension with a SBP of less than 90 mmHg, penetrating object injuries, serious injuries to the face, thorax, abdomen, extremities including the pelvis, and the use of life-saving interventions such as advanced airway management and pelvic binding. The AuROC was 0.943 (95% CI 0.914 to 0.972, p<0.001). The probability of receiving massive transfusion was 94.79% in patients with score of 5 or higher.

Conclusion: The prehospital MBT score demonstrates good performance and discrimination for predicting MBT using simple and rapidly obtainable parameters in a prehospital setting.

Keywords: Massive transfusion; Massive bleeding; Prehospital care

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Trauma continues to be a major cause of death, accounting for nearly 8% of mortalities worldwide, and among individuals aged 5 to 29, motor vehicle accidents are the leading cause of injury[(1)]. In Thailand, trauma is responsible for 11% of deaths, with road traffic accidents being the primary contributor[(2)]. Massive hemorrhage is the most common cause of traumatic death within the first 24 hours and is a significant factor in potentially preventable mortalities. Hemorrhage control surgeons emphasize the importance of rapidly addressing bleeding sources, while prompt management of hemodynamic stability is also essential[(3)].

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The introduction of massive transfusion protocols (MTPs) has reduced mortality rates by 29%[(4)]. MTPs are guidelines agreed upon by healthcare professionals and blood banks to efficiently prepare blood products and reduce unnecessary blood component usage. In recent years, efforts have been made to identify clinical, laboratory, and imaging factors that can predict significant bleeding and enable early MTP activation. Common systems like the Assessment of Blood Consumption (ABC) score and the Trauma Associated Severe Hemorrhage (TASH) score have demonstrated strong predictive performance[(5)]. However, current massive bleeding prediction scales, such as the ABC score, can be impractical for prehospital use, as they rely on complex calculations, laboratory tests, and imaging[(6-8)]. For the prehospital setting, studies have suggested using the prehospital shock index to predict MTP activation, but its performance has been unsatisfactory[(9)]. Alternatively, the prehospital ABC score showed a sensitivity of 51% and specificity of 85% in predicting massive transfusion when used with a cutoff of 2[(6)]. Other studies have recommended using anatomical injury mechanisms and resuscitative procedures, which have shown good prediction performance but were developed for military settings[10].

As mentioned earlier, there is a lack of suitable prehospital scoring systems for predicting MTP activation in civilian populations, where motor vehicle accidents are the primary cause of injury. The present study aimed to develop an appropriate prehospital scoring system for predicting massive blood transfusion (MBT) in trauma patients. The author would focus on trauma patients who received care from the Narenthorn Emergency Medical Services (EMS) Center, a hospital-based ambulance center at Rajavithi Hospital. Currently, the MTP is activated in the Emergency Department using common scoring systems such as the ABC score. The proposed scoring system may improve prehospital care destination selection for patients requiring MBT while also optimizing the preparation of in-hospital blood components and minimizing unnecessary blood product usage.

Materials and Methods

Study design and population

The present study was a single-center, retrospective cohort study focused on trauma patients who received prehospital care from the Narenthorn EMS Center, which manages an average of approximately 1,300 EMS operations annually. The present research involved a retrospective review of prehospital trauma records of patients treated between January 2018 and December 2022.

Selection of participants

The study population consisted of all trauma patients transported to the Emergency Department of Rajavithi Hospital, a tertiary care facility in Bangkok, Thailand, during the study period. Inclusion criteria were patients aged 18 years or older. Exclusion criteria included trauma patients who required cardiopulmonary resuscitation at the scene, being pregnant, had suspected injury mechanisms such as hanging or burns, or had a "do not resuscitate" order.

Definition of massive blood transfusion

A massive transfusion can be defined as any of the following, the transfusion of more than ten units of packed red blood cells (PRBCs) in 24 hours, the transfusion of more than four units of PRBCs in one hour when an ongoing need is foreseeable, or the replacement of 50% of total blood volume (TBV) or five units of PRBCs within three hours[11,12].

Data collection

Clinical characteristics and potential predictors were identified from electronic EMS medical records, including age, gender, first prehospital vital signs, shock index, POCT glucose, and mechanism of injury, such as motor vehicle accidents, falls from height, contact with penetrating objects, contact with blunt objects, gunshot wounds, and explosions. Serious injuries were defined using the Abbreviated Injury Scale score of 3 or greater[13]. Life-saving interventions included advanced airway management, needle decompression, pelvic binder application, and tourniquet use.

Sample size calculation

Calculation of the sample size was made for the present study aiming to estimate the sensitivity of a diagnostic test or a proportion formula[14]. The estimated number of samples (n) was derived from data obtained in a previously published study, which reported that the incidence of MBT was 9%[8]. To achieve adequate statistical power (80%) and a significance level of 0.05, at least 508 participants were needed, with at least 54 participants in the MBT group.

Ethical considerations

The present study was conducted in accordance with the principles of the Declaration of Helsinki and the Good Clinical Practice Guidelines, and was approved by the Rajavithi Hospital Ethics Committee for Human Research (approval number 65049). The requirement for informed consent was waived due to retrospective study. To protect the privacy of the participants, their names were replaced with hospital numbers, and all data used in the study were de-identified.

Statistical analysis

Continuous variables were summarized as mean and standard deviation (SD), while categorical data were represented as frequencies and percentages. Comparisons between categorical variables were performed with chi-square tests or Fisher's exact probability tests as appropriate. The IBM SPSS Statistics, version 26.0 (IBM Corp., Armonk, NY, USA) was used to perform all statistical analyses.

Model development

Initial predictors of MBT were chosen based on previously reported scoring systems, such as the ABC score, in which the author selected hypotension with systolic blood pressure (SBP) of less than 90 mmHg, tachycardia with a heart rate of more than 120 per minute, and a shock index greater than 1. An exploratory analysis was conducted for all potential predictors using univariable logistic regression. Odds ratios (ORs) with their corresponding p-values and areas under the receiver operating characteristic curve (AuROC) with their 95% confidence intervals (CI) were reported separately for each predictor variable. Multivariable logistic regression analysis was then performed to identify independent predictors of MBT. The removal of non-contributing predictors was primarily based on clinical relevance and statistical significance. The reduced multivariable model was evaluated for its predictive performance in terms of discrimination and calibration. Discrimination was measured using AuROC, while calibration was calculated using the Hosmer-Lemeshow goodness of fit statistics.

Each final predictor was assigned a specific score based on its logistic regression coefficient. The logistic coefficient of each predictor was divided by the lowest coefficient in the model and subsequently rounded up to the nearest whole number for improved applicability. The total score was then further categorized, based on massive transfusion risk, as being lower, medium, or higher risk. Measures of calibration and discrimination were also performed using regression of MBT on the score model. A calibration plot comparing score-predicted risk versus observed risk was presented. The predictive performance was internally validated and compared between the full model and the simplified model using non-parametric ROC regression with 300 bootstrap replicates. A p-value of less than 0.05 was considered statistical significance.

Results

The Narenthorn EMS database included 537 prehospital trauma patients transported to Rajavithi Hospital between January 2018 and December 2022. Of these, 26 were excluded from the analysis as 17 suffered cardiac arrest at the scene, six had injury caused by burn, and three had burn mechanism. The final dataset consisted of 511 patients with 72 receiving MBTs and 439 not receiving MBTs (Figure 1). The incidence of MBT in the present study cohort was 14.1%. The baseline clinical characteristics of the patients are presented in Table 1.

The study population had an average age of 36.4±16.5 years, with 390 participants (76.3%) being male. Tachycardia, defined as a heart rate of over 120 beats per minute, was more frequent in patients who received massive transfusion at 45.8% versus 10.3% ($p<0.001$), as was hypotension with systolic blood pressure less than 90 mmHg at 41.7% versus 5.7% ($p<0.001$) and shock index greater than 1 at 72.2% versus 16.2% ($p<0.001$). The primary mechanism of injury was motor vehicle accident, while penetrating object injuries were significantly more frequent in the MBT group at 23.6% versus 9.1% ($p<0.001$). Serious injuries were mostly found in the head/neck and extremities, including the pelvis. Advanced airway management and pelvic binding were more frequently required in patients who received MBTs.

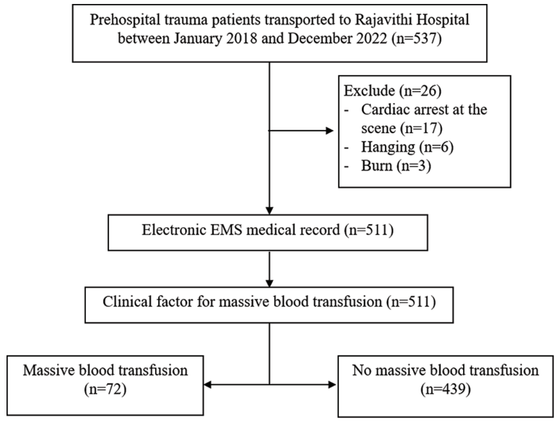

Figure 1. Study Flow showing the selection of eligible patients for use in tool for prediction of massive blood transfusion.

Model development and validation

The evaluation results of the effective factors in predicting MBT using the univariate logistic regression model are reported in Table 2. The author analyzed potential clinical predictors using multivariable logistic regression and identified those with a statistically significant p-value of less than 0.05. In the development of the full model, the author incorporated all significant factors strongly associated with receiving a massive transfusion. The AuROC of the full model was 0.956 (95% CI 0.931 to 0.982).

Subsequently, the author developed a simplified model that incorporates clinically relevant factors that were easily applicable in a prehospital setting. These included hypotension of SBP of less than 90 mmHg, penetrating object injuries, severe injuries to the face, thorax, abdomen, or extremities including the pelvis, and the use of life-saving interventions such as advanced airway management and pelvic binding. These factors were included in the final logistic model. To calculate the impact of each predictor, the

Table 1. Clinical characteristics

Variables	Total (n=511)	Massive transfusion		p-value
		Yes (n=72)	No (n=439)	
Male; n (%)	390 (76.3)	61 (84.7)	329 (74.9)	0.070
Age (years); mean±SD	36.4±16.5	35.5±13.8	36.5±17.0	0.615
SBP (mmHg); mean±SD	120.2±27.8	97.5±28.7	123.9±25.8	<0.001
SBP <90 mmHg; n (%)	55 (10.8)	30 (41.7)	25 (5.7)	<0.001
Heart rate (bpm); mean±SD	98.5±21.7	117.2±25.1	95.4±19.5	<0.001
Heart rate >120 bpm; n (%)	78 (15.3)	33 (45.8)	45 (10.3)	<0.001
Respiratory rate (bpm); mean±SD	19.8±4.0	20.9±7.6	19.7±3.0	0.164
SpO_2 (%); median (IQR)	98 (95 to 99)	93 (82.5 to 98)	98 (96 to 99)	<0.001
Glasgow coma score; median (IQR)	15 (10 to 15)	10 (3.75 to 15)	15 (11 to 15)	<0.001
POCT glucose (mg%) (n=277); mean±SD	146.0±45.0	170.±40.8	144.0±44.7	0.002
Shock index; mean±SD	0.9±0.4	1.3±0.6	0.8±0.3	<0.001
Shock index >1; n (%)	123 (24.1)	52 (72.2)	71 (16.2)	<0.001
Mechanism of injury; n (%)				
Motor vehicles	341 (66.7)	46 (63.9)	295 (67.2)	0.652
Fall form height	68 (13.3)	9 (12.5)	59 (13.4)	0.827
Penetrating object	57 (11.2)	17 (23.6)	40 (9.1)	<0.001
Contact with blunt object	41 (8.0)	0 (0.0)	41 (9.3)	NA
Gunshot	3 (0.6)	0 (0.0)	3 (0.7)	NA
Explosion	1 (0.2)	0 (0.0)	1 (0.2)	NA
Serious injury body part; n (%)				
Head/neck	204 (39.9)	46 (63.9)	158 (36.0)	<0.001
Face	40 (7.8)	13 (18.1)	27 (6.2)	<0.001
Thorax	56 (11.0)	32 (44.4)	24 (5.5)	<0.001
Abdomen	35 (6.8)	17 (23.6)	18 (4.1)	<0.001
Extremities include pelvis	174 (34.1)	44 (61.1)	130 (29.6)	<0.001
Skin	11 (2.2)	3 (4.2)	8 (1.8)	0.192
Life-saving intervention; n (%)				
Advanced airway	86 (16.8)	35 (48.6)	51 (11.6)	<0.001
Needle decompression	6 (1.2)	4 (5.6)	2 (0.5)	0.004
Tourniquet application	2 (0.4)	2 (2.8)	0 (0.0)	NA
Pelvic binder	33 (6.5)	22 (30.6)	11 (2.5)	<0.001

SBP=systolic blood pressure; POCT=point of care testing; SD=standard deviation; IQR=interquartile range; NA=not applicable

Table 2. Univariate analysis of massive blood transfusion predicting factors

Variables	OR	95% CI	p-value
Male	1.85	0.94 to 3.65	0.074
Age (years)	0.99	0.98 to 1.01	0.614
Hypotension (SBP <90 mmHg)	11.83	6.37 to 21.95	<0.001
Tachycardia (heart rate >120 bpm)	7.41	4.25 to 12.93	<0.001
Respiratory rate (bpm)	1.00	0.98 to 1.03	0.609
SpO_2 (%)	0.86	0.83 to 0.90	<0.001
Glasgow coma score	0.84	0.80 to 0.90	<0.001
POCT glucose (mg%) (n=277)	1.01	1.00 to 1.01	0.005
Shock index >1	13.48	7.58 to 23.95	<0.001
Mechanism of injury			
Motor vehicles	0.86	0.51 to 1.45	0.581
Fall form height	0.92	0.43 to 1.95	0.828
Penetrating object	3.08	1.64 to 5.81	<0.001
Serious injury body part			
Head/neck	3.15	1.87 to 5.29	<0.001
Face	3.36	1.64 to 6.88	0.001
Thorax	13.83	7.44 to 25.74	<0.001
Abdomen	7.23	3.52 to 14.85	<0.001
Extremities include pelvis	3.74	2.23 to 6.26	<0.001
Skin	2.34	0.61 to 9.05	0.217
Life-saving intervention			
Advanced airway	7.20	4.17 to 12.43	<0.001
Needle decompression	12.85	2.31 to 71.53	0.004
Pelvic binder	17.12	7.84 to 37.38	<0.001

SBP=systolic blood pressure; POCT=point of care testing; OR=odds ratio; CI=confidence interval

Table 3. Significant predictors of massive blood transfusion in trauma patients from multivariable logistic regression analysis, adjusted odds ratio (OR_{adj}), 95% confidence interval (CI), beta coefficient (β), and assigned item scores

Factors	β	OR_{adj}	95% CI	p-value	Score
Hypotension (SBP <90 mmHg)	1.827	6.22	2.46 to 15.69	<0.001	1
Penetrating object	2.388	10.89	3.28 to 36.13	<0.001	1
Serious injury body part					
Face	2.522	12.45	3.40 to 45.63	<0.001	1
Thorax	3.182	24.08	8.47 to 68.49	<0.001	2
Abdomen	2.441	11.48	3.25 to 40.56	<0.001	1
Extremities include pelvis	2.638	13.99	4.34 to 45.12	<0.001	1
Life-saving intervention					
Advanced airway	2.990	19.89	6.05 to 65.42	<0.001	2
Pelvic binder	2.406	11.09	3.13 to 39.35	<0.001	1

SBP=systolic blood pressure

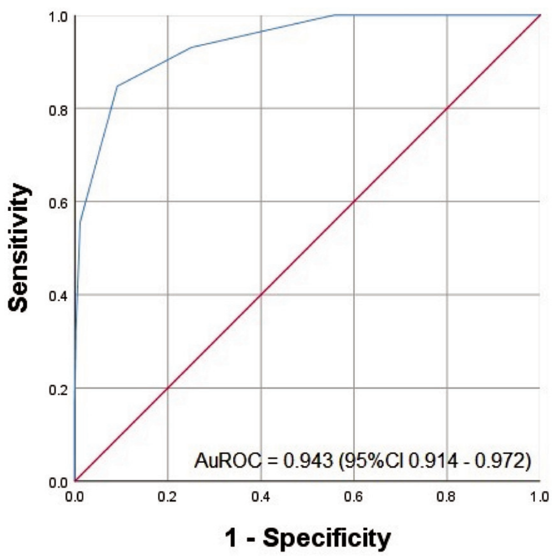

Figure 2. Area under received operating characteristic curve (AuROC) of clinical prediction score of massive blood transfusion.

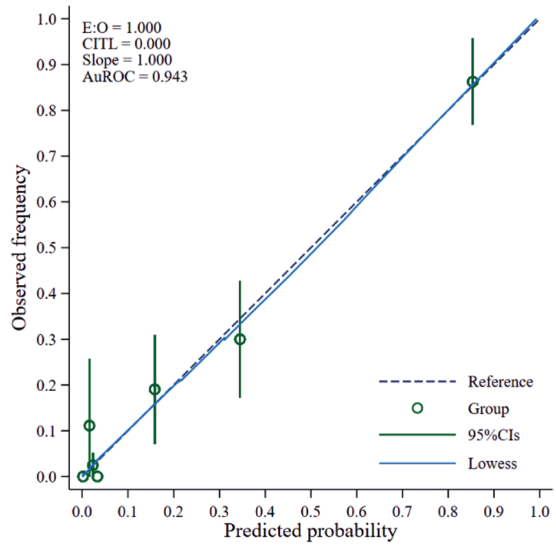

Figure 3. Calibration plot between score-predicted probability of massive blood transfusion and observed massive blood transfusion.

author used a method called logit coefficient that gave us a weight for each predictor, which was then given a score based on its weight with 1 point for patients who had low blood pressure of less than 90 mmHg, injuries from a penetrating object, serious injuries to the face, abdomen, extremities including the pelvis, or needed a pelvic binder and 2 points for patients who had serious injuries to the thorax and needed advanced airway management. The score ranged from a minimum of 0 points to a maximum of 10 points (Table 3), and they predicted the risk of MBT with good discriminative ability AuROC of 0.943 (95% CI 0.914 to 0.972) (Figure 2). Calibration measures, visualized through a calibration plot, revealed that the predicted and observed risks of MBT in the derivation cohort increased concurrently (Figure 3). The Hosmer-Lemeshow goodness of fit test supported these findings with a non-significant p-value of 0.406. Internal validation of the scores was performed using 300 bootstrap samples, yielding acceptable predictive performance (c-statistic of 0.933). The prehospital MBT score estimated the probability of MBT occurrence on a scale of 0 to 10, with a mean of 1.33±1.49 points (IQR 0 to 8 points). In the MBT group, the mean score was 3.85±1.50 points, while in the non-MBT group, it was 0.91±1.02 points, exhibiting a significant difference with a p-value less than 0.001. The predictive probability of each

Table 4. Predictive score of massive blood transfusion

Predictive score	Predicted probability
0	0.3%
1	2.0%
2	10.1%
3	38.0%
4	76.9%
5	94.8%
6	99.0%
≥7	99.9%

massive transfusion score is described in Table 4.

Discussion

In the present study, the author identified early prehospital factors that could predict the need for massive transfusion in urban settings, where motor vehicle accidents account for 66.7% of the injuries. Among EMS trauma patients arriving during the study period at Rajavithi Hospital's emergency department in Bangkok, 14.1% required massive transfusion. Significant prehospital predictors of massive transfusion included hypotension with SBP of less than 90 mmHg, penetrating injuries, serious injuries to the face, thorax, abdomen, extremities including the pelvis, and the use of life-saving interventions such as advanced airway management and pelvic binding. The AuROC was 0.943 (95% CI 0.914 to 0.972), with a 94.79% probability of requiring massive transfusion in patients with a score of 5 or higher. The present study prehospital predictor of MBT is partially consistent with that of a previous study in the literature which examined tactical field settings, such as a SBP of less than 90 mmHg and serious extremity injuries[10]. The MBT incidence rate was similar to the previous research in the same area in Thailand, where motor vehicle accidents are the primary cause of injury but not representative of the prehospital trauma patient population[15,16].

The strengths of the present study include the diversity of the patient cohort and the exclusion of high-risk MTB populations, such as those experiencing cardiac arrest at the scene and trauma patients unlikely to be involved in hemorrhage mechanisms. The prehospital MBT score can be applied in clinical practice in urban areas in middle-income countries where motor vehicle accidents are the primary cause of injury. It offers good discrimination for prehospital trauma patients likely to require MBT, potentially facilitating EMS decision-making regarding the appropriate trauma center destination, optimizing in-hospital blood component preparation, and minimizing unnecessary blood product usage.

The present study findings should therefore be confirmed by larger, multi-center studies to determine their generalizability to diverse healthcare settings. The author suggests that future research directions include external validating the present study prehospital MBT scoring system in different settings or populations, exploring additional predictive parameters, and assessing the impact of implementing the MBT score on patient outcomes and healthcare resource utilization.

Limitation

The present study had limitations that should be considered when interpreting the results. Firstly, the derivation cohort included a small number of patients, and the data were retrospectively collected at a single center, limiting the generalizability of the findings to other healthcare settings. A prospective study should be conducted before applying the findings in real clinical practice. Secondly, potential confounders, such as the fact that motor vehicle accidents are the primary cause of injuries, may have contributed to the non-significance of tourniquet use as a predictive factor, which has been found to be significant in another research. This could be attributed to the lower frequency of tourniquet use in the present study setting due to fewer instances of external hemorrhage, such as extremity injuries. Thirdly, the present study may not have undergone external validation, which is essential for assessing the generalizability of the findings. Conducting validation studies in different populations and settings can help confirm the robustness and applicability of the identified predictors.

Conclusion

The Prehospital MBT Score is a practical tool that consists of eight initial factors, which can be rapidly assessed in a prehospital setting without the need for laboratory tests or imaging. This makes it particularly well-suited to civilian prehospital care, especially in resource-limited situations. When a Prehospital MBT Score is 5 or higher, there is a 95% likelihood of a massive transfusion will be required, which indicates the need to activate the MTP directly from the prehospital setting. In such cases, EMS personnel are advised to choose the most suitable trauma center for the patient's needs.

What is already known on this topic?

Currently, in prehospital settings where investigative and imaging resources are limited, there are no suitable scoring systems available for predicting MTP activation in civilian populations.

What does this study add?

The prehospital MBT score consists of predictive factors suitable for prehospital scoring systems in predicting MTP activation in civilian populations, where motor vehicle accidents are the primary cause of injury.

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Conflicts of interest

The author reports no conflicts of interest in this work.

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