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Original Article

Prehospital shock index, modified shock index, and pulse pressure heart rate ratio as predictors of massive blood transfusions in modern warfare injuries: A retrospective analysis

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ARTICLE INFO

Article history:

Received 19 July 2017

Accepted 11 July 2018

Available online 9 October 2018

Keywords:

Shock index

Modified shock index

Pulse pressure heart rate ratio

Massive blood transfusion

Warfare injuries

ABSTRACT

Background: Massive hemorrhage is the leading preventable cause of death in modern warfare injuries. Early and accurate detection of source of hemorrhage and massive blood transfusions remain the mainstay of management in such cases. Hemodynamic indices like shock index (SI), modified shock index (MSI), and pulse pressure heart rate (PP/HR) ratio have shown promising results in predicting massive transfusion in trauma patients. The present study aimed at assessing the accuracy of SI, MSI, and PP/HR ratio to predict the requirement of massive blood transfusions.

Methods: A retrospective analysis was done from 1st January 2016 to 31st December 2016 of the data taken from the trauma register of our hospital. Data were analyzed, and scores of SI, MSI, and PP/HR ratio were evaluated using area under receiver operating curves (AUROCs). Massive transfusion was defined as requirement of ≥ 10 packed red blood cells (PRBCs) in the first 24 hours or ≥ 4 PRBCs in first hour of hospital admission.

Results: Of the 326 warfare casualties received, a total of 254 patients were enrolled, and 51(23%) patients required massive transfusion on arrival. SI had an AUROC value of 0.798 (95% confidence interval [CI] = 0.739–0.848) which is comparable to MSI at 0.787 (95% CI = 0.728–0.839) and PP/HR ratio with a value of 0.744 (95% CI = 0.681–0.800), ($p < 0.001$).

Conclusion: SI, MSI, and PP/HR ratio are equally efficient in predicting massive transfusion in warfare injuries and can be used as rapidly available marker for prediction of massive transfusion in warfare injuries which can be lifesaving and time-saving.

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Introduction

Modern warfare injuries comprise of a special group of high-velocity projectile injuries with massive internal damage. Analysis from Joint Theater Trauma Registry by the US forces has ranked hemorrhage at the top of the list of preventable combat-related deaths.^{1,2} The recognition of hemorrhage as a potentially preventable cause of death has led to improvement in techniques for hemorrhage control and management of survivable injuries. Emphasis has been laid on rapid evacuation of warfare casualties to nearest echelon hospitals for definitive management, advancements in training routines of on-field paraclinical personnel, and newer resuscitative and surgical techniques. These measures have led to decrease in mortality and morbidity risk among warfare casualties. In spite of the advanced efforts, the mainstay of management of trauma casualties lies in early hemostasis and appropriate replacement of lost volume with crystalloids, colloids, or more importantly blood and blood products. The conventional methods of assessing blood loss by Advanced Trauma Life Support classification may not be effective or always accurate in assessing the blood loss in warfare injuries owing to the delay in evacuation and other confounding factors like cold weather.³

Massive blood transfusion (MBT) protocols improve patients' outcome and restrict blood product wastage. Early identification of patients needing massive transfusion (MT) may further lower mortality rates by cutting down time for availability of blood and blood products in the first "golden hour" in trauma.⁴ Most predictive MT scores are based on clinical parameters and biochemical values, and because prehospital blood gas analysis and sonography is a far reality, the need of a strong predictable scoring system based on easily attainable clinical parameters is paramount to save time and lives as well.

Shock index (SI), modified shock index (MSI), and pulse pressure heart rate ratio (PP/HR) scores have been useful in predicting the severity of injury of the patients, requirement of MTs, and a medium of communication between healthcare providers resulting in better patient care and decreased mortality and morbidity in trauma patients.^{5,6}

SI which is heart rate (HR) divided by systolic blood pressure (SBP) has been suggested as a medium to predict the severity of hypovolemic shock of traumatic etiology in emergency departments and critical care units for assessing the severity of critically ill patients. Most studies have shown the accuracy of SI in diagnosing the severity of shock even when the HR and or blood pressures are within normal range. A SI of ≥ 0.9 is associated with increased morbidity and mortality warranting aggressive resuscitation in an intensive care unit (ICU).^{7,8}

MSI is the score achieved by dividing HR with mean arterial pressure (MAP) because of the undeniable importance of diastolic blood pressure (DBP) in determining patients' clinical severity. An MSI of ≥ 1.3 has been found to be a predictor of increased probability of ICU admission and MBTs.⁹

PP/HR ratio has been found to have some significance in predicting requirement of MBT in certain studies. Our review

of the existing literature on PP/HR ratio has not revealed any normal physiological range. Pottecher et al. have found that a ratio of >0.443 could be a reliable marker for predicting the need for a MT.^{5,10}

Various clinical parameters namely, HR, SBP, MAP, urine output, mental status, and respiratory rate are used as guides in predicting the prognosis as well as the requirement of MTs. These parameters may be cumbersome to evaluate sometimes and fail to give a qualitative approach to quantify the need of massive resuscitations. An attempt to simplify the evaluation process and identify patient who needs MBT was made in this study by testing quantifiable parameters namely SI, MSI, and PP/HR ratio, retrospectively.

Materials and methods

All patients who sustained warfare-related injuries received in the trauma center of our hospital between January 2016 and December 2016 were enrolled. The trauma center receives warfare casualties as a first responder, by evacuation from field after basic field resuscitation or by referral from a field hospital after initial management. Patients who were dead on arrival or within 1 h of arrival, referred after initial resuscitation and management at a field-level hospital, and patients with incomplete data were excluded from the study.

The trauma center received a total of 326 warfare injuries in the study period, of which 254 patients were enrolled into the study, and the study parameters were obtained from our trauma center. First read prehospital hemodynamic parameters were used to calculate SI, MSI, and PP/HR ratio.

SI = HR/SBP (shock index is heart rate divided by systolic blood pressure)⁶

Physiological range: 0.5–0.7¹¹

Threshold for initiation of MBT ≥ 0.9 ¹²

MSI = HR/MAP (modified shock index is heart rate divided by mean arterial pressure).⁶

Physiological range: 0.7–1.3⁶

Threshold for initiation of MBT ≥ 1.3 ⁶

MAP = (SBP + 2 × DBP)/3.

PP/HR ratio [(SBP – DBP) divided by heart rate].

Even after extensive research of literature, we could not find published normal physiological limits of PP/HR ratio. But review of literature revealed that a value > 0.44 has been useful in predicting massive blood loss in trauma patients. So, a cut-off of 0.44 has been used in our study.^{5,10}

Massive blood transfusion

MBT has many definitions as per medical literature. We have adopted the commonly used and the practically viable definition of MBT.¹³

1. Transfusion of ≥ 10 units of packed red blood cells (PRBCs) in the first 24 h of patient admission.
2. Transfusion of ≥ 4 PRBCs in the first 4 h of hospital admission.

Statistical analysis

The obtained study data are analyzed using Windows EXCEL and XLSTAT plug-in. Descriptive analysis includes frequencies for categorical variables and mean $\pm$ standard deviation for continuous variables. To assess the accuracy of SI, MSI, and PP/HR ratio in detecting MTP, a receiver operating characteristic curve analysis is done using the Bamber variance approach. The area under the receiver operating characteristic curve (AUROC) for the three variables was compared using the DeLong method.¹⁴ A two-curve representation is provided to illustrate the sensitivity and specificity of the study parameters.

Results

From 1st January to 31st December of 2016, a total of 326 patients were admitted in the trauma center with warfare injuries. After careful evaluation of the trauma register and application of criteria for inclusion and exclusion, a total of 254 patients were enrolled. The casualties mainly comprised of gunshot wounds, mine blasts, and shrapnel injury due to grenade blasts.

Patient characteristics

All the patients included were young healthy males with no previous comorbidities within the age group of 21–58 years (32.7 ± 7.42 yrs). Of the 254 patients, 131 (51.57%) patients were admitted due to gunshot wounds, 29 (11.42%) were admitted with mine blasts, and 63 (24.81%) had splinter injuries as the mode of injury. MT was initiated in 51 patients (22.8%) as per Advanced Trauma Life Support guidelines and clinical requirements.

Study parameters

Shock Index, MSI, and PP/HR ratio proved to be statistically significant in predicting MT ($p < 0.0001$, confidence interval [CI] = 95%). The PP/HR ratio found to be highly predictable with a value of 0.517 ± 0.156 ($p < 0.001$, CI = 95%).

The AUROCs were 0.798 (95% CI, 0.739–0.848) for SI, 0.787 (95% CI, 0.728–0.839) for MSI, and 0.744 (95% CI, 0.681–0.800) for PP/HR ratio ($p < 0.001$) (Fig. 1 and Table 1).

All the patients enrolled into the study were followed up for the next 7 days for complications of MTs. No patient reported any complications attributable to MT.

72 trauma cases have been excluded from the study of which 26 patients were referred to higher centers for emergency super-specialty interventions, on-field data of 41 patients were unavailable, and five patients succumbed to their injuries enroute to our trauma center and could not be revived even after extensive resuscitative efforts.

Discussion

In the retrospective analysis of the data available in our hospital trauma register, it was found that all the study

Fig. 1 – Comparison of AUROC of SI, MSI, and PP/HR ratio in their predictability of MTP. AUROC, area under the ROC curve (SI, shock index, MSI, modified shock index; PP/HR, pulse pressure heart rate ratio).

parameters SI, MSI, and PP/HR ratio could be useful in predicting the need for MBT. SI (AUROC = 0.798) and MSI (0.787) had equal predictability of MBT, and the PP/HR ratio (0.744) had a slightly lower predictability. Generally, an AUROC value of 0.7 is accepted as a lower cut-off margin for potentially useful clinical predictability.¹⁵

Other predictive scores of MTs (Trauma Associated Severe Hemorrhage and Assessment of Blood Consumption) were previously described to have an AUROC value of 0.85–0.89.^{16,17} These scores used laboratory and radiological parameters along with clinical parameters. In spite of the study parameters being only based on easily attainable vital and clinical parameters in field conditions, they have shown comparable efficacy in predicting the MT requirement. Hence, in the process saving valuable time in resuscitation of these critically injured warfare casualties.

Vogt et al., in 2012, have found that early activation of MT protocol in resuscitation has found to have a double benefit of improved patient outcome as well as limit the usage of blood

Table 1 – AUROC evaluation of study parameters.

Variable	AUC	SE ^a	95% CI ^b
SI	0.798	0.0397	0.739–0.848
MSI	0.787	0.0394	0.728–0.839
PP/HR	0.744	0.0411	0.681–0.800

AUROC, area under the ROC curve; AUC, area under the curve; SE, standard error; CI, confidence interval; SI, shock index, MSI, modified shock index; PP/HR, pulse pressure heart rate ratio.

^a DeLong et al., 1988.

^b Binomial exact.

components and hence decreasing the complications associated.¹⁸

The SI has proved to be a robust marker of ongoing hemorrhage, the need for MTs and is easily available in almost every setting. Vandromme et al. has found SI to be important clinical marker in a prehospital setting but will need further evaluation before incorporating into clinical practice.¹² Sohn et al. also demonstrated SI to be a powerful tool in predicting MT requirement in obstetric patients with severe postpartum hemorrhage.¹⁹ Our study has found that SI could be a predictor for identifying patients requiring MT.

Major studies have been done by using SBP as a part of the scoring systems in predicting outcomes in critically ill patients. However, Liu et al. in their retrospective study have found that using MAP which incorporates both SBP and DBP could result in better predictability of the severity of critically ill patients.⁹ As MAP can best represent tissue perfusion scores using it could have a better predictability at least theoretically. Singh et al. also confirmed the predictability of MSI in outcomes in adult trauma patients and found it to be at par with other predictive scoring systems.⁶ Our study also found that MSI is at par with SI in predicting MTs in warfare injuries. MSI needs MAP which can be calculated by using SBP and DBP which can sometimes be cumbersome during emergency resuscitation. But with the advent of newer hemodynamic monitors which readily display MAP calculating MSI has become much easier and can be used as an adjunct in predicting MTs in field conditions.

Theoretically speaking the PP/HR ratio should be able to better predict blood loss due to the combined influence of stroke volume and arterial stiffness as proved by Chemla et al.²⁰ The results of our study suggest that PP/HR ratio is equally effective as SI and MSI in predicting MT.

The study is limited by the patient profile as we could enroll only healthy individuals with no prior comorbidities and hence the reliability of these scoring systems in patients with prevalent disorders like hypertension, diabetes, etc need to be further studied. The study could not compare the scoring systems against any standardized and accepted scoring systems and hence future studies could be directed towards it.

Conclusions

Simply attainable SI, MSI, and PP/HR ratios can be used in the field setting with hemodynamic variables to predict the severity of ongoing hemorrhage and the need for MTs. All the three scoring systems have equal statistical efficacy in clinical practice. These can be used for better communication between healthcare personnel and early activation of MT protocol in a tertiary care center and in the process, save lives and reduce morbidity in warfare casualties.

Conflicts of interest

The authors have none to declare.

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