ORIGINAL ARTICLE

Evaluation of peripheral perfusion index in predicting blood product need for trauma patients

Ertuğ Dinçer,[1] Ayhan Aköz,[2] Ali Duman,[2] Yunus Emre Özlüer,[2] Ahmet Melih Savaş,[2] Onur Cem Büyüktaş[2]

[1]Department of Emergency Medicine, Bilecik Training and Research Hospital, Bilecik-*Türkiye*

[2]Department of Emergency Medicine, Aydın Adnan Menderes University Faculty of Medicine, Aydın-*Türkiye*

ABSTRACT

BACKGROUND: Early detection of hemorrhagic shock and the need for blood product replacement in trauma patients is crucial. The present study aimed to evaluate the effectiveness of peripheral perfusion index (PPI) measurements in determining the severity of hemorrhagic shock and predicting the need for blood product replacement in trauma patients.

METHODS: A total of 43 patients who presented to the emergency department due to trauma and were diagnosed with hemorrhagic shock according to the Advanced Trauma Life Support (ATLS) guidelines were included in this prospective cross-sectional study. Demographic characteristics, vital signs, laboratory parameters, PPI values, ATLS shock classification, and blood product replacement status were evaluated.

RESULTS: The median age of the patients was 35 years (range: 18-94), and 12 (27.9%) were female. The median PPI value was 1.30 (range: 0.15-10.00), and 23 (53.5%) patients received blood product replacement. PPI values were found to be statistically significantly lower in patients who received blood product replacement compared to those who did not. The PPI values of ATLS Class I patients were statistically significantly higher than those of ATLS Class III and IV patients. Among patients in the Class II shock group, the PPI value was 0.75 (range: 0.30-4.70) in patients who received blood product replacement and 2.20 (range: 1.10-10.00) in those who did not, indicating a statistically significant difference between the groups. According to the receiver operating characteristic curve analysis performed to determine the effectiveness of PPI measurement in predicting the need for blood product replacement in Class II shock patients, the cut-off value was 1.2.

CONCLUSION: The findings of this study demonstrated that PPI values were lower in patients who required blood product replacement due to traumatic shock compared to those who did not. These results suggest that PPI measurements may serve as an effective assessment method for predicting the need for blood product replacement, particularly in patients in the Class II shock group according to the ATLS shock classification.

Keywords: Trauma; hemorrhagic shock; peripheral perfusion index.

INTRODUCTION

Hemorrhagic shock remains the most common cause of trauma-related deaths. In trauma patients, bleeding is the most common preventable cause of death when promptly identified and treated.[1] Therefore, early detection of bleeding in trauma patients is of vital importance.

Scoring systems utilizing clinical and laboratory findings have been developed for the early detection of shock and the determination of its severity. The Advanced Trauma Life Support (ATLS) shock classification is the most commonly used scoring

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Address for correspondence: Ertuğ Dinçer

Department of Emergency Medicine, Bilecik Training and Research Hospital, Bilecik, Türkiye

E-mail: ertugdincer@gmail.com

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system. According to the ATLS approach, hemorrhagic shock is classified into four classes based on clinical signs to estimate the percentage of acute blood loss. Clinical signs predict ongoing bleeding and only guide initial treatment.[2] Studies have shown that the ATLS approach to hemorrhagic shock reduces treatment errors that could result in preventable deaths and decreases trauma-related mortality.[3] Since the initial treatment is determined based on the stage of shock the patient is in, accurate determination of the patient's current shock stage is vital. Therefore, developing additional measurements or parameters alongside those used in the ATLS shock classifications may be beneficial in accurately predicting the shock stage. Peripheral perfusion index (PPI) measurements could serve as a complementary assessment method to these parameters.

PPI is a non-invasive parameter obtained using a pulse oximeter, allowing for the evaluation of tissue perfusion at the measurement site. The measurement value reflects the ratio of pulsatile to non-pulsatile blood flow. A PPI value below 1.4, particularly in critically ill patients, indicates impaired peripheral perfusion.[4] In trauma patients, PPI values may fluctuate due to vasoactive changes in peripheral regions, offering insights into the presence and severity of hemorrhagic shock.[5]

In the present study, we aimed to assess the effectiveness of PPI measurements in determining the severity of hemorrhagic shock in trauma patients and predicting the need for blood product replacement. We also aimed to examine the distribution of PPI values according to ATLS shock classes.

MATERIALS AND METHODS

Study Design

This research was designed as a prospective cross-sectional study. The study was conducted with the approval of the Scientific Research Evaluation and Ethics Committee of Aydın Adnan Menderes University Faculty of Medicine (Approval Number: 2020/153, Date: 06.08.2020). Informed consent was obtained from all patients prior to the procedure. All procedures were conducted in accordance with ethical guidelines and the principles of the Declaration of Helsinki.

The study included patients who presented to the emergency department due to trauma and were diagnosed with hemorrhagic shock according to the ATLS guidelines. Patients aged 18 years or older, who were not pregnant, had no chronic illnesses, and were not using long-term medication were included in the study.

Prior to the study, the minimum sample size was calculated as 38 patients based on the study by Özakın et al.[6] Accordingly, a total of 43 patients diagnosed with hemorrhagic shock were included in the study. The diagnosis and severity of hemorrhagic shock were determined using the definitions and classification provided in the 2018 ATLS guidelines[2]

Table 1. Distribution of gender, type of trauma, injured body parts, vital signs, laboratory data, and peripheral perfusion index (PPI) values of the patients

Gender	**n (%)**
Female	12 (27.9%)
Male	31 (72.1%)
Mechanism of Trauma	**n (%)**
Motor Vehicle Accidents	21 (48.8%)
Falling from Height	11 (25.6%)
Sharp Object Injury	6 (14.0%)
Firearm Injury	3 (7.0%)
Pedestrian-Involved Collisions	1 (2.3%)
Fight-Related Injury	1 (2.3%)
Vital Signs	**Mean±SD/Median (Min-Max)**
Systolic Blood Pressure (mmHg)	119.0±22.5
Diastolic Blood Pressure (mmHg)	72.7±17.4
Pulse Rate (/min)	98.3±21.3
Pulse Pressure (mmHg)	48.5±16.9
Respiratory Rate (/min)	18 (12-35)
Oxygen Saturation (%)	97 (85-100)
Body Temperature (°C)	36.3 (35.0-37.6)
Glasgow Coma Scale	15 (3-15)
Peripheral Perfusion Index (PPI)	1.30 (0.15-10.00)
Laboratory Parameters	**Mean±SD/Median (Min-Max)**
Hemoglobin (g/dL)	13.2±2.5
Hematocrit (%)	39.8 (18.2-49.5)
pH	7.34±0.08
Lactate (mmol/L)	3.1 (0.7-9.9)
Base Deficit (mmol/L)	-3.1±3.9
Ionized Calcium (mmol/L)	1.13 (0.68-1.25)
Prothrombin Time (sec)	11.9 (10.5-20.8)
International Normalized Ratio	0.98 (0.79-1.79)
Activated Partial Thromboplastin Time (sec)	22.3 (10.5-41.5)
Advanced Trauma Life Support Shock Classes	**n (%)**
Class I	10 (23.3%)
Class II	21 (48.8%)
Class III	9 (20.9%)
Class IV	3 (7.0%)
Blood Product Replacement	n (%)
Yes	23 (53.5%)
No	20 (46.5%)

Table 2. Distribution of Advanced Trauma Life Support shock classes and peripheral perfusion index (PPI) values according to blood product replacement status

	Blood Product Replacement Needed	No Blood Product Replacement	p value
Class I	0 (0.0%)	10 (100.0%)	0.000*
Class II	10 (47.6%)	11 (52.4%)	
Class III	9 (100.0%)	0 (0.0%)	
Class IV	3 (100.0%)	0 (0.0%)	
PPI	0.70 (0.15-4.70)	2.20 (1.00-10.00)	0.000 †

*p value based on Chi-Square test. †p value based on Mann-Whitney U test.

During the first 5 minutes of patients' admission to the emergency department, physiological variables including heart rate, systolic blood pressure, diastolic blood pressure, mean arterial pressure, pulse pressure, oxygen saturation, PPI, and body temperature were recorded. Additionally, demographic characteristics such as age, gender, mechanism of injury, and laboratory results including hemoglobin, hematocrit, lactate, base deficit, ionized calcium, prothrombin time, international normalized ratio, and activated partial thromboplastin time were documented in the case files. The ATLS shock stage of each patient was identified and recorded. Finally, blood product replacement status within the first 24 hours was recorded in the case files.

PPI measurements of the patients included in the study were performed using the Masimo Radical-7® Pulse CO-Oximeter® (Masimo, Irvine, CA, USA) device by holding both index fingers at heart level for approximately 30 seconds at room temperature. PPI measurements were conducted concurrently with the assessment of vital signs within the first 5 minutes of the patient's arrival at the emergency department.

Statistical Analysis

Research data were analyzed using IBM SPSS Statistics for Windows, version 25.0. (IBM Corp., Armonk, NY, USA, released 2011) and Jamovi for Windows version 1.6.13. Descriptive statistics were presented as numbers and percentages for categorical variables. The normality of quantitative variables was assessed using the Shapiro-Wilk test. Normally distributed variables were expressed as mean ± standard deviation, while non-normally distributed variables were expressed as median and minimum-maximum values (min-max). The Chi-Square test was used to compare categorical variables between groups. The Mann-Whitney U and Kruskal-Wallis tests were used to compare non-normally distributed continuous variables between independent groups. PPI measurements were subjected to receiver operating characteristic (ROC) curve analysis to determine a cut-off value for predicting the need for blood product replacement, and sensitivity, specificity, positive predictive value, negative predictive value, and positive and negative likelihood ratios were calculated. A p value of <0.05 was considered statistically significant for all analyses.

RESULTS

The median age of the 43 patients included in the study was 35 years (range: 18-94), and 12 patients (27.9%) were female. Table 1 summarizes the gender, type of trauma, vital signs, laboratory data, PPI values, ATLS shock classification, and blood product replacement status of the patients.

Table 2 shows the distribution of ATLS shock classes and PPI values according to the blood product replacement status of the patients. Statistically significant differences were found regarding the need for blood product replacement in all group comparisons, except between Class II vs. Class IV and Class III vs. Class IV (p<0.05).

PPI values of the patients according to ATLS shock classes are summarized in Table 3. Significant differences in PPI values were observed among the groups (p<0.05). Subgroup analysis revealed statistically significant differences between the PPI values of Class I patients and those of Class III and IV patients (p<0.05).

Among Class II patients, the PPI was 0.75 (range: 0.30-4.70)

Table 3. Distribution of peripheral perfusion index (PPI) values according to Advanced Trauma Life Support shock classes

	PPI Median (Min-Max)	p value
Class I	2.25 (1.00-9.10)	0.005*
Class II	2.00 (0.30-10.00)	
Class III	0.80 (0.20-1.50)	
Class IV	0.50 (0.15-0.70)	

*p value based on Kruskal-Wallis Test.

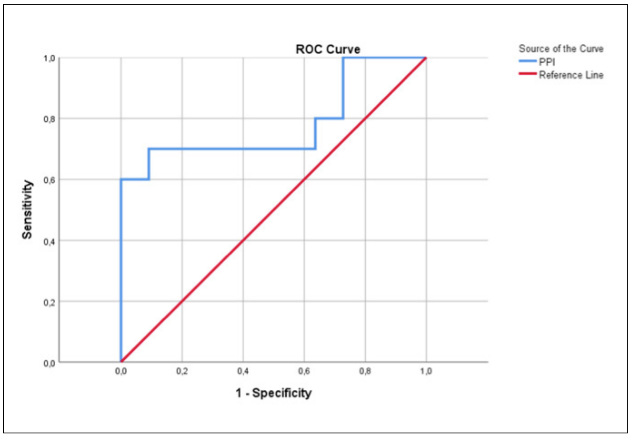

Figure 1. Receiver operating characteristic curve of peripheral perfusion index (PPI) measurement with a cut-off value of 1.2 for predicting the need for blood product replacement in patients with Class II shock.

Table 4. Diagnostic test parameters of peripheral perfusion index measurement with a cut-off value of 1.2 for predicting the need for blood product replacement in Class II patients

		95% Confidence Interval
Sensitivity	70.00%	34.75%-93.33%
Specificity	90.91%	58.72%-99.77%
Positive Likelihood Ratio	7.7	1.14-52.12
Negative Likelihood Ratio	0.33	0.13-0.87
Positive Predictive Value	87.5%	50.84%-97.93%
Negative Predictive Value	76.92%	55.95%-89.74%
Accuracy	80.95%	58.09%-94.55%
AUC	0.782	0.565-0.998

AUC: Area under the curve.

in those who received blood product replacement and 2.20 (range: 1.10-10.00) in those who did not, with a statistically significant difference between the groups ($p<0.05$). The relationship between PPI values and the need for blood product replacement could not be evaluated for other shock classes due to the absence of patients in at least one of the comparison groups.

According to the ROC analysis performed to determine the predictive value of PPI measurement for the need for blood product replacement in Class II shock patients, the cut-off value was identified as 1.2. The ROC curve of PPI measurement with a cut-off value of 1.2 for predicting the need for blood product replacement in Class II patients is presented in Figure 1, and the diagnostic test parameters are provided in Table 4.

DISCUSSION

The main finding of the present study was that PPI values were lower in trauma patients requiring blood product replacement due to traumatic shock compared to those who did not require blood product replacement. These results suggest that PPI measurements may serve as an effective assessment tool for predicting the need for blood product replacement, particularly in patients classified as Class II shock according to the ATLS shock classification.

Hemorrhagic shock is characterized by decreased tissue perfusion, cellular hypoxia, organ damage, and significant blood loss. Early diagnosis of shock, along with prompt intravenous fluid resuscitation and blood transfusion, can significantly improve patient outcomes.[7] Therefore, early detection of hemodynamic instability in trauma patients is critical. PPI measurements, which can be obtained rapidly, may aid in the early identification of hemorrhagic shock.

A review of the literature reveals that PPI values have been utilized for various purposes. Studies conducted in trauma patients have reported that low PPI values are associated with an increased need for blood product replacement and higher mortality rates.[6,8] Other studies have also emphasized that low PPI values are indicative of impaired hemodynamics and perfusion abnormalities in patients presenting with critical illness and poisoning.[9-11] Consistent with the literature, the present study also found that patients with more severe hemorrhagic shock who required blood product replacement had lower PPI values.

The ATLS guidelines continue to be widely used for the assessment and management of patients with traumatic hemorrhagic shock.[12,13] However, in recent years, several studies have raised questions regarding the adequacy of this classification system. In a study conducted by Guly et al.,[14] an association was found between clinical parameters such as blood pressure, heart rate, respiratory rate, and Glasgow Coma Scale, but the same level of association was not observed with the ATLS shock classification. Similarly, in a study conducted by Mutschler et al.[15] in 2014, it was reported that the ATLS shock classification may be insufficient for accurately assessing trauma patients with hemorrhagic shock. The authors suggested that a new classification system based on base deficit might provide a more accurate assessment. Subsequently, base deficit has been incorporated into the parameters evaluated in ATLS shock classification guidelines.[2] In a study by Parks et al.,[16] it was found that as the severity of ATLS hemorrhagic shock class increased, mortality, emergency transfusion rates, and emergency procedure rates also increased. However, it was also observed that nearly half of all trauma patients did not meet the criteria for any shock category under the ATLS classification system. Additional measurements or parameters developed alongside those used in the ATLS shock classifications may be beneficial in accurately predicting the stage of shock.

According to the recommendations of the ATLS guidelines, blood product replacement is typically not required in Class I shock patients, while early blood product transfusion is strongly emphasized for patients in Class III and IV. It is noted that Class II patients may initially be stabilized with crystalloid solutions but may later require blood product transfusion.[2] Predicting the need for early blood product replacement in Class II patients can enable more accurate planning of follow-up and treatment strategies for this patient group. The results of the present study demonstrate that PPI measurements with a cut-off value of 1.2 can be used to predict the need for blood product replacement in Class II hemorrhagic shock patients.

Limitations

In the present study, prehospital fluid treatments were not taken into account. In trauma patients, fluid therapy is often initiated by prehospital personnel, particularly when signs of shock are present. This may have influenced the PPI measurement values.

CONCLUSION

In Class II hemorrhagic shock patients, as classified by the ATLS guidelines, PPI measurements, easily and rapidly obtained through a non-invasive method, may be useful in early identification of the need for blood product replacement. Particularly at values below 1.2, PPI may support timely intervention in hemorrhagic shock.

PPI measurements can be used in combination with other vital signs and laboratory parameters for the early detection of hemorrhagic shock. They may also be valuable in predicting the need for blood product replacement, particularly when low values are observed. Assessing PPI values alongside the parameters included in the ATLS shock classification may enable a more accurate determination of the patient's shock class.

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Ethics Committee Approval: This study was approved by the Scientific Research Evaluation and Ethics Committee of Aydın Adnan Menderes University Faculty of Medicine Ethics Committee (Date: 06.08.2020, Decision No: 2020/153).

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Conflict of Interest: None declared.

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ORİJİNAL ÇALIŞMA - *ÖZ*

Travma hastalarında kan ürünü ihtiyacını öngörmede periferik perfüzyon indeksinin değerlendirilmesi

AMAÇ: Travma hastalarında hemorajik şok varlığı ve kan ürünü replasmanı ihtiyacının erken tespiti hayati önem taşımaktadır. Çalışmamızda, periferik perfüzyon indeksi (PPI) ölçümlerinin, travma hastalarında hemorajik şok şiddetinin belirlenmesinde ve kan ürünü replasmanı ihtiyacının öngörülmesindeki başarısını değerlendirmeyi amaçladık.

GEREÇ VE YÖNTEM: Prospektif kesitsel nitelikte olan çalışmamızda acil servise travma nedeniyle başvurmuş, travma sonrasında Advanced Trauma Life Support (ATLS) kılavuzuna göre hemorajik şok tanısı konulan 43 hasta dahil edildi. Hastaların demografik bilgileri, vital parametreleri, laboratuvar değerleri, PPI değerleri, ATLS şok evreleri, kan ürünü replasmanı yapılma durumları değerlendirildi.

BULGULAR: Hastanın ortanca yaşı 35 (18-94) saptandı ve 12'si (%27.9) kadındı. PPI ortanca değeri 1.30 (0.15-10.00) saptandı, 23 (%53.5) hastaya kan ürünü replasmanı yapıldığı tespit edildi. Kan ürünü replasmanı yapılan hastalarda, yapılmayan hastalara göre PPI değerleri istatistiksel olarak anlamlı şekilde daha düşük bulundu. Evre I şoktaki hasta grubunun PPI değerlerinin evre III ve IV şoktaki hastaların PPI değerlerine göre istatistiksel olarak anlamlı şekilde daha yüksek seyrettiği tespit edildi. Evre II şok grubundaki hastaların, kan ürünü replasmanı yapılması durumları ve PPI değerleri incelendiğinde, kan ürünü replasmanı yapılan grupta PPI değeri 0.75 (0.30-4.70), yapılmayan grupta PPI değeri 2.20 (1.10-10.00) saptandı ve gruplar arasında istatistiksel olarak anlamlı fark bulundu. Evre II şok grubundaki hastalarda PPI ölçümünün kan ürünü replasmanı ihtiyacını tahmin etmedeki gücünün belirlenmesi amacıyla yapılan ROC analizine göre kestirim değeri (cut-off) 1.2 saptandı.

SONUÇ: Çalışmamız sonucunda PPI değerlerinin travmatik şok nedeniyle kan ürünü replasmanı ihtiyacı bulunan hastalarda, kan ürünü replasmanı ihtiyacı bulunmayan hastalara göre daha düşük seyrettiğini saptadık. Özellikle ATLS şok sınıflamasına göre evre II şok grubunda bulunan hastalarda, PPI ölçümlerinin kan ürünü replasmanı ihtiyacını öngörmede güçlü bir değerlendirme yöntemi olabileceğini belirledik.

Anahtar sözcükler: Travma; hemorajik şok; periferik perfüzyon indeksi.

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