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Association between peripheral perfusion index and five vital signs in patients admitted to the emergency department

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Abstract

Aim: Mental status, skin temperature and color, urine output, mean arterial pressure, lactate levels, and capillary refill time are widely used in the evaluation of peripheral perfusion. However, reliable, simple, and objective tests are needed. The peripheral perfusion index (PI), derived from the pulse oximeter signal, has been lately suggested for providing fast, continuous, bedside, and affordable clinical data. This study aimed to investigate the association between the perfusion index and five vital parameters in a large emergency medicine patient population.

Material and Methods: A single-center, prospective, cross-sectional study was carried out on 2330 adult patients who were admitted to the emergency department during five consecutive days. Patients who required emergency operation and cardiopulmonary resuscitation, and were unable to communicate with were excluded from the study. PI was measured at the 4th finger of the non-dominant hand by using Masimo RDS-7 pulse oximeter. Simultaneously, vital signs were taken.

Results: The mean PI, independent of diagnosis and the severity of a disease, was calculated as 3.71±2,83. The mean PI was found to be significantly higher in males than females, respectively 4,03±3,04 and 3,36±2,56 ($p<0.001$). A significant difference in the mean PI levels was detected across four age groups. PI was positively correlated with SBP, DBP, and MAP. Moreover, it correlated negatively with heart rate and body temperature ($p<0,001$). The correlation between the PI and respiratory rate and oxygen saturation was not statistically significant.

Discussion: Even though PI cannot replace clinical assessment in assessing peripheral perfusion, it has great potential to be a useful tool in recognizing poor peripheral perfusion at the triage level and lead to improved outcomes of emergency department patients.

Keywords

Perfusion Index, Emergency Medicine, Vital Signs, Blood Pressure, Peripheral Perfusion

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Introduction

Sufficient tissue perfusion and oxygenation are vital for the continuity of metabolic processes in cells, healing process, and resistance to infections [1]. It is well known that the early recognition of tissue hypoxia with adequate oxygen supply can decrease mortality and morbidity in critical patients [2].

In the clinical assessment of peripheral tissue perfusion, many subjective parameters can be used such as mental status, skin temperature and color, urine output, pulse volume, mean arterial pressure, and capillary refill time [3]. However, these parameters may be seen as normal at the early stages of a shock [3]. Tissue oxygen status can be directly monitored by invasive electrodes or non-invasively using light absorbance (pulse oximetry (SpO2)). Pulse oximetry may be more useful in emergency medicine practice compared to invasive perfusion measurement methods in terms of the ability to provide fast, continuous, real-time, bedside, and inexpensive data.

Perfusion Index (PI) is the ratio of the pulsatile blood flow to non-pulsatile static blood flow in peripheral tissue that is measured by a pulse oximeter. PI is calculated by dividing the pulsatile signal (during arterial inflow) by the non-pulsatile signal, both of which are derived from the amount of infrared (940 nm) light absorbed, times 100 (available at: https://www.masimo.co.uk/siteassets/uk/documents/pdf/clinical-evidence/whitepapers/lab3410f_whitepapers_perfusion_index.pdf). It is expressed as a percentage ranging from 0.02% (very weak pulse strength) to 20% (very strong pulse strength) [4].

PI= (Pulsatile infrared light signals / Non-pulsatile infrared light signals) x100

The objective of this study to assess the variation of PFI in adult emergency patients and its relationship between 5 vital parameters including blood pressure, heart rate, respiratory rate, body temperature, and oxygen saturation.

Material and Methods

The present study was designed as a single-center, prospective, and cross-sectional study. It was conducted with adult patients who were admitted to the Emergency Medicine department of Istanbul Research and Training Hospital for five consecutive days, after obtaining approval from the research ethics committee of the hospital. Patients with cardiac arrest during the initial admission, requiring emergency surgery, and unable to communicate with were excluded from the study.

All PI measurements were performed within 5 minutes of admission to the emergency department at the triage area except for patients with red triage tags or brought by an ambulance. Patients with red triage tags or brought in by an ambulance were enrolled in the study at the bedside. After getting written informed consent for participation in the study from patients or their next-of-kin, hemodynamic monitoring included systolic blood pressure (SBP), diastolic blood pressure (DBP) mean arterial pressure (MAP), heart rate (HR), respiratory rate (RR), body temperature and oxygen saturation (SpO2) were done using Carescape V100 Vital Signs Monitor by General Electric by the nurses who trained for the study. Simultaneously, PI was monitored for over 60 seconds at the 4th finger of the non-dominant hand by using Masimo RDS7 pulse oximeter (Massimo Corp, Irvine, CA) [Figure 1]. The PI level was calculated as the average of the value measured at 15 seconds, 30 seconds, 45 seconds, and 60 seconds.

Statistical Analysis:

Statistical data analysis was performed with SPSS Statistics software version 25.0. Categorical variables were expressed as percentages and numerical values were expressed as mean, median, standard deviation, minimum and maximum. Comparisons between the two independent groups were made using the Mann-Whitney U test, since the numerical variables did not meet the normal distribution condition. Relationships between numerical variables were examined by Spearman's correlation analysis, since parameter test conditions were not met. The factors determining the numerical variable were examined using the Linear Regression Analysis Backward method. The statistical significance level sought was $p < 0.05$.

Results

Study Population

Recruitment and Enrollment

Daily emergency visits ranged between 500 and 600 patients per day, and a total of 2,880 patients were admitted to the emergency department during the entire study period. Among them, 244 patients did not meet the inclusion criteria. One hundred forty-two patients were excluded from the study due to missing clinical data such as RR, SpO2, or body temperature. One hundred seventy patients were excluded for lack of written consent. Finally, 2330 patients who were screened, confirmed eligible, agreed to participate, and completed in-person consent were studied (Figure 2).

Baseline characteristics

This study involved 1236 female (53%) and 1094 male (47%) patients with a wide variety of complaints, disorders, and diseases. Participants' ages ranged from 18 years to 101 years. The mean age was 43.1(±17,83) years.

Peripheral Perfusion Index and Hemodynamic Data

Our study was designed to cover every single patient who admitted to our emergency department, regardless of diagnosis and severity of diseases. Since our subjects had a variety of complaints, diseases and disorders, our hemodynamics data exhibited a wide distribution [Table 1]. For example, our subjects' SBP ranged between 49 mmHg to 258 mmHg. Similarly, HR ranged between 36 bpm to 207.

The mean PI of 2330 study subjects was identified as 3,71±2,83 (Table1). The mean PI of female patients was 3,36±2,56 and of male subjects was 4,03±3,04. The PI value was found to be significantly higher in male subjects ($p<0.001$). The patients were also divided into four age groups as follows; Group 1: 18-44 years old (58%), Group 2: 45-64 years old (27%), Group 3: 65-84 years old (13.5%), and Group 4: 85 years old and older (1.5%). The mean PI was 3,46±2,73 in Group 1, 4,22±3 in Groups 2, 3,83±2,85 in Group 3, and 3,02±1,79 in Group 4. A significant difference between age groups was detected ($p<0.0001$).

Our findings revealed that PI was positively correlated with SBP, DBP, and MAP ($p<0.001$) and negatively correlated with body temperature and heart rate ($p<0.001$). In addition, no correlation was detected with RR and SpO2 (p=0,368 p=0,348) (Table2).

According to multivariable linear regression analysis DBP MAP, HR, and body temperature are the most important parameters in terms of affecting PI.

Table 1. PI and Hemodynamic Data

	Mean ± SD (min-max)
SBP	127,48±23,18 (49-258)
DBP	71,03±12,41 (30-150)
MAP	89,83±14,32 (37,67-180)
HR	89,35±16,66 (36-207)
RR	17,01±2,90 (10-40)
Temperature	36,45±0,75 (34-41)
SpO2	97,08±3,44 (55-100)
PI	3,71±2,83 (0.1-20)

SBP: Systolic blood pressure, DBP: Diastolic blood pressure, MAP: Mean arterial pressure, HR: Heart rate, RR: Respiratory rate, SpO2: Oxygen saturation, PI: Perfusion index.

Table 2. The relationship between PI with age and vital parameters

	PI	
	Rho	P
SBP	0.098	<0,001
DBP	0.064	0.002
MAP	0.092	<0,001
HR	-0.168	<0,001
RR	0.019	0.368
Temperature	-0.081	<0,001
SpO2	-0.019	0.348

SBP: Systolic blood pressure, DBP: Diastolic blood pressure, MAP: Mean arterial pressure, HR: Heart rate, RR: Respiratory rate, SpO2: Oxygen saturation, PI: Perfusion index.

Figure 1. An example of vital signs and PI assessment at the triage. Blue arrow Carescape V100 Vital Signs Monitor's pulse oximetry. Red arrow Masimo SET pulse oximetry.

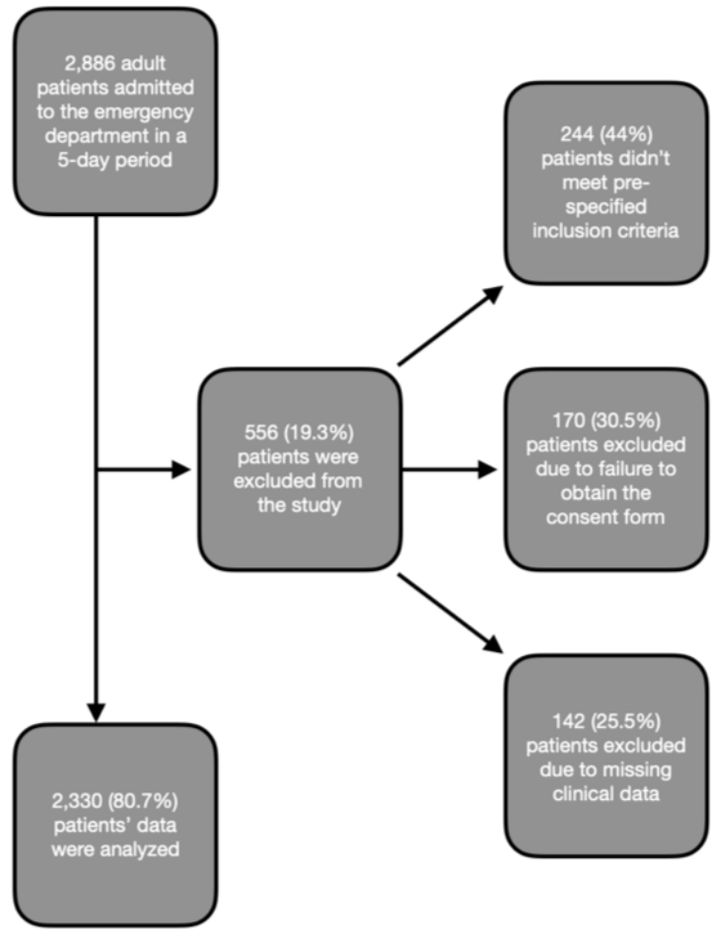

Figure 2. Patient inclusion flowchart detailing the inclusion and exclusion criteria.

Discussion

Rapid identification of critical patients and recognizing shock early, even before it occurs, are associated with improved outcomes in emergency departments. Traditional vital signs are poor indicators of shock, especially in the geriatric population [5]. During the early stages of uncomplicated shock, blood pressure may be normal, because hypotension occurs once the compensatory mechanisms are overwhelmed. In order to recognize compromised peripheral perfusion early, clinicians should assess the perfusion of less vital organs such as skin and subcutaneous tissue. Clinical features of circulatory failure involve decreased urinary output, confusion, sluggish capillary return, widen central-to-toe temperature difference, lactatemia, tachypnea, and cold, pale, clammy, and mottled skin. However, these findings can be normal in the early stages of shock [3]. Besides, assessing them consumes time and requires a clinical experience. Therefore, simple and objective tests are needed to assess peripheral perfusion. Lately, the pulse oximetry signal has been suggested to assess peripheral perfusion for non-invasiveness, continuity, speed, availability, and ease of use without the need for advanced skills. However, studies indicating variances based on age, gender, and specific patient groups are still limited.

We studied the variation of PI in a large population of adult emergency patients and its relationship between five vital parameters including SBP, DBP, MAP, HR, RR, SpO2, and body

temperature. In simple terms, PI is the strength of the peripheral pulse. It is measured by the ratio of pulsatile and non-pulsatile components of the blood flow at the sensor site [4]. Lima et all reported normal values in adults range from 0.3 to 10.0% with a median of 1.4% [6]. Several studies have used 1.4 as a cut-off point in identifying abnormal peripheral perfusion.

Although there is a limited number of studies in the previous literature reporting the mean PI values of emergency patients, reference PI values based on ages, gender, and specific patient groups have not yet been evaluated. From this perspective, the current study reporting the mean PI value of a significant number of adult emergency patients, adds great value to the medical literature. Previously, Yeniocak et al. reported the mean PI of patients with synthetic cannabinoid use as 3.16 ± 3.26 [7], Ozakin et al. reported PI levels of adult multi-trauma patients as 4.1 ± 2.2 [8], and Acar N. et al. reported PI levels of critically ill patients who need blood glucose check as 4.56±3.59 [9]. Our subject's PI values ranged from 0.1% to 20%. The mean PI value, independent from diagnosis and the severity of a disease, was reported as 3,71±2,83.

Our results revealed that there was a statistically significant difference in the PI levels between female (3,36±2,56) and male (4,03±3,04) emergency patients. PI was found to be higher in male subjects ($p<0.001$). In agreement with the current study, in a study investigating the age-related and sex-related changes in perfusion index in response to pain, it was demonstrated that baseline PI values were significantly different between male and female groups, respectively 4.99±0.459 and 3.56±0.312 ($p<0.05$) [10]. Similarly, the study conducted with diabetic patients who have a high peripheral arterial occlusive disease risk revealed that PI was higher in men than in women ($p<0.0001$) [11].

In the present study, we detected a significant difference in the PI levels across four age groups ($p<0.0001$). After age 64, the mean PI decreased. We can attribute this decline to the increasing prevalence of chronic medical conditions such as peripheral arterial diseases or severe medical conditions such as septic shock in the elderly population. However, further research with large elderly population is needed in this area.

Another significant result we reached was that PI had a positive correlation with SBP, DBP, and MAP. Peripheral PI is mainly affected by cardiac output and peripheral resistance. It is well known that in a case of shock peripheral organ perfusion compromises simply due to decreased CO in hypovolemic, cardiogenic, and obstructive shock and decreased peripheral resistance in distributive shock [12]. Højlund J. et al. demonstrated that PI can immediately reflect changes in central hemodynamics with a high degree of correlation R=0.9, P<0.001 [13]. In our study, we found a positive correlation between PI and SBP, DBP, and MAP. Similarly, Ozakin and his colleagues reported a positive correlation between PI and SBP and DBP in emergency multi-trauma patients [14]. Sivaprasath P. et al. also reported a good correlation with pulse pressure and SBP [15]. However, further research involving cardiac output (CO) and invasive blood pressure monitoring should be done to confirm or refute the explanations and further refine the knowledge above.

On the other hand, there was a negative correlation between PI and heart rate. The cardiovascular system responds to circulatory failure by increasing the heart rate, increasing myocardial contractility, and constricting peripheral blood vessels [16]. Peripheral vasoconstriction mainly reduces the pulsatile component of the light that reaches the detector of pulse oximeter, hence decreases the PI [17]. In agreement with the present study, van Genderen ME et al. demonstrated a negative correlation between HR and PI in the study investigating changes in PI induced by changes in circulating volume. In that study, applying -60 mmHg lower body negative pressure increased the subjects' heart rate from 63 ±1.8 to 83 ±2.0, whereas decreased PI from 2.2 (1.6-3.3) to 1.3 (0.9-1.7) [18].

The relationship between body temperature and PI levels is quite controversial. In case of circulatory failure, organ blood flow will be shifted away from the skin, non-exercising skeletal muscles and splanchnic viscera in order to optimize CO and maintain adequate perfusion to coronary arteries, brain, and kidneys [19]. As a result, skin looks cold, pale, clammy, and mottled. Additionally, during advance stages of hypovolemic shock, spontaneous hypothermia can occur due to depleted energy stores [20] and is usually associated with worse outcomes [21]. Moreover, removing clothes, cold iv fluid and blood product administrations and the use of anesthetic agents contribute to hypothermia. Therefore, low body temperatures with low PI levels can be seen together in hypovolemic shock. On the other hand, septic shock is often accompanied by fever. High body temperature with low PI levels can be seen together in septic shock. In the current study, we detected a weak negative correlation between PI and body temperature. However, a great number of our subjects had normal body temperature. Studies involving a large number of hypothermia and hyperthermia patients are needed in this area.

Limitations

In the current study, we reported a significant difference in PI across age groups. Our results revealed that patients over 64 years old had lower PI levels. However, the age of our subjects did not show the homogeneous distribution and it created bias here. For example, we had 1355 patients in group 1, whereas there were only 34 patients in Group 4.

Another important limitation in this study is that a great number of our patients had normal body temperature. We had only 26 patients with hypothermia and 192 patients with hyperthermia. This dissimilarity could have led to negative results. A large-scale study including more patients with hypothermia and hyperthermia is needed to explore the relationship between PI and body temperature.

Lastly, there are several factors influencing PI such as emotional stress and pain. In the present study, these factors were ignored.

Conclusion

Monitoring of tissue perfusion is an essential step in the management of acute circulatory failure. In emergency situations, assessing capillary refill time and measuring central-to-toe temperature gradient are usually found time consuming. Recognizing the clinical signs of poor peripheral perfusion requires clinical experience. On the other hand, the PI derived from pulse oximeter has many advantages; it is fast, easy to operate, simple, inexpensive, and it provides a simple numerical

value. Even though PI cannot replace clinical assessment in recognizing poor tissue perfusion, we believe that PI has high potential to become a useful tool in triage and help clinicians to monitor tissue perfusion continuously, which may lead to improved outcomes in emergency patients. However, we need more studies done in a large patient population. Cut-off values for the geriatric population should be redefined.

Scientific Responsibility Statement
The authors declare that they are responsible for the article's scientific content including study design, data collection, analysis and interpretation, writing, some of the main line, or all of the preparation and scientific review of the contents and approval of the final version of the article.

Animal and human rights statement
All procedures performed in this study were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. No animal or human studies were carried out by the authors for this article.

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Conflict of interest
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