ORIGINAL ARTICLE

# Evaluation of perfusion index in pediatric trauma patients

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## ABSTRACT

**BACKGROUND:** The aim of this study is to investigate the effectiveness of perfusion index (PI) measured by non-invasive pulse oximetry in the evaluation of pediatric trauma patients and to show its correlation with pediatric trauma score (PTS).

**METHODS:** Patients hospitalized in the pediatric intensive care unit due to trauma were examined between March 2017 and March 2018. Characteristic variables of the patients, Pediatric Index of Mortality 2 score, Pediatric Logistic Organ Dysfunction score, PTS, type of trauma, number of systems affected by trauma, mechanical ventilation, transfusion, hemoglobin, lactate, PI at admission, length of ICU stay, and prognosis were recorded.

**RESULTS:** Ninety-one pediatric trauma patients were included in the study. The majority of the patients were male (64.8%), with a mean age of 99.47±71.27 months, the most common cause of trauma was an out of-vehicle traffic accident. There was a positive correlation between PI and PTS ($p<0.05$). In patients with PTS TS ≤8, the mean PI was 0.89, the standard deviation was 0.35; however, the mean PI was 1.77, the standard deviation was 0.95 in the group with PTS >8, and it was statistically significant ($p=0.000$).

**CONCLUSION:** PI can be used for non-invasive and rapid assessment of unstable patients separately or in combination with PTS in pediatric trauma patients.

**Keywords:** Pediatric trauma; pediatric trauma score; perfusion index.

## INTRODUCTION

Internal organ damage in trauma leads to more damage in pediatric patients compared to adults due to anatomical and physiological differences. The step-by-step evaluation process, such as the transfer of the patients to the medical institution and treatment in the medical institution, from the moment the event occurs, is a serious team work. Patients who are brought to the emergency department and in need of intensive care must be evaluated quickly, decisions should be made quickly, and the interventions should be performed effectively. Various scoring systems are used to determine the injury severity of the trauma patients and to predict mortality and morbidity. The Pediatric Index of Mortality 2 (PIM 2) scores and Pediatric Logistic Organ Dysfunction scores (PELOD) used in pediatric intensive care units (PICUs) are the main ones. The Pediatric Trauma Score (PTS) is the score for triage in trauma patients and for determining the trauma severity of the pediatric patients. A score ranging from −6 to +12 is calculated on certain parameters (Table 1). A score of PTS <8 indicates a potentially significant trauma and indicates that referral to the trauma center should be appropriate. PTS is a scoring system that is easy to calculate. It correlates with mortality rates.[1]

In addition to trauma scoring systems in children, objective data determined hemodynamically can provide information about the severity of trauma. Blood pressure, pulse, oxygen saturation, and urine output are the main ones. Perfusion index (PI) is a new non-invasive measurement method that shows peripheral perfusion. PI is a parameter which is calculated as the ratio (AC/DC × 100) of pulsatile arterial blood flow (AC) to non-pulsatile (static) blood flow (DC) in peripheral tissues measured by pulse oximeter. It gives values from 0.02 to 20. Its normal average value is 1.4.[2] It is thought that PI can be used to determine the severity of the diseases in

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**Table 1.** The Pediatric Trauma Score

| Clinical parameter | Score | | |
|---|---|---|---|
| | -2 | +1 | +2 |
| Weight (kg) | <10 | 10–20 | ≥20 |
| Airway | Unmaintainable | Maintainable | Normal |
| Systolic blood pressure (mmHg) | <50 | 50–90 | ≥90 |
| Central nervous system | Coma or decerebrate | Obtunded/Loss of Consciousness | Awake |
| Open wound | Major/penetrating | Minor | None |
| Skeletal | Open/multiple fractures | Closed fracture | None |

critically ill patients hospitalized in the intensive care unit. In a few studies on this subject, it has been shown that the low PI value is compatible with peripheral perfusion disorder.[3] There is no study in the literature evaluating the effectiveness of PI in children with trauma. Therefore, in this study, it was aimed to show the effectiveness of PI measured by non-invasive pulse oximetry in the evaluation of unstable pediatric trauma patients and to show its correlation with PTS.

## MATERIALS AND METHODS

Patients hospitalized in Mersin University School of Medicine Hospital PICU with the ages of >28 days–<18 years were included in the study between March 2017 and March 2018. Characteristic variables of patients, PIM2, PELOD scores, PTS, type of trauma, number of systems affected by trauma, mechanical ventilation, transfusion, hemoglobin, lactate, PI at admission, duration of ICU stay, and outcome (discharge/death) were collected by review of patient charts and electronic medical records. All PI measurements of the patients included in the study were performed within the first 30 min of admission to the PICU. A photoelectric plethysmographic signal of the pulse oximeter (Masimo Root™, Masimo Corp. Irvine, CA) was used for PI measurements. Measurements were performed in the supine position. A reusable probe (Masimo O3 Regional Oximeter, pediatric sensor) which was attached to the patient's right or left finger was held for about 3 min. The numerical values were recorded during the period when the device displayed the brightest and steady on the monitor. Patients in whom PI measurement was performed incorrectly or could not be performed at all, patients with missing informations were excluded from the study. The study was approved by the Mersin University Clinical Research and Ethics Committee (2019/169). Consent form was obtained from each patient's relative.

### Statistical Analysis

SPSS 23.0 package program (IBM SPSS Statistics for Windows, version 23.0, released 2015; IBM Corporation, Armonk, NY) was used for statistical analysis of the data. Categorical measurements were summarized as numbers and percentages, and numerical data as mean, standard deviation, and lower-upper. The conformity of the variables to normal distribution was examined using visual (histogram and probability graphs) and analytical methods (Kolmogorov–Smirnov/Shapiro–Wilk Tests). Chi-square test and Fischer's Precision Test were used for comparisons of categorical variables. Independent student t-test was used for parameters conforming to normal distribution, Mann–Whitney U test was used for binary variables in groups that did not comply with normal distribution, and Kruskall–Wallis tests were used for more than two variables. In the study, the sensitivity (sensitivity) and specificity (specificity) values were calculated based on the PI values of the patients and the PTS variable, and the area under the ROC curve was examined and the cutoff value was determined. The relationship between numerical variables was analyzed using Pearson and Spearman correlation analysis. The statistical significance level was taken as 0.05 in all tests.

## RESULTS

Ninety-one trauma patients who met the study criteria out of 397 patients followed in the PICU for a specified 1-year period were included in the study. The characteristic variables and medical parameters of the patients were given in Table 2.

Most of the patients were male (64.8%). The average age was 99.47±71.27 months. According to the types of trauma, the highest etiology for hospitalization was non-vehicle traffic accident. Mechanical ventilation was required in 20.9% of trauma patients. About 6.6% of them were transfused. Four patients died. It was observed that PIM 2 (p=0.000) and PELOD values (p=0.000) of the patients who died were statistically significantly higher than the mean values of the patients transferred to the service (p<0.05) (Table 3).

The PTS median was 9, and the median number of affected systems was 2. While the mean PI was 1.53±0.91, the median value was 1.3. The mean and median values of PTS according to the characteristic variables of the patients who were followed up in the PICU due to trauma are given in Table 2.

**Table 2.** Characteristic variables and parameters of trauma patients

| | n | % |
|---|---|---|
| Gender | | |
| Female | 32 | 35.2 |
| Male | 59 | 64.8 |
| Trauma type | | |
| In vehicle traffic accident | 20 | 22.0 |
| Out of vehicle traffic accident | 53 | 58.2 |
| Blunt trauma, suicide | 11 | 12.1 |
| Stabbing, cutting tool injury | 6 | 6.6 |
| Electric shock | 1 | 1.1 |
| Mechanical ventilation | | |
| No | 72 | 79.1 |
| Yes | 19 | 20.9 |
| Transfusion | | |
| No | 85 | 93.4 |
| Yes | 6 | 6.6 |
| Prognosis | | |
| Discharged (survived) | 87 | 95.6 |
| Exitus | 4 | 4.4 |

| | Mean±SD | Median (Lower-Upper) |
|---|---|---|
| Age (month) | 99.47±71.27 | 84 (2–212) |
| Pediatric trauma score | 9.07±1.45 | 9 (4–12) |
| Number of systems affected | 2.26±0.88 | 2 (1–4) |
| PIM 2 | 5.62±11.71 | 0 (0–60) |
| PELOD | 4.9±8.75 | 1 (0–40) |
| PI | 1.53±0.91 | 1.3 (0.24–4.8) |
| Hemoglobin (g/dL) | 11.59±2.01 | 11.7 (4.7–16) |
| Lactate (mmol/L) | 4.30±3.39 | 3.5 (0–19.71) |
| Length of intensive care stay (days) | 7.40±9.32 | 4 (1–51) |

Characteristic variables and parameters of trauma patients who were followed up in Pediatric Intensive Care (n=91) (PIM 2: Pediatric Index of Mortality 2 scores; PELOD: Pediatric Logistic Organ Dysfunction scores; PI: Perfusion Index; SD: Standard deviation).

PTS was statistically significantly higher in male patients compared to female patients ($p<0.05$). The PTS values of the patients in the groups of in-vehicle traffic accident and out of-vehicle traffic accident were higher than the PTS averages of the other groups ($p<0.05$). The PTS average of the patients who were mechanically ventilated was found to be statistically significantly lower than those without mechanical ventilation ($p<0.05$). The difference between PTS findings of transfused and non-transfused patients was not statistically significant ($p>0.05$).

In terms of correlation with these findings, there was a positive correlation between PTS and gender ($r=0.208$) and also between PI ($r=0.568$). On the other hand, type of trauma ($r=-0.293$), mechanical ventilation ($r=-0.359$), prognosis ($r=-0.638$), number of affected systems ($r=-0.265$), PIM 2 ($r=-0.375$), PELOD ($r=-0.333$), and length of stay in intensive unit (days) ($r=-0.224$) had negative correlation with PTS ($p<0.05$).

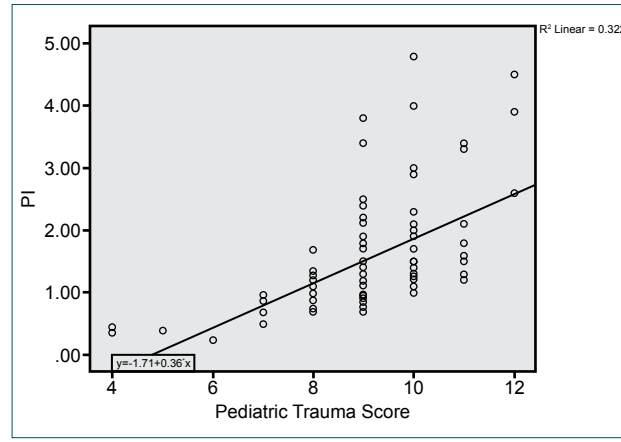


**Figure 1.** Investigation of the correlation between pediatric trauma score and perfusion index.

| Measurements | AUC | Cut off | Sensitive (95% -CI%) | Specificity (95% -CI%) | PPV/NPV | +LR/- LR | p |
|---|---|---|---|---|---|---|---|
| PI | 0.96 | ≤0.96 | 100<br>63.1–100 | 84.34<br>(74.7–91.4) | 36.8/98.6 | 0.16/6.84 | 0.001 |

*P<0.05, Roc Curve.

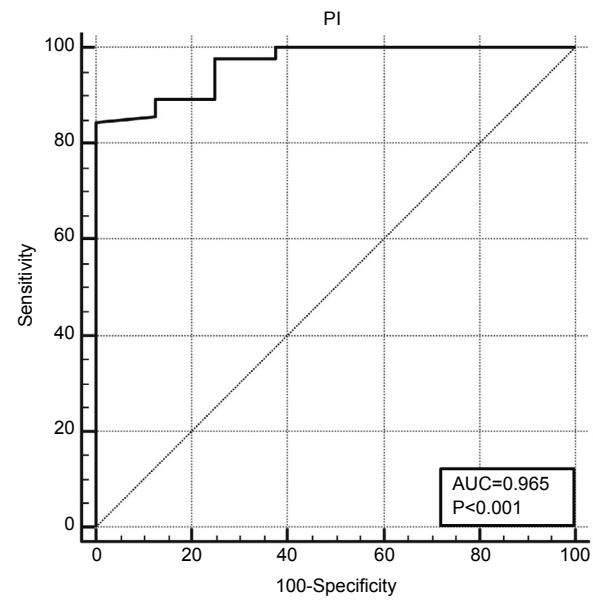


**Figure 2.** ROC analysis arranged according to the pediatric trauma scores and perfusion index parameters of pediatric trauma patients. AUC: Area under the curve; Se: Sensitivity; Sp: Specificity; PPV: Positive Comparison value; NPV: Negative Comparison value.

**Table 3.** Variables and Pediatric Trauma Score's means and medians

| | | Pediatric Trauma Score | | |
|---|---|---|---|---|
| | | **Mean±SD** | **Median (Lower-Upper)** | **p** |
| Gender | Female | 8.66±1.57 | 9 (4–12) | 0.048 |
| | Male | 9.29±1.35 | 9 (4–12) | |
| Trauma type | In vehicle traffic accident | 9.65±2.08 | 10 (4–12) | 0.001 |
| | Out of vehicle traffic accident | 9.13±1.21 | 9 (4–12) | |
| | Blunt trauma, suicide | 8.09±0.94 | 8 (7–10) | |
| | Stabbing, cutting tool injury | 8.50±0.83 | 8 (8–10) | |
| | Electric shock | 8.0±0.0 | 8 (8–8) | |
| Mechanical ventilation | No | 9.33±1.17 | 9 (7–12) | 0.011 |
| | Yes | 8.05±1.95 | 9 (4–11) | |
| Transfusion | No | 9.13±1.34 | 9 (4–12) | 0.513 |
| | Yes | 8.17±2.63 | 8.5 (4–11) | |
| Prognosis | Discharged (Survived) | 9.26±1.13 | 9 (7–12) | 0.000 |
| | Exitus | 4.75±0.95 | 4.5 (4–6) | |

*P<0.05 statistical significance, Chi-square test, Fischer's Precision Test. Examination of the differences between Pediatric Trauma Score and gender, type of trauma, mechanical ventilation monitoring and transfusion findings of trauma patients followed in the Pediatric Intensive Care Unit (n=91) (SD: Standard deviation).

When the PI and the characteristic variables of trauma patients were evaluated, the PI was found to have an inverse correlation with and the exitus group (r=−0.276) and the number of affected systems (r=−0.435) (p<0.05). However, PTS had positive correlation with PI. The directional correlation between PI and PTS was shown in Figure 1 (p<0.05).

There was not a significant difference between the PI values of the patients when they were grouped according to gender (p=0.144), type of trauma (p=0.285), mechanical ventilation (p=0.103), and transfusion (p=0.195) (p>0.05).

Patients were also divided into two groups as PTS ≤8 and PTS >8 when the correlation of PTS and PI was re-evaluated on the basis of scoring. In PTS ≤8 patients, the mean PI was 0.89, the standard deviation was 0.35. In the group with PTS >8 and the mean PI was 1.77, the standard deviation was 0.95, and the difference between the groups was statistically significant (p=0.000). ROC analysis and ROC curve were created to create a cutoff value for the PI value with PTS. As a result of ROC analysis, the area under the ROC curve was 96.5% and, a cutoff value of PI value ≤0.96 was found with 100% sensitivity and 84.34% specificity (Fig. 2).

## DISCUSSION

Internal organ injuries after high-energy traumas are more common in pediatric patients compared to adults due to anatomical and physiological differences. Therefore, prevention of trauma should be aimed first. The evaluation and treatment of trauma patients in the pediatric age group require the cooperation of many disciplines and a well-organized intensive care support if necessary. It should be aimed to provide the airway, circulation, and hemodynamics of the patient. In our study, the majority of those who were hospitalized in intensive care were male and the most common type of trauma was the out of vehicle traffic accident group. Öztan et al.[4] from Turkey evaluated the Turkish children admitted to the emergency room due to trauma and they showed that most of the children were male and the most common cause of trauma was out of vehicle traffic accidents. Their results were similar to our study. 20.9% of the patients admitted to the pediatric intensive unit due to trauma received mechanical ventilator support. Anıl et al.[5] found that 12.2% of trauma patients who were admitted to the PICU were intubated and connected to a mechanical ventilator. Compared to this study, the number of patients mechanically ventilated was higher in our study. This may be because of the fact that our PICU is a third grade intensive care unit and more severe patients are admitted to our unit.

Transfusion rate was 6.6% in our study. Anıl et al.[5] reported that they have transfused 7% of trauma patients which was similar to our study. While the mortality rate was 1.8% in Anıl et al.'s study, it was 4.4% in our study. The reason for this difference can be attributed to the differences in the severity of hospitalized patients and the higher intubation rates in patients followed up in our intensive care unit. PIM2 and PELOD, which are the scoring systems applied to ensure standardization in PICU s and to compare intensive care mortality and morbidity, were used in our study. PIM2 and PELOD were statistically higher in patients who died, as expected, and they were statistically significant. There are also scoring

systems to be used to evaluate the patients about the severity of trauma. The most ideal scoring system should be easy to measure and powerful in predicting the severity of trauma. In this respect, pediatric Glasgow coma score, trauma score, revised trauma score, and PTSs are validated systems.[6–8] Since we have PTS as well as clinical data to show the severity of the trauma all parameters were compared with PTS. PTS was defined by Tepas et al.[9] in 1987. It includes the sum of six parameters used to predict triage and visceral injury in children with traumatic injuries (Table 1).

PTS ≤8 are considered as major trauma in the literature.[9,10] In our study, 23% of patients were major trauma patients with PTS ≤8. Anıl et al.[5] reported that major trauma patients' rate was 32.3% in their study. The low rate in our study can be attributed to the fact that pediatric patients were not followed in surgical intensive care units of our hospital. We showed that the mean PTS was statistically significantly lower in patients who were exitus. This was an expected result for us and it also showed that PTS is an useful tool for us to evaluate trauma patients for severity. We also found a significantly lower PTS scores in patients who were mechanically ventilated. Ramenofsky et al.[1] showed the correlation of PTS with mortality. In our study, when we look generally, PTS was low in patients who had high mortality scores, mechanically ventilated and, who were exitus, these results suggest that PTS is a useful tool to predict severe trauma in patients with hemodynamic instability.

PI which has been started to be used recently in anesthesia reanimation, pediatric intensive care, and neonatal intensive care units indicates the insufficiency of peripheral perfusion in low values. Measuring with a non-invasive pulse oximeter provides convenience and rapid evaluation. There is no value specified in children with trauma. In the study reported by Lima et al.,[3] PI value lower than 1.4 was considered to be compatible with poor peripheral perfusion in adult intensive care patients. De Felice et al.[11] showed that PI can be used as a marker to show the severity of severe disease. In this study, the mean PI was found to be 1.54, while Zaramella et al.[12] found the average PI 1.26 in their study on healthy infants. Another study Ozakin et al.[13] found that the use of PI in the emergency department together with vital signs and shock parameters in adult emergency trauma patients could predict hemorrhage in trauma patients.

In our study, the mean PI of all trauma patients was 1.53±0.91 while the median value was 1.3. The PI value had an inverse statistical significance with the mortality scores. We also found that the PI value was lower in trauma patients who were exitus than the survivors and the PI was decreasing as the number of affected systems increase. Therefore, we found that PI may be low in patients with multiple trauma whose general condition is poor. When we looked at the correlation with the PTS, there was a positive relationship between them. Low PTS scores were associated with lower PI. Our finding that the PI value was significantly lower in patients with PTS 8 and below indicates that peripheral perfusion disorder accompanied trauma in these patients.

In patients with severe trauma, decreased perfusion due to causes such as increased vasomotor tone, bleeding, hypotension, sepsis, and shock, becomes aggravated in hypoxic conditions such as lung trauma. As expected traumatic patients in this group were the ones with high mortality rates and their PTSs were mostly under eight. Ramenofsky et al. reported that PTS was associated with mortality and our results were supporting their thesis.[1] The lower median of the PI value in patients who were exitus may be explained by tissue oxygenation impairment, severe acidosis, and impaired peripheral perfusion secondary to hypotension. The decrease in PI was statistically significant in the patient group with PTS <8. However, we do not have any literature information about the PI level, which correlates PTS with values below 8. The area under the ROC curve, which we evaluated together with PTS <8 and PI, was calculated as 96.5%. In other words, the cutoff value on hand gave the correct answer at the rate of 96.5%. It was found that PI could define severe trauma patients with 100% sensitivity and 84.34 specificity with a threshold value of ≤0.96. Therefore, we think that children with trauma with PI values below 0.96 can be considered as severe trauma.

PI is affected by conditions such as pain, emotional stress, or hypothermia. In this respect, in the conscious patients, PI measurements were made, when the patient was the calm and compatible. In unconscious intubated patients, PI measurement has been attempted to be performed when the patients were in a low pain score, sedated, and normothermic period. Although these conditions are tried to be fulfilled, it cannot be ignored that PI is not affected by these factors. There is no other study in the literature other than our study evaluating PI in pediatric trauma patients. In the treatment and evaluation of pediatric trauma patients, many disciplines should work together and there should be a well-organized pediatric intensive care team. Hemodynamic monitoring is important in terms of decisions to be made and responses to applications in pediatric emergency and intensive care. In this respect, in addition to the oxygen saturation and the other vital signs of the patient, physical examination and urine output should be followed frequently. In addition to these hemodynamic markers, we think that PI can be a guide with the indicator of perfusion impairment. The limitation of the study is that it is uniquely and the results cannot be generalized to the pediatric population. Therefore, larger and multi-center studies are needed.

## Conclusion

Our study is the first study evaluating PI in pediatric trauma patients in the literature. PI can be used separately or in combination with PTS to predict morbidity and mortality in pediatric trauma patients as a non-invasive, easy, and rapid marker.

**Ethics Committee Approval:** This study was approved by the Mersin University Faculty of Medicine Ethics Committee (Date: 14.04.2019, Decision No: 80/169).

**Peer-review:** Internally peer-reviewed.

**Authorship Contributions:** Concept: M.A.; Design: M.A.; Supervision: M.A.; Resource: M.A.; Materials: M.A.; Data: M.A.; Analysis: A.E.A.; Literature search: A.E.A.; Writing: M.A.; Critical revision: A.E.A.

**Conflict of Interest:** None declared.

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ORİJİNAL ÇALIŞMA - *ÖZ*

## Pediatrik travma hastalarında perfüzyon indeksinin değerlendirilmesi

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AMAÇ: Çocuk travmalarında non invaziv pulse oksimetre ile ölçülen Perfüzyon indeksinin acil ve yoğun bakım ünitelerinde düşük pediatrik travma skoru olan hastalarda etkinliğini değerlendirmek.

GEREÇ VE YÖNTEM: Bir yıllık süreçte yoğun bakım ünitesine yatırılarak takibi yapılan hastaların karekteristik değişkenleri, Pediatric Index of Mortality 2 skoru, Pediatric Logistic Organ Dysfunction skoru, pediatrik travma skoru, travma türü, travmadan etkilenen sistem sayısı, mekanik ventilatör izlemi olup olmaması, transfüze edilip edilmemesi, hemoglobin, laktat değerleri, yatış esnasında Perfüzyon indeksi değeri, yoğun bakım yatış gün süresi (gün) ve sonuç (taburcu/eksitus) kaydedildi.

BULGULAR: Belirlenen süreçte 91 çocuk travma hastası sonuçlarına eksiksiz ulaşılabildi. Hastaların çoğunluğu erkek (%64.8) yaş ortalaması 99.47±71.27 aydı, yatış nedeni en çok araç dışı trafik kazasıydı. Perfüzyon indeksi ile Pediatrik travma skoru arasında pozitif yönlü bir korelasyon vardı ($p<0.05$). PTS ≤8 hastalarda PI ortalaması 0.89, standart sapma 0.35, PTS >8 olan grupta PI ortalaması 1.77, standart sapma 0.95 olarak saptandı ve istatistiksel olarak anlamlı idi ($p=0.000$).

TARTIŞMA: Perfüzyon indeksi çocuk travma hastalarında tek başına veya pediatrik travma skoru ile birlikte unstabil hastaları non invaziv hızlı şekilde değerlendirmemizi sağlamaktadır.

Anahtar sözcükler: Pediatrik travma; Pediatrik Travma Skoru; perfüzyon indeksi.

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