



Research article

Perfusion index versus visual analogue scale: as an objective tool of renal colic pain in emergency department

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ABSTRACT

Background: Perfusion index (PI) has use to monitor sympathetic response changes to pain. In this study, we aimed to evaluate the utility of using perfusion index as an objective marker of pain relief and of the need for rescue analgesia in ED patients with documented renal colic.**Methods:** We conducted a prospective observational study between January 2020 and December 2020. The demographic characteristics of the patients, their complaints, nephrolithiasis histories, vital signs, PI, and VAS scores (on admission and after treatment) were recorded.**Results:** A total of 144 patients were included. All patients were administered 20 mg of Tenoxicam on admission. There was a statistically significant difference between the PI (<0.001) and VAS scores (<0.001) on admission and after the administration of Tenoxicam. 43.1% (n = 62) of the patients needed rescue analgesia. Accordingly to ROC curve, the ability of both PI₂ (AUC: 0.615, 95%CI 0.519–0.711, p = 0.018) and ΔPI (AUC: 0.601, 95%CI 0.508–0.694, p = 0.039) indices were determined as statistically significant. The cutoff value of the PI₂ level for the prediction of the needed rescue analgesia was 4.65 and the cutoff value for ΔPI (PI₂PI₁) was 2. All patients had a pain VAS score of <3 and a mean PI of 5.7 ± 2.9 at discharge from the emergency department.**Conclusion:** In patients presenting to the emergency department with renal colic, the PI value on admission and after analgesic therapy can be helpful in assessing the severity of pain and predict the need for rescue analgesia.

1. Introduction

Renal colic is one of the most severe pains that the body can feel due to obstruction of the urine flow due to stones, masses, or any other reason [1]. The glomerular vasodilation that develops in the initial phase of occlusion leads to a further increase in urine output and ureteral pressure. The increased pressure stimulates the synthesis and release of prostaglandins from the ureteral wall. Prostaglandins induce vasodilation and contraction of smooth muscle, causing more severe pain [2]. Pain control of patients intends to inhibit pain via prostaglandin synthesis (non-steroidal anti-inflammatory drugs (NSAIDs)), reduce pain at the central nervous system level (opioids) or reduce spastic ureteral contraction (antispasmodics) [3].

Subjective pain scores such as visual analogue scale (VAS) or numeric rating scale (NRS) are frequently used in patients' pain control and in predicting their rescue analgesia needs, based on patients' facial

expressions and self-reported pain scores [4, 5]. However, objective evidence is needed to accomplish adequate analgesia and prevent unnecessary medication use [5]. Perfusion index (PI) is promising in pain monitoring. PI is the ratio of pulsatile blood flow to nonpulsatile blood flow in peripheral tissue. The pulse is measured by oximetry allowing continuous non-invasive measurement of peripheral perfusion. It has also been used to monitor sympathetic response changes. The link between pain and sympathetic stimulation supported the hypothesis that the perfusion index could be used in pain assessment. Pain is usually associated with vasoconstriction caused by increased sympathetic activity. PI is a known parameter to increase with vasodilation and decrease with vasoconstriction [6]. In the literature, PI has been studied in the evaluation of postoperative pain, in labor pain, and to determine the success of nerve blocks [4, 7, 8]. However, to our knowledge, PI was not studied in patients with renal colic pain in the literature.

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This study aimed to evaluate the utility of using perfusion index as an objective marker of pain relief and of the need for rescue analgesia in ED patients with documented renal colic.

2. Materials and methods

The research was conducted as a prospective observational cohort study in patients admitted to the tertiary emergency department with renal colic. The study was initiated after obtaining approval from the Adana City Training and Research Hospital Clinical Research Ethics Committee (meeting numbered 46 and Decision 640, dated 18 December 2019). Written informed consent was obtained from the all patients to participate in the study.

2.1. Inclusion criteria

Patients over the age of 18 years, who were admitted to the emergency department with the complaint of flank pain between January 01, 2020, and December 31, 2020, and whose renal colic diagnosis was confirmed by computed tomography or bedside ultrasonography performed after the pain subsided, were included in the study.

2.2. Exclusion criteria

Those who used analgesic drugs in the last 6 h before admission to the emergency department, those who regularly use any drugs, those who are allergic to the drugs to be used in the treatment, those who are unstable hemodynamically, patients with hepatic, cardiac, and respiratory failure, patients with a single kidney, and those with a history of renal transplantation, patients with serum creatinine level >2 mg/dl, those with a history of gastrointestinal bleeding and peptic ulcer, those who are pregnant, suspected of pregnancy or breastfeeding, patients who cannot fill the pain scale due to vision problems, and patients under the age of 18 were excluded from the study.

2.3. Monitoring

The patients were monitored before any treatment was initiated. The 0–10 cm VAS scale was used to determine the degree of pain. Before the treatment, the patient was told to mark a point on the line per the severity of the pain. Vital findings on admission, PI_1 , and VAS_1 scores were recorded in the study form. Perfusion index measurement is performed from the patient's index finger with a pulse oximetry probe (Masimo Radical 7; Masimo Corp. Irvine, CA, USA).

PI_1 : $PI_{on\ admission}$ VAS_1 : $VAS_{on\ admission}$

2.4. Analgesia protocol

All patients included in the study were given 100 ccs 0.9% NaCl +20 mg Tenoxicam infusion in 15 min. Thirty minutes after the infusion, the patient's vital signs, PI_2 , and VAS_2 scores were recorded in the study form. VAS markings were made by the patient himself/herself, regardless of the previous mark. The patients whose complaints regressed were discharged. If the VAS score improved by less than 40% of the baseline VAS level and according to the patient's symptoms, an additional dose of analgesia was administered to the patient. Each patient was followed by at least 2 physicians. Physicians who were blinded to the perfusion index determined whether the patient needed rescue analgesia. 100 ccs 0.9% NaCl +1 μ g/kg Fentanyl infusion in 15 min was given as the additional analgesic treatment. Thirty minutes after the infusion finished, the patient's vital signs, PI_3 , and VAS_3 scores were recorded in the study form. If the VAS score improved by less than 40% of the 30th minute VAS level and according to the patient's symptoms, an additional dose of analgesic (Fentanyl) was titrated and given to the patient. The patients whose complaints regressed were discharged.

PI_2 : $PI_{after\ tenoxicam\ administration}$ VAS_2 : $VAS_{after\ tenoxicam\ administration}$

PI_3 : $PI_{after\ fentanyl\ administration}$ VAS_3 : $VAS_{after\ fentanyl\ administration}$

2.5. Data collection

In addition to the demographic characteristics of the patients, their complaints, nephrolithiasis histories, vital signs, PI, and VAS scores (on admission and after treatment) were recorded in the standard data form.

To reduce the bias of individual variation in the perfusion index, we also evaluated the ΔPI and ΔVAS .

ΔPI (ΔPI) = ($PI_2 - PI_1$)

ΔVAS (ΔVAS) = ($VAS_2 - VAS_1$)

The ROC curve of ΔPI and PI_2 was constructed to predict the need for rescue analgesics.

Correlation analysis was performed between PI and VAS scores in pain follow-up.

2.6. Outcome

The study's primary outcome was to evaluate the using perfusion index as an objective marker of pain relief. The secondary outcome was the anticipation of the need for rescue analgesics.

2.7. Statistical analysis

SPSS 22 package program was used for statistical evaluation of the data obtained in the study (SPSS Inc, Chicago, Illinois, USA). Continuous data were summarized as mean and standard deviation, while categorical data were summarized as numbers and percentages. Categorical data were compared with the Chi-square test. The Kolmogorov-Smirnov test was used to compare the averages of the parameters, and the Student's t-test was used when the variables were normally distributed in the evaluations made with the histogram Mann-Whitney U test was used when the variables were not normally distributed. Paired samples t-test was used to compare two groups before and after treatment. While performing correlation analysis between perfusion index and VAS scores, Pearson correlation analysis was used because the variables were per the normal distribution. The receiver operating characteristic (ROC) curve was used to investigate the accuracy of the perfusion index in predicting the need for rescue analgesics.

3. Results

One hundred and forty-four patients were included in the study. Flow chart of the patients included in the study showed in [Figure 1](#). The mean age of the patients was 35.4 ± 10.1 , and 66.7% ($n = 96$) were male. While all patients had lumbar pain, the second most common complaint was hematuria, with 43.1% ($n = 62$). 48.6% of the cases had a previous history of renal colic. The demographic data of the patients are shown in [Table 1](#).

All patients were administered 20 mg of Tenoxicam by intravenous infusion on admission. There was a statistically significant difference between the mean blood pressure (96 ± 10 vs 91.8 ± 9.2 , <0.001), pulse rate (81.3 ± 10.5 vs 77.2 ± 8.8 , <0.001), $PI_1 - PI_2$ (3.1 ± 2.4 vs 5.5 ± 2.8 , <0.001), and $VAS_1 - VAS_2$ scores (8.5 ± 1.7 vs 3.9 ± 3.1 , <0.001) on admission and after the administration of Tenoxicam ([Table 2](#)).

After tenoxicam administration, 43.1% ($n = 62$) of the patients needed rescue analgesia (Fentanyl). While the mean PI of 62 patients who needed rescue analgesia was 4.9 ± 2.9 , the mean PI of 82 patients who did not need an additional analgesia dose was 6 ± 2.6 , and the difference was statistically significant ($p = 0.028$). When the patients' ΔPI was compared; while $\Delta PI = 2 \pm 1.5$ in patients who needed rescue

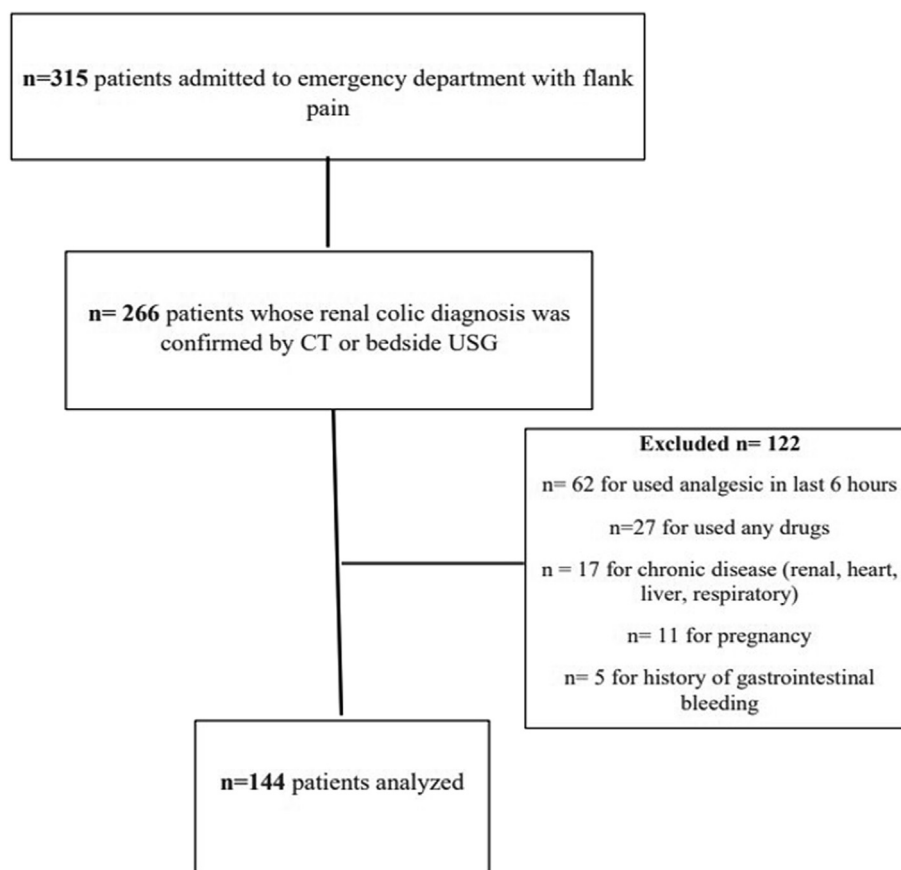


Figure 1. Flow chart of the patients included in the study.

analgesia, Δ PI was 2.6 ± 1.8 in patients who did not need rescue analgesia, and the difference was significant ($p = 0.032$).

ROC curves comparing the PI_2 and Δ PI indices to predict the need for rescue analgesics are shown in Figure 2, and the analytical measurements of these curves are shown in Table 3. Accordingly, the ability of both PI_2 (AUC: 0.615, 95%CI 0.519–0.711, $p = 0.018$) and Δ PI (AUC: 0.601, 95% CI 0.508–0.694, $p = 0.039$) indices were determined as statistically significant. If the cut-off values determined to predict the need for rescue analgesia were taken as 4.65 for PI_2 , the sensitivity was 73.2%, the specificity was 61.3%, and if 2 was taken for Δ PI, the sensitivity was 61%, and the specificity was 54.8%.

Table 1. Demographic data.

Data	n = 144
Sex, n (%)	
Male	96 (66.7)
Female	48 (33.3)
Age, years (mean \pm SD)	35.4 \pm 10.1
Symptoms, n (%)	
Lumbar pain	144 (100)
Hematuria	62 (43.1)
Dysuria	36 (25)
Emesis-vomiting	24 (16.7)
Abdominal pain	14 (9.7)
Urgency	4 (2.8)
History of urolithiasis, n (%)	70 (48.6)
Rescue analgesia need, n (%)	
One time	62 (43.1)
Twice	8 (5.6)

While there was no statistically significant difference between MAP ($p = 0.116$), HR ($p = 0.405$), and PI ($p = 0.579$) before and after the treatment, there was a difference between the VAS scores of the patients who were administered rescue analgesia (fentanyl) according to their complaints and VAS scores ($p < 0.001$) (Table 4).

There was a weak negative correlation between PI_1 and VAS_1 scores ($r = -0.178$, $p = 0.033$) on admission. There was no correlation between post-treatment PI and VAS scores (Table 5).

Only 5.6% ($n = 8$) of the patients were given a second dose of fentanyl by titration. All patients had a pain VAS score of <3 and a mean PI of 5.7 ± 2.9 (min = 1.15 max = 11.2) at discharge from the emergency department.

4. Discussion

In our study, $PI_2 < 4.65$ or Δ PI < 2 after treatment with non-steroidal anti-inflammatory drugs in patients who were admitted to the emergency department with renal colic indicated the presence of pain requiring

Table 2. Comparison of VAS, PI, HR and MAP values before and after administration of Tenoxicam.

Data	Before analgesia (n = 144)	After Tenoxicam (n = 144)	p-value
MAP (mmHg)	96 \pm 10	91.8 \pm 9.2	<0.001
HR (beat/min)	81.3 \pm 10.5	77.2 \pm 8.8	<0.001
PI	3.1 \pm 2.4	5.5 \pm 2.8	<0.001
VAS	8.5 \pm 1.7	3.9 \pm 3.1	<0.001

MAP = Mean arterial pressure.

HR = Heart rate.

PI = Perfusion index.

VAS = Visual analogue scale.

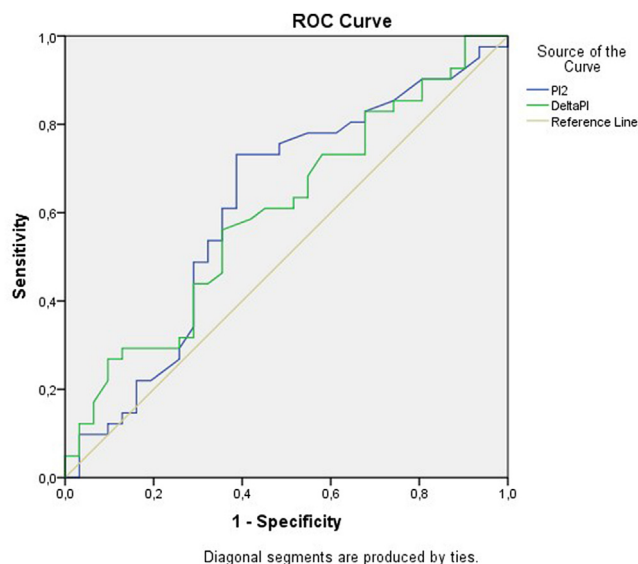


Figure 2. ROC curve of Δ PI and PI_2 scores to predict the need for rescue analgesics.

rescue analgesia. The mean perfusion index of the patients after treatment was 5.7 ± 2.9 , indicating sufficient analgesic response for the patients to be discharged.

Pain is a subjective sensation that can negatively affect psychological and physiological health [5]. Relentless pain in critically ill patients activates the sympathetic nervous system, increases stress hormones that cause vasoconstriction, increases oxygen demand, alters glycemic control, and impairs immune system function [6]. The direct relationship between pain and sympathetic stimulation increases heart rate and causes peripheral vasoconstriction. When pain activates sympathetic tone, vasoconstriction can cause a decrease in the PI, and an increase occurs after administering analgesics [5, 6]. Based on this, we hypothesized that PI could be used as an indirect tool to assess pain and predict the need for rescue analgesics in patients with renal colic. PI has been studied in the literature to evaluate postoperative pain in pediatric patients who underwent adenotonsillectomy under general anaesthesia. The change in the preoperative baseline perfusion index (Δ PI-pre) was found to be a good objective measure to predict the presence of postoperative pain (AUROC 0.83 with 71% sensitivity, 83% specificity, and a cut-of value of ≥ 0.26) [4]. In our study; when the patients' Δ PI was compared; while Δ PI = 2 ± 1.5 in patients who needed rescue analgesia, Δ PI was 2.6 ± 1.8 in patients who did not need rescue analgesia; the difference was statistically significant. When ROC analysis was performed, it was determined that the ability of both PI_2 and Δ PI indices to predict the need for rescue analgesics was statistically significant.

Pain in renal colic is severe, and the first step in treatment is providing fast, safe, and adequate analgesia [2]. Due to the severity of the pain complaint of these patients, the first place of admission is the emergency services. However, the current patient density of emergency services may cause difficulties for these patients to reach effective and ongoing analgesia in the early period. Therefore, there is a need for an evidence-based protocol to minimize the delay in the rapid

Table 4. Comparison of MAP, HR, PI and VAS scores of 62 patients in need of rescue analgesia before and after fentanyl administration.

Data	Before Fentanyl (n = 62)	After Fentanyl (n = 62)	P-value
MAP (mmHg)	92.6 \pm 10.2	91 \pm 7.4	0.116
HR (beat/min)	79.4 \pm 9.2	79.9 \pm 8.7	0.405
PI	4.9 \pm 2.9	5.1 \pm 3.2	0.579
VAS	7.1 \pm 1.9	2.5 \pm 2.3	<0.001

MAP = Mean arterial pressure HR = Heart rate.

PI = Perfusion index VAS = Visual analogue scale.

administration of effective and safe analgesics [9]. The visual analogue scale (VAS) is the most commonly used pain assessment scale [7]. However, the pain assessment of this scale is generally based on subjective scores that require patient cooperation. These assessments are affected by patients' personality, age, gender, sociocultural differences, psychological factors such as fear, anxiety, depression, and anger. Therefore, more objective scores and measurements are needed [10]. In the study of Nishimura et al., it was determined that the PI values examined after applying painful stimulus in volunteer patients were correlated with pain. Concluding that the increase in sympathetic nerve tone due to pain may affect PI, this study presents PI as a non-invasive option for the objective evaluation of pain perception [11]. Our study supports this study, and while the admission PI of the patients was lower, PI levels increased as the pain was relieved with analgesics. However, the negative correlation between PI and VAS was weak due to the subjectivity of VAS. An observational study showed that the normal value of PI was between 0.2% and 20%, and the mean normal value of PI was 4.3 (2.9–6.2) [12]. In our study, the mean PI measured at the time of discharge of the patients was 5.7 ± 2.9 (min = 1.15 max = 11.2). Since PI values are in this wide range, it is recommended that each individual's follow-up value should be compared to the initial findings [12]. In our study, to reduce the bias of individual variation in perfusion index, we also evaluated the Δ PI (PI_2-PI_1). A Δ PI < 2 was statistically significant in demonstrating the presence of pain requiring rescue analgesia. When the patients' HR, MAP, and PI scores were compared before and after the administration of rescue analgesia, no statistical difference was found. Only the VAS score decreased significantly. Even with adequate analgesia, patients may report higher VAS scores due to the emotional state of severe pain. No significant change was observed in MAP, HR, and PI as a result of the rescue analgesia, which led us to think that administering analgesics to patients only according to VAS score may lead to analgesic overuse.

This study has some limitations. One of them is that the sample size was small. The another one is about PI. PI is characterized by a wide measurement range (from 0.2 to 20) among normal individuals; therefore it is better to evaluate its changes compared to baseline readings of the same person. Therefore follow-up PI measurements are required for accurate assessment of patients. Also PI cannot be used in all patients. PI may be low due to cold extremities, low temperatures and high dose vasopressors. It is also not suitable for patients receiving extra-corporeal membrane oxygenation. Large-scale studies involving different pain types and different patient groups are needed to investigate the benefit of perfusion index measurements in pain management in the emergency department.

Table 3. Analysis of the ROC curve for Δ PI and PI_2 scores to predict the need for rescue analgesics.

	AUC	SE	95% CI	Cut-off	Sensitivite	Spesifite	p value
PI_2	0.615	0.049	0.519–0.711	4.65	73.2	61.3	0.018
Δ PI	0.601	0.047	0.508–0.694	2	61	54.8	0.039

$PI_1 = PI_{on\ admission}$ $PI_2 = PI_{after\ tenoxicam\ administration}$ Δ PI = $PI_2 - PI_1$.

Table 5. Correlation analysis of PI and VAS scores on admission and after analgesic.

	PI ₁ -VAS ₁	PI ₂ -VAS ₂	ΔPI-ΔVAS	PI ₃ -VAS ₃
r	-0.178	-0.114	-0.102	-0.114
p	0.033	0.174	0.225	0.377

PI₁ = PI_{on admission} VAS₁ = VAS_{on admission}

PI₂ = PI_{after tenoxicam administration} VAS₂ = VAS_{after tenoxicam administration}

PI₃ = PI_{after fentanyl administration} VAS₃ = VAS_{after fentanyl administration}

ΔPI = PI₂ - PI₁ ΔVAS = VAS₂ - VAS₁

5. Conclusion

In this study, when pain decreased due to the administration of analgesics in patients with renal colic; PI has showed an increasement. Monitoring changes in PI specific to each patient from the time of admission may help predict patients' pain relief and the need for rescue analgesia. In addition, the non-invasive, inexpensive, reproducible and easy method of PI measurement may increase its preferability. However, changes in PI should be evaluated with patient symptoms, PI alone is not sufficient to change the treatment decision.

Declarations

Author contribution statement

Muge Gulen; Salim Satar: Conceived and designed the experiments; Performed the experiments; Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data; Wrote the paper.

Selen Acehan: Conceived and designed the experiments; Analyzed and interpreted the data; Wrote the paper.

Dervis Yildiz: Performed the experiments; Contributed reagents, materials, analysis tools or data.

Ebru Funda Aslantürkiyeli; Deniz Aka Satar; Melike Kucukceylan: Performed the experiments; Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data.

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Data availability statement

The authors do not have permission to share data.

Declaration of interests statement

The authors declare no conflict of interest.

Additional information

No additional information is available for this paper.

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