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ORIGINAL RESEARCH

Perfusion index in the follow-up of postoperative pain: hypertensive patient sample

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Abstract

Background: The relative changes in perfusion index following postoperative analgesia were investigated. The study also aimed to investigate the ability of perfusion index to predict analgesic requirements. As a secondary aim, the results of the relative changes in perfusion index in individuals with hypertension were analyzed. **Methods**: A total of 100 patients with American Society of Anesthesiologists (ASA) 1–3 with or without hypertension who were scheduled to undergo open abdominal surgery between 01 April 2023 and 30 November 2023 were included in the study. The relative variability of visual analogue scale and perfusion index in patients receiving postoperative analgesia was examined. We also studied at which these variables predicted postoperative pain following rescue analgesia. The patients with hypertension were analysed alongside other patient groups. **Results**: The relative change in perfusion index was found to have a higher ability to predict the need for analgesia in patients with high postoperative Visuel Analogue Scale (VAS) scores. This ability was found to be increased in patients with hypertension. The number of patients with moderate to high pain (VAS >6) in the postoperative period was found to be 86. **Conclusions**: The area under the Receiver Operating Characteristic (ROC) curve was found to have a sensitivity of 64% with a positive predictive value of 86%. Therefore relative changes in perfusion index can be used as a method to predict postoperative pain. **Clinical Trial Registration**: Protocol ID: 76988455-050, Identification No NCT06535581.

Keywords

Perfusion index; Postoperative pain; Hypertension

1. Introduction

The impact of post-operative pain and analgesia on the quality of life is crucial. The ageing population and age-related comorbidities make this process more complex. Therefore, it is important to examine the indicators of postoperative pain and investigate the changes that occur. The visual analogue scale (VAS) is accepted as one of the objective criteria for the assessment of perioperative pain. However, in addition to this scale, other objective assessment tools are often used. The perfusion index (PI) is an accepted objective parameter in pain assessment [1]. PI pulse oximetry is a method that indirectly measures peripheral PI. Pain-induced sympathetic vasoconstriction causes relative changes in PI. Therefore, PI is one of the helpful methods in defining perioperative pain [2, 3]. The PI monitoring provides an idea of the maintenance of tissue perfusion using a non-invasive method [4]. The PI value varies depending on the sympathetic-parasympathetic vasomotor response in the peripheral vessels and the elasticity of the vessel walls. It is recognized as an indirect indicator of cardiac output [5]. Hemodynamic instability occurs in patients with hypertension. As these patients have a high intravascular pressure for a long time, there is a decrease in the vasoconstrictor-vasodilator response in the vessel wall. A complex situation occurs in patients with hypertension [6]. Postoperative analgesia causes a change in PI values and is becoming increasingly important in follow-up patients following analgesia [7]. Laparotomic abdominal surgery is among the most frequently performed types of surgery. Although it is a type of surgery with a high level of pain, there is no study in the literature on laparotomic abdominal surgery and relative PI change as an indicator of analgesic need. Hypertension is a disease that manifests itself with vasoconstriction in tissues and has blood flow changes [6]. There is no study found in the literature regarding relative PI change in individuals with hypertension; hence the need for our study. This study aimed to investigate the changes in PI values following analgesia and as an indicator of the need for analgesia, and to investigate its effect in hypertensive patients. The aim was to evaluate the need for postoperative analgesia in patients with hypertensive disease and to show the differences in the changes in PI values after analgesia with the other group of patients.

2. Materials and methods

2.1 Study design

In this prospective randomized single-blind cohort study, postoperative VAS and PI changes were examined. The relative changes in VAS and PI were then analyzed.

2.2 Patient

We included a total of 100 adult participants with American Society of Anesthesiologists (ASA) physical statuses ranging from 1 to 3, male and female patient, who were scheduled to undergo laparotomic abdominal surgery under general anesthesia. Patients with difficulty in cooperation, patients with speech and communication difficulties, and patients with advanced heart failure and valvular heart disease were excluded from the study.

2.3 Allocation, randomization

On surgery day, patients without hypertension (group 1) and those with hypertension (group 2) were separated and taken into surgery. Routine electrocardiography (ECG), non-invasive blood pressure measurement and mean arterial pressure (MAP) values were used before anesthesia induction. In the postoperative care unit, these values were recorded together using a peripheral pulse oximetry device (SpO_2) (Datex-OhmedaS/5 (Datex-Ohmeda, Madison, WI, USA) and a plethysmographic peripheral perfusion index device (a device that reflects the ratio of pulsatile blood flow to non-pulsatile blood flow in the capillary bed using a finger probe) (Masimo Corp, Irvine, CA, USA) and PI and pleth variability index (PVI) values.

2.4 Anesthesia protocols

The study was conducted at Amasya Sabuncuoğlu Şerefettin Training and Research Hospital approved by the ethics committee with the number 2023000037-1 and registered at ClinicalTrials.gov (Protocol ID: 76988455-050, Identification No. NCT06535581). All patients were informed about the study and they gave their informed consent. All patients were routinely given 500 cc of Ringer's lactate solution intravenously in the preoperative period before anaesthesia and taken to the operating room. Written informed consents were obtained from volunteers and included in the study. All patients received intravenous (IV) hydration with 500 cc of Ringer's lactate after a 6-hour fast. For premedication, midazolam 1 mg IV and pantoprazole 40 mg IV were administered 10 minutes before the surgery Routine electrocardiography (ECG), pulse oximetry and blood pressure monitoring and pulse oximetry devices (Masimo Corp, Irvine, CA, USA) were used to record mean arterial pressure (MAP), PI and PVI values at the start of anaesthesia. Propofol 2 mg/kg, fentanyl 2 μg/kg and rocuronium 0.6 mg/kg were administered intravenously to induce anaesthesia. Endotracheal intubation was performed after muscle relaxation under deep anaesthesia. Post induction anaesthesia was maintained with sevoflurane 2%, and 50–50% oxygen-air mixture. Following surgery, the muscle relaxation effect was terminated using sugammadex 200 mg and the patients were transferred to the post-anaesthesia care unit when sufficient muscle strength was observed. Paracetamol 500 mg Intravenously (IV) and tramadol 100 mg IV were administered postoperatively.

2.5 Data collection

Postoperative pain was assessed using the VAS. When the patient first arrived at the post anesthesia care unit, the VAS 0 was accepted and scoring was performed every 30 minutes (VAS 0, VAS 30, VAS 60, VAS 90). The PI and PVI values were recorded at the first arrival at the post anesthesia care unit and at the 90th minute (PI 0, PI 90, PVI 0, PVI 90). The postoperative pain was assessed with VAS and scored on a scale of 0–10. The VAS scores >6 was evaluated as high pain, 4–6 as middle pain, 1–3 as low pain, and 0 as no pain. The VAS score >6 was accepted as the pain cut-off point for rescue analgesia. If the VAS score >6, 0.05 mg/kg morphine was repeated every 15 minutes until VAS <4 was observed. Relative changes in VAS scores were calculated in patients who received rescue analgesia. VAS 0 was accepted as the score at the first admission to the post anesthesia care unit. VAS 1 was accepted as the last value measured following rescue administration analgesia in the post anesthesia care unit. Relative change was calculated according to the formula $(\Delta VAS) = (VAS\ 0 - VAS\ 1)/(VAS\ 0)$. The PI value measured at the first admission to the post anesthesia care unit was recorded as PI 0. The PI value measured following rescue analgesia administration was recorded as PI 1. Relative changes in the PI value were calculated using the formula $(\Delta PI) = (PI\ 0 - PI\ 1)/(PI\ 0)$. The patients followed up in the post anesthesia care unit were transferred to the clinical units after a 90-minute follow-up period. The relative changes in VAS and PI values (ΔVAS, ΔPI) were analyzed in (group 1 and group 2). The ability of the relative variability in the postoperative PI value to predict the need for analgesia was examined.

2.6 Statistical analysis

The sample size was calculated using the G*power 3.1.9.4 for Windows (Open Source) package program in accordance with the study of Ahmed [8]. The effect size was calculated as 1.11 with a margin of error of 0.05 and the total number of patients was 95. A total of 100 patients were included in the study to avoid missing data. A total of 100 patients with ASA 1–3 with or without hypertension who were scheduled to undergo laparotomic abdominal surgery between 01 April 2023 and 30 November 2023 were included in the study. Data were analysed using the SPSS version 25 software (IBM Corp, New York, NY, USA). The Kolmogorov Smirnov and Shapi-Wilk tests were used to analyze the normality of the data distribution. Continuous numerical data were expressed as standard deviation and median range. Demographic characteristics were summarized as frequency percentages. The *t*-test or Wilcoxon test was used to analyze variables before and after analgesia. The dependent *t* test was used to analyse the variables of patients in groups 1 and 2. Anova test with *post-hoc* Bonferroni correction was used to calculate the relative variability of the perfusion index in patients with low-medium-high VAS scores. Spearman's correlation analysis was used

to determine the possible relationship between VAS and PI variables. A value of $p < 0.05$ was considered statistically significant. To measure the ability of the relative variability of the PI score to predict postoperative pain, the ROC curve was calculated with the best cut-off using the Youden index. The statistically significant level was accepted as $p < 0.05$.

3. Results

The data of a total of 100 patients were analyzed. While 52% (n = 52) of the patients had hypertension, the remaining 48 (n = 48) had no hypertesion disease. The demographic characteristics are presented in Table 1.

The difference between the study variables before and after analgesia is presented in Table 2.

After rescue analgesia was applied, the PI and PVI values were found to be statistically higher than before analgesia (*p*: <0.001–<0.001). VAS score was lower after analgesia (*p*: <0.001). There was no statistical difference in MAP value before and after analgesia (*p*: 0.365) (Table 2).

The difference between group 1 and group 2 patients after analgesia is presented in Fig. 1.

MAP 0, MAP 90, PI 0, PI 90 values were statistically higher in Group 2 patients than in Group 1 patients (*p*: <0.001–<0.001–0.028–<0.001).There was no statistical difference in the VAS 0–30–60–90 values (*p*: 0.763–0.244–0.221–0.191) (Fig. 1).

The relationship between VAS value and PI values is presented in Table 3.

It was observed that there was a statistical difference between the relative change in PI value (ΔPI) after rescue analgesia was applied in patients with low-medium-high VAS scores (*p*: 0.01). The *post-hoc* Bonferroni correction was used for the analysis of this statistical difference. It was observed that the ΔPI relative change value was statistically higher in patients with high VAS scores (Table 3).

There was a moderate negative correlation between the relative change of VAS and PI values (ΔPI and ΔVAS) (Spearman's correlation coefficient −0.64 and *p*: <0.001).

The number of patients with moderate to high pain (VAS >6) in the postoperative period was 86. The ability of the relative change in baseline perfusion index (ΔPI) after analgesia to predict the need for postoperative analgesia was analysed. For this purpose, an ROC curve was constructed (Fig. 1). The area under the ROC curve was found to have a sensitivity of 64% and a with a positive predictive value of 86%. The cut-off value according to the maximum Youden index was 0.73 in the 56–84% confidence interval (*p*: 0.016) (Fig. 2).

4. Discussion

The first finding of our study was that the PI, PVI and VAS scores measured before and after analgesia changed statistically significantly following analgesia (Table 2). Another finding that supports this is that a moderate degree of collinearity was observed in the SEM collinearity analysis between the relative values calculated following analgesia ((ΔPI) = (PI 0 − PI 1)/(PI 0) and (ΔVAS) = (VAS 0 − VAS 1)/(VAS 0)), which supports the idea that the perfusion index value and its changes are predictive of postoperative pain.

In the intraoperative period, blood pressure elevation and tachycardia are clinically expected changes as a result of the painful stimulus caused by surgical stress under anaesthesia. The perception of these changes is a stimulus for the anesthetist

TABLE 1. Demographic data and anesthetic parameters.

	Total	Group 1	Group 2
Group 1/2	N = 100	N = 52	N = 48
Sex, male/female	58/42	27/25	31/17
Age	49.3 ± 8.9	47.7 ± 9.9	51.1 ± 7.2
ASA	(1–3)	(1–3)	(2–3)
Basaline MAP (mmHg)	93.2 ± 10.1	87.8 ± 6.4	100.1 ± 10.3
Basaline PI	3.5 (1.9–6.7)	3.4 (1.9–6.7)	3.7 (2.4–5.3)
Basaline PVI	10.7 (8.6–13.4)	10.8 (8.8–13.4)	10.6 (8.6–12.1)

Variables are presented as Mean ± sd (standard deviation), Median or Ratio, categorical variables are presented as "number". ASA: American Society of Anesthesiologists; MAP: Mean arterial pressure; PI: Perfusion index; PVI: Pleth variability index.

TABLE 2. VAS score, PI, PVI and MAP values before and after analgesia.

	Before Analgesia	After Analgesia	*p*
MAP (mmHg)	92.7 ± 10.1	92.6 ± 9.5	0.365
PI	3.5 (1.9–6.7)	5.0 (2.5–7.1)	<0.001
PVI	10.3 (3.2–12.6)	11.2 (3.9–13.6)	<0.001
VAS	7 (2–10)	3 (1–5)	<0.001

Data are expressed as Mean ± sd or median range. MAP: Mean arterial pressure; PI: Perfusion index; PVI: Pleth variability index; VAS: Visual analogue scale.

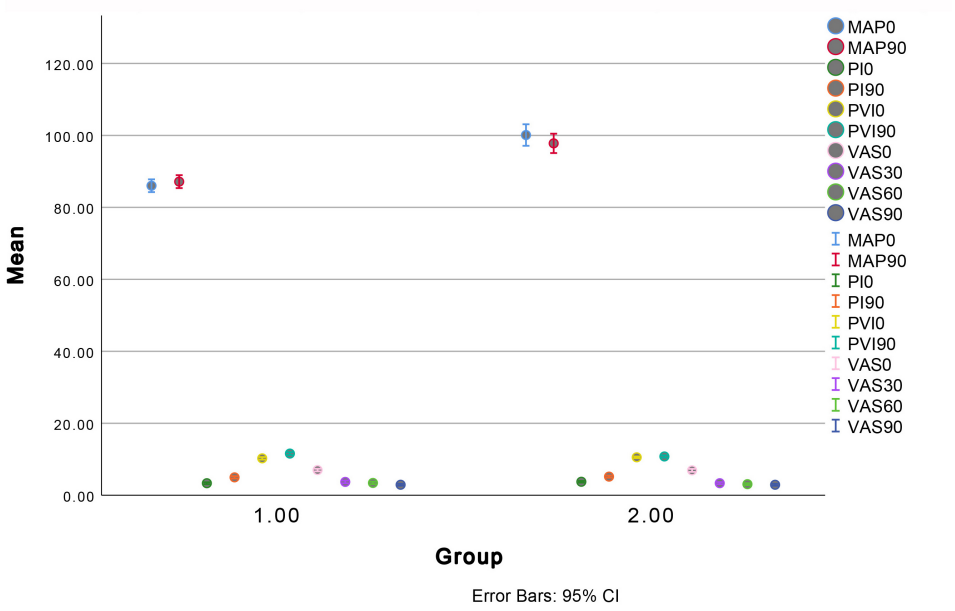

FIGURE 1. MAP, PI, PVI and VAS score in group 1 and 2. Categorical variables are presented as "number". MAP: Mean arterial pressure; PI: Perfusion index; PVI: Pleth variability index; VAS: visual analogue scale; 95% CI: 95% Confidence Interval. Independent sample *t*-test.

TABLE 3. ΔPI score in low, middle and high level of VAS score.

VAS	N	X	Ss	Varians	sd	Main Square	*F*	*p*
Low	13	4.41	1.34	Between groups	2	5.82		
Middle	31	3.48	0.72	Within groups	97	0.76	7.59	0.01
High	56	3.37	0.82	Total	99			

VAS: visual analogue scale; N: N factorial; X: Independent variable; Ss: Sum of Squares; sd: Standart deviation.

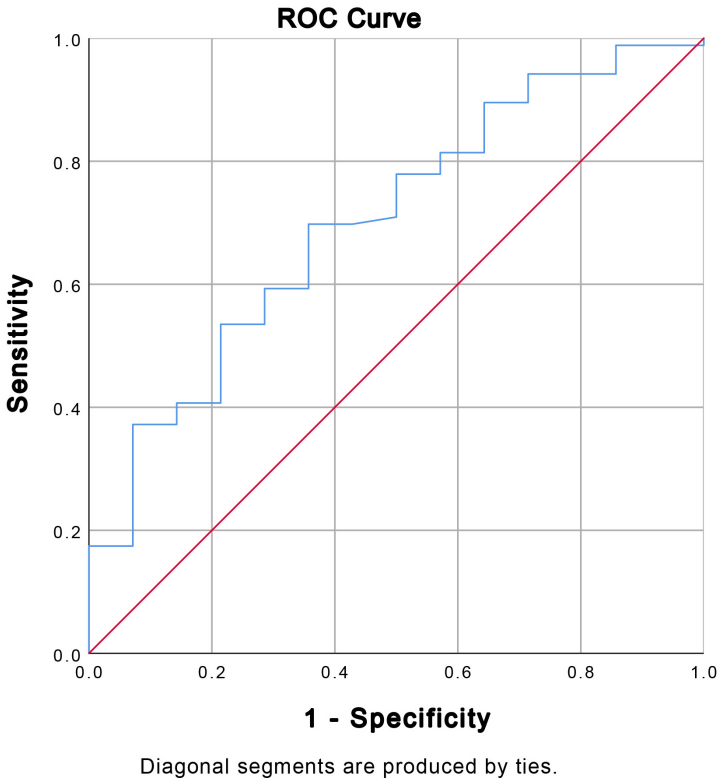

FIGURE 2. ROC analysis. ROC: Receiver Operating Characteristic.

[8, 9]. Some studies have measured the relationship between PI and postoperative analgesia. Some studies in which the clinical severity of pain is reduced show that the PI increases in these patients [10, 11]. However, the PI value, which provides an assessment of peripheral circulation, may increase in patients with hypertension and in patients with relatively elevated blood pressure [12]. In this case, the observation of an increase in PI in patients with hypertension postoperative pain and the clinical relationship of follow-up in groups of patients with hypertension compared with other patients form the basis of our study.

Some studies have found PI to be an effective objective measure of pain. In these studies, PI values were shown to decrease as a result of pain-induced sympathetic vasoconstriction [13, 14]. In the literature, there has been little or no correlation between the change in postoperative PI and the use of postoperative analgesia [15].

Other factors influencing PI are the balance between vasodilation and vasoconstriction and IV fluid status. Clinically, it is known that the PI value increases with the development of vasodilatation and the attainment of optimal values of IV fluid status. This is supported by evidence that PI increases after peripheral nerve blocks and in clinical situations such as passive leg raising [16, 17].

In our study, patients who received IV hydration in the preoperative period were included in the surgical procedure. There was no statistical difference between the PVI values in the groups of patients with and without hypertension. This is useful for measuring the effectiveness of IV hydration in patient groups. Although the PVI values were similar, the postoperative PI value was statistically higher in the group with hypertension than in the group without hypertension (Fig. 1). According to other results, there was no statistical difference between the MAP value before and after analgesia. On the other hand, PVI and PI were statistically higher and VAS was lower after analgesia (Table 2). This supports the view that the vasodilator effect caused by the analgesic effect leads to an increase in PI. There was a statistical difference between the relative change in PI value (ΔPI) in patients with low (1–3), medium (4–6) and high (7–10) VAS 0 scores. *Post hoc* Bonferroni correction showed that this difference was observed in patients with high VAS scores (Table 3). The ability of the relative variability of the PI score to predict the need for postoperative analgesia was analyzed. An ROC curve was constructed. The area under the ROC curve showed a sensitivity of 64% and a specificity of 37% with a positive predictive value of 86%. 56–84% confidence interval (p: 0.016). The cut-off value according to the maximum Youden index was 0.73 (Fig. 2).

The limitation of the study is that it was restricted to a population of patients undergoing abdominal surgery by laparotomy. Another limitation is that the effect of antihypertensive treatment on postoperative hypotension is evident in patients receiving antihypertensive treatment on the same day, especially in patients receiving calcium channel blockers [12].

5. Conclusions

The use of PI as a pain measurement tool can be used as an adjunct to postoperative pain. This may not be accurately measured in patients taking vasodilators or vasoconstrictors. For this purpose, the use of PI and VAS correlation and the maintenance of PVI values used to monitor fluid status in patients with hypertension at optimal levels will be useful in prospective observational studies.

AVAILABILITY OF DATA AND MATERIALS

The data presented in this study are available on reasonable request from the corresponding author.

AUTHOR CONTRIBUTIONS

HTD and MK1—conducted the trial conception and design the trial. MK1, OÖK, OH and İCD—collected the data. HTD—analyzed the data. HTD, MKa, ST—wrote the draft. All authors read and approved the final manuscript. All authors contributed to editorial changes in the manuscript. All authors read and approved the final manuscript.

ETHICS APPROVAL AND CONSENT TO PARTICIPATE

All patients were informed about the study and they gave their written informed consent. The study was conducted at Amasya Sabuncuoğlu Şerefettin Training and Research Hospital and approved by the ethics committee with the number 2023000037-1 and was registered at ClinicalTrials.gov (protocol ID: 76988455-050, Identification No NCT06535581).

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

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