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Original Article

Correlation Between Baseline Perfusion Index and Post-Spinal Hypotension in Patients Undregoing Orthopaedic Surgery

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ABSTRACT

Objective: To determine the correlation between baseline perfusion index and post-spinal hypotension.
Study Design: Prospective longitudinal study
Place and Duration of Study: Combined Military Hospital, Rawalpindi from April to July, 2021.
Methodology: Male and female ASA I and II adult patients undergoing elective orthopaedic surgery under spinal anaesthesia were included in the study. Non-randomized, consecutive sampling was used. Brachial Non Invasive Blood Pressure (NIBP) was measured before administration of spinal anaesthesia and immediately post-spinal plus 2 additional readings at 3 minute intervals. Lowest post-spinal NIBP reading for a subject was considered in determining occurrence of hypotension. Hypotension was defined as either a drop of systolic B.P. to 100 mmHg or lower, or a drop to 80% baseline or lower.
Results: Of the 371 subjects, 189(50.9%) were male. Mean age was 47.19±18.93 years. 203(54.7%) subjects were ASA I. Most frequently performed procedure was Knee Arthroscopy (n=54 [14.6%]). Mean Perfusion Index at baseline was 3.52±2.05 (from 0.3 to 7.7). At baseline, mean systolic B.P. was 135.53±17.12 mmHg, mean diastolic B.P. was 76.10 ±12.27 mmHg, and mean MAP was 95.92±10.09 mmHg. Post-spinal mean values were 112.37±17.24 mmHg for systolic, 68.19±11.65 mmHg for diastolic, and 82.60±10.85 mmHg for MAP, respectively. Overall, 201(54.2%) of the subjects exhibited post-spinal hypotension. Correlation between PI and Post-spinal Hypotension revealed a statistically significant association (p =0.043).
Conclusion: A higher PI score at baseline could have predictive value for development of post-spinal hypotension in orthopaedic procedures. Further studies are needed to determine utility of PI as a predictor of post-spinal hypotension.

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INTRODUCTION

Clinical assessment of tissue perfusion can be done by measuring skin temperature, paleness, mottling, and capillary refill time. Biochemically, global tissue perfusion can be assessed by measuring serum lactate and central venous oxygen saturation.[1] Clinical assessments are subjective and biochemical assessments are invasive, require more time and resources. The optimal method of estimating tissue perfusion would be one that is non-invasive, fast, and easy to measure. Tissue perfusion can be estimated by calculating perfusion index (PI) with a pulse oximeter. PI is the non-pulsatile flow rate of the pulsatile flow and a pulse oximeter is used to measure changes in peripheral perfusion.[2] PI is a quick biomarker of microcirculatory alterations that anaesthetists might use to detect circulation status.[3] PI is the ratio of pulsatile blood flow to non-pulsatile blood flow in peripheral tissue. PI is computed by dividing the amplitude of the pulsatile component (arterial compartment) by the amplitude of the nonpulsatile component (venous and capillary blood, and other tissues) of the light reaching the pulse oximeter sensors.[4] The ratio is unaffected by the oxygen saturation of haemoglobin. The ratio changes because a change in peripheral vasomotor tone largely induces a corresponding change in the pulsatile component of the signal. As a result, the PI value reflects changes in peripheral vasomotor tone. The PI is a measurement of pulse strength at the site the sensor is attached to.[5] Cardiac output and the balance between the sympathetic and parasympathetic nervous systems are the two key determinants of PI values and is a representation of those two primary hemodynamic parameters.[6] The typical PI value was thought to be between 0.2 and 20%; however, an observational study found that the median normal PI value was 4.3 (2.9–6.2).[7] Patients, physiological factors, and monitoring sites all influence the perfusion index. Because the PI values are extremely skewed, it is more typically used

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for follow-up than the baseline measurements of each individual.[8,9] PI has been used in surgical and critical care settings to predict and monitor hypovolemia and hypotension. A study looking into the link between PI and the need for blood transfusions in the first 24 hours and at different stages of haemorrhagic shock in trauma patients found that PI could help with the detection and prioritization of critical patients, and with estimating blood transfusion demands. Authors concluded that in the early identification of bleeding, PI can be used with vital signs and other shock markers.[10] Hypotension during dialysis is a serious complication. Early prediction of allows adequate prophylactic measures. In patients undergoing haemodialysis, PI has been studied as a predictor for development of hypotension and it was found to be consistent and reliable.[11,12] The reliability of PI has increased to the point where anaesthesiologists are starting to look into other ways they might use it to help their patients. PI has become a valuable diagnostic and monitoring tool in the operation theatre, with uses in a variety of surgical settings. An increase in PI has been demonstrated in studies to be an early indicator that general anaesthesia has started peripheral blood vessel dilatation, which usually occurs before anaesthesia begins.[13,14] PI has long been thought to be a valuable instrument for accurately monitoring changes in peripheral perfusion after neuraxial anaesthesia. Increased PI is considered a sign that neuraxial anaesthesia has started peripheral vasodilation, which happens before the anaesthetic fully takes effect. In contrast, no increase in PI in a patient who has been given anaesthetic could be a sign of anaesthetic failure.[15-17] Post-spinal hypotension (PSH) is a common problem in surgical settings.[18] Studies have found that PI changes can predict development of hypotension after spinal anaesthesia in different surgeries and patient populations.[18-23] Even before administration of spinal anaesthetic, decreased peripheral vascular tone as represented by a higher baseline PI could cause blood volume to be trapped in the extremities, and after the spinal anaesthesia, sympathetic blocking with spinal anaesthesia would exacerbate the blood pooling, exacerbating the hypotension. As a result, patients with lower baseline vascular tone may be more likely to suffer hypotension following spinal anaesthesia. Limited research has been conducted to investigate the effects of PI on probability of developing hypotension during orthopaedic surgeries in our local population. The aim of this pilot study was to determine whether baseline PI correlates with the development of PSH for orthopaedic surgery and whether baseline PI can predict such hypotension. The results of this study will add to the body of knowledge on utility of PI as a predictor of PSH and will assist local anaesthesiologists in considering PI as a diagnostic and monitoring tool in the operation theatre.

METHODOLOGY

This Prospective longitudinal studywas conducted at Department of Anaesthesiology, Combined Military Hospital, Rawalpindi, June to November, 2021 after approval from Ethics Committee IERB no 224. Non-probability, consecutive sampling technique was employed for this pilot study with convenience sampling and non-experimental design. A total of 371 adult male or female subjects were included in the study. Sample size was calculated with World Health Organization sample size calculator for health studies. Sample size was calculated using PSH rate of 40% from the literature and employing proportions reported by the study18. Alpha (α) (2-sided): 5%; Confidence Level: 95%; Beta (β): 20%; Power (1-β): 80%.

Inclusion Criteria: Subjects falling in American Society of Anaesthesiologists (ASA) categories I and II, and undergoing elective orthopaedic surgery under spinal anaesthesia.

Exclusion Criteria: Subjects were excluded from the study if the subject were undergoing emergency surgery, required general anaesthesia for surgery, exhibited pre-spinal hypotension, had peripheral vascular disease or history of cardiac dysrhythmias, or had fever (oral temperature of 990F or higher).

Informed consent was taken and documented from patients fulfilling subject selection criteria, ensuring confidentiality. Baseline demographics, vital signs, date, time, ASA score and type of surgery were recorded. Brachial NIBP was measured before administration of spinal anaesthesia and immediately post-spinal plus 2 additional readings were taken at 3 minute intervals. Lowest post-spinal NIBP reading for a subject was considered in determining occurrence of hypotension. Spinal anaesthesia was administered using a 26 or 27 gauge Quincke or pencil point spinal needle at the level of either intervertebral space between lumbar vertebrae 3 & 4, or 4 & 5, in sitting position with intrathecal administration of 2.5 mL of 0.5% hyperbaric bupivacaine. PSH was defined as either a drop of systolic blood pressure to 100 mmHg or lower, or a drop of systolic blood pressure to 80% baseline or lower. PI was measured by the standard pulse oximeter being used in each operation theatre.

Data were analysed in Statistical Package for the Social Sciences (SPSS) version 23.00. For each group, descriptive statistics (frequency and percentages) were computed for categorical variables like ASA score and type of surgery. Mean ± Standard Deviation (SD) were presented for quantitative variables like age, duration of surgery, and baseline PI. Chi square and independent t-test were to determine the relationship between PI and PSH. The p value ≤ 0.05 was considered significant.

RESULTS

Of the 371 subjects, 189(50.9%) were male. Mean age was 47.19 ± 18.93 years. 203(54.7%) subjects fell into ASA physical status category I. There were no significant differences between the group of patients that developed PSH and the group which did not in terms of baseline characteristics. Table I summarizes the two groups in terms of baseline characteristics and their respective correlations with development of PSH. Mean PI at baseline was 3.52 ± 2.05 (from 0.3 to 7.7). At baseline, mean systolic B.P. was 135.53 ±17.12 mmHg, mean diastolic B.P. was 76.10±12.27 mmHg, and mean MAP was 95.92±10.09 mmHg. Post-spinal, mean values were 112.37±17.24 mmHg for systolic, 68.19 ± 11.65 mmHg for diastolic, and 82.60 ± 9.68 mmHg for MAP, respectively. Overall, 201(54.2%) subjects exhibited PSH. Correlation between baseline PI and development of PSH was found to be statistically significant (p=0.043) (Table – I). The most frequently performed procedure was Knee Arthroscopy (n=54 [14.6%]). There was no significant difference between the group of patients that developed PSH and the group which did not in terms of type of surgery performed (p=0.347) or the duration of surgery (p = 0.741). The distribution of type and duration of surgery within each group is summarized in Table–II.

DISCUSSION

PI, which is a non-invasive approach, is the ratio between non-pulsatile flow rate and the pulsatile flow rate. Peripheral PI based on pulse oximetry signal processing has been used as a measure of peripheral perfusion in surgical settings. Previous studies have evaluated the usefulness of monitoring PI for early detection of effectiveness of spinal and epidural anaesthesia as well as various nerve blocks. PI has also been studied as a tool to predict the development of post-spinal and post epidural hypotension which is a very commonly occurring phenomenon. In a prospective observational study which evaluated role of PI in prediction of hypotension following spinal anaesthesia in lower segment caesarean section

106 subjects were included.[19] The authors divided the subjects into two groups based on their baseline PI values. Subjects with value < 3.5 were assigned to the low PI group while those with baseline PI ≥ 3.5 were assigned to high PI group. Pre and post-spinal blood pressure values were monitored recorded and a comparison between the two groups was done. The authors found that 26% of the subjects in the lower PI group developed PSH whereas 48% of the subjects did so in the high PI group. The authors found a significant correlation between baseline PI of >3.5 and development of PSH (rs = 0.26 and p<0.05). The results of this study are similar to our findings in that we also found a statistically significant correlation between a higher baseline PI value and development of PSH but the methodology differed in that we did not use a cut-off value to divide patients into low and high baseline PI groups and used point biserial correlation to detect statistical significance. Another prospective observational study that evaluated the role of PI in predicting occurrence of hypotension during spinal anaesthesia in lower segment caesarean section involved 63 subjects undergoing elective surgery.[20] Baseline PI via pulse oximetry and NIBP were measured for each subject prior to administration of spinal anaesthesia. Serial post-spinal NIBP measurements were taken. The authors defined hypotension as more than 25% decrease from the baseline value in systolic blood pressure. The results showed that a significant correlation existed between the baseline PI value and the occurrence of PSH (p<0.001). The authors further plotted a Receiver Operating Characteristic (ROC) curve for the baseline PI values against the occurrence of PSH and calculated that for prediction of PSH, cut-off value baseline PI value was 1.75. The results of this study are consistent with our findings in that they demonstrate a significant correlation between baseline PI value and presence of PSH. Our study design did not include calculation of a cut-off value of PI for optimal prediction of incidence of PSH using an ROC curve. Association between PI and PSH was investigated by the authors of another study in which they selected subjects undergoing elective caesarean.[21] The primary purpose of this research was to see if PI trend could detect hypotension before NIBP values altered. 109 subjects with a singleton foetus who had an elective caesarean section and an ASA status of I or II were included in this study. Emergency surgeries, subjects with morbid obesity, pre or post term

Table-I: Baseline Patient Characteristics and Correlation with Post-Spinal Hypotension (n=371)

			Post-spinal Hypotension				*p*-value
	Overall		Yes		No		
Baseline Characteristics	n (%)		n (%)		n (%)		
Sex	Male	Female	Male	Female	Male	Female	
	189(50.9%)	182(40.9)	104(28.0%)	97(26.1%)	85(22.9%)	85(22.9)	0.755
ASA Category	ASA I	ASA II	ASA I	ASA II	ASA I	ASA II	
	203(54.7%)	168(45.3%)	111(29.9%)	90(24.3%)	92(24.8%)	78(21.0%)	0.835
	Mean±SD		Mean± SD		Mean ± SD		
Age (Years)	47.19±18.93		47.69±19.42		46.60±18.378		0.582
Heart Rate (beats/min)	95.34±19.79		94.81±20.10		95.97±19.45		0.573
Body Surface Temperature (°C)	37.03±0.06		37.03±0.06		37.02±0.06		0.653
Respiratory Rate (breaths/min)	20.52±4.58		20.48±4.78		20.56±4.34		0.873
Systolic Blood Pressure (mmHg)	135.53±17.12		138.85±17.03		131.61±16.42		0.072
Diastolic Blood Pressure (mmHg)	76.10±12.27		75.99±12.39		76.23±12.16		0.852
Mean Arterial Pressure (mmHg)	95.92±10.09		96.94±9.90		94.72±10.19		0.061
Perfusion Index	3.52±2.05		3.71±2.12		3.28±1.96		0.043

Table-II: Correlation of Type and Duration of Surgery with Post-Spinal Hypotension (n=371)

			Post-spinal Hypotension		*p*-value
		Overall	Yes	No	
		n (%)	n (%)	n (%)	
Type of Surgery	Knee Arthroscopy	54(14.6%)	25(6.7%)	29 (7.8%)	0.347
	Sliding Hip Screw Femur	48(12.9%)	26(7.0%)	22 (5.9%)	
	Total Hip Replacement	44(11.9%)	22(5.9%)	22 (5.9%)	
	Open Reduction Internal Fixation Tibia/Fibula	42(11.3%)	22(5.9%)	20 (5.4%)	
	Hip Hemiarthroplasty	40(10.8%)	18(4.9%)	22 (5.9%)	
	Cannulated Screw Femur	37(10.0%)	22(5.9%)	15 (4.0%)	
	Knee ACL Reconstruction	36(9.7%)	20(5.4%)	16 (4.3%)	
	Intramedullary Nail Femur	36(9.7%)	22(5.9%)	14 (3.8%)	
	Total Knee Replacement	34(9.2%)	24(6.5%)	10 (2.7%)	
Total		371(100.0%)	201(54.2%)	170(45.8)	
Duration of Surgery (min)		Mean ± Standard Deviation			0.741
			Post-spinal Hypotension		
		Overall	Yes	No	
		69.98±10.41	69.81±10.40	70.17±10.44	

pregnancies, any heart pathology, and obstetric complications including foetal growth abnormalities, were excluded from this observational study. The authors employed by using the point biserial correlation coefficient (Pearson's) to measure the strength and direction of association between the baseline PI values and the incidence of PSH. Data analyses revealed that subjects with hypotension had higher baseline PI readings which increased more quickly on average. Higher PI was found to be associated with lower systolic and mean arterial and the correlation was significant at the 0.01 level. These findings add further evidence to the utility of monitoring PI for prevention of post-anaesthesia hypotension. Most of the studies examining correlation between PI and PSH involved subjects undergoing caesarean section. Some studies, however, were conducted among patients who underwent other surgeries. One such study was designed to explore the relation between baseline PI and hemodynamic changes, including the probability of development of hypotension, after administration of spinal anaesthesia

in lower abdominal surgeries.[22] This was a prospective randomised observational research in which 120 subjects were divided into two groups based on their baseline PI. Subjects in one group had baseline PI of <3.5 and those in the second group had baseline PI ≥ 3.5. Hypotension was defined as mean arterial blood pressure reading of less than 65 mmHg. Incidence of PSH was found to be 12.3% in the low baseline PI group while it was 74.6% in high baseline PI group. This was a statistically significant difference ($p < 0.001$). The authors plotted an ROC curve as well mapping baseline PI values against incidence of PSH. In this investigation, the ROC curve revealed a baseline PI value of 3.3 as the cut-off point for predicting PSH. For the prediction of hypotension, the area under the ROC curve was 0.912. The sensitivity of a baseline PI ≥ 3.3 for detecting PSH was 75.4% and specificity 94.1 %. The authors concluded that baseline PI was a valuable parameter for identifying surgical patients at risk of developing PSH. These findings are in line with our findings in that we also found that a higher baseline PI strongly correlated with development of PSH in surgical patients, however, ROC mapping was not a part of our statistical analysis. The authors used mean arterial pressure as their operational definition for hypotension whereas in our study we based it on systolic blood pressure. The cut-off value of baseline PI for prediction of PSH calculated by these authors (3.3) was close to the value (3.5) calculated by Pradhan *et al*.[19] but not to the value (1.75) calculated by Jabarulla et al20. The issue of diminished vascular tone and venous pooling under spinal anaesthesia makes geriatric patients even more at risk of developing hypotension which may become significant. It is therefore critical to recognise and treat PSH in the elderly. A study looked at the predictive usefulness of baseline PI levels in geriatric individuals with PSH.[23] The efficacy of the baseline PI to predict the occurrence of hypotension in elderly individuals was investigated in this study. This research comprised 80 subjects over the age of 65 who underwent general and orthopaedic surgery under spinal anaesthesia. Baseline PI readings, as well as pre and post-operative systolic blood pressure were compared. Hypotension was defined as 30% or more reduction in systolic blood pressure compared to the baseline. The authors did not find a statistically significant relationship between basal PI value and development of PSH. Using an ROC analysis with Confidence Interval of 95%, the AUC was found to be 0.655 and the *p*-value was 0.056. Therefore the authors concluded that in geriatric patients, baseline PI was not a useful test to predict occurrence of PSH. They did, however, note that higher baseline PI values could predict lower post-spinal systolic blood pressure values ($r = -0.155$, $p=0.041$). Our study includes 84(38.9%) subjects aged 65 and above. In our subgroup analysis of geriatric subjects, we also did not find a statistically significant correlation between baseline PI value and incidence of PSH ($r=0.213$, $p=0.053$). The lack of an experimental design, limited sample size, and single research centre are limitations of our work. The findings are significant, however, because there is no data on the use of PI as a predictor of PSH in our local patient population. Our research contributes to the corpus of knowledge on PI, and the findings will aid anaesthesiologists in identifying individuals at risk of developing PSH. According to the findings, looking at a basic non-invasive parameter before induction can anticipate and avoid the development of PSH, which is a key concern for anaesthesiologists. More research is needed to discover whether PI has broader therapeutic uses.

CONCLUSION

A higher PI score at baseline could have predictive value for development of PSH in orthopaedic procedures. Further studies are needed to determine utility of PI as a predictor of PSH.

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Authors' Contribution

Following authors have made substantial contributions to the manuscript as under:

MAS & SAK: Data acquisition, data analysis, critical review, approval of the final version to be published.

BY & SQAS: Study design, data interpretation, drafting the manuscript, critical review, approval of the final version to be published.

HMM & WT: Conception, data acquisition, drafting the manuscript, approval of the final version to be published.

Authors agree to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

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