



Evaluation of Pulse Oximeter Perfusion Index as an Indicator of Successful Supraclavicular Brachial Plexus Block in Adult Patients Posted for Elective Upper Limb Surgeries

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ABSTRACT:

Background: Regional anaesthesia has been a part of perioperative medicine for more than a century. Ultrasound guided supraclavicular brachial plexus block is a common technique of regional anaesthesia. The subjective methods to predict success of a block such as assessment of sensory and motor functions are time consuming and depend on patient co-operation. The objective methods available are either time consuming or dependent on sophisticated equipment. The goal of this study was to determine whether the perfusion index (PI) can be used to predict block success and to provide a cut-off value for ultrasound guided supraclavicular brachial plexus block success.

Method: 100 patients belonging to American Society of Anaesthesiologists Physical Status (ASA PS) class I and II scheduled for elective hand, wrist and forearm procedure were selected. Ultrasound guided supraclavicular brachial plexus block was performed using 12ml of 0.5% Bupivacaine + 12ml of 2% Lignocaine with adrenaline and PI recorded from 10 min before injection of local anaesthetic (LA) to the brachial plexus to 30 min following block termination at



5 min intervals in both blocked and contralateral unblocked limb while simultaneously assessing both the limbs for sensory and motor weakness thus block success.

Results: At all-time points the PI and PI ratio was higher in the blocked limb when compared with the unblocked limb. The PI at 10 min showed a sensitivity of 73.3% and specificity of 100% for block success at a value of 7.2 and PI ratio showed a sensitivity of 87.8% and specificity of 100% at a cut-off value of 2.26

Conclusion: The PI provides a valuable tool for evaluation of a successful ultrasound guided supraclavicular brachial plexus block. A PI ratio of >2.26 is a good predictor of block success.

INTRODUCTION:

Supraclavicular brachial plexus block is a commonly used regional anaesthetic technique, favoured for its rapid onset and reliable anaesthesia. It is particularly effective for surgeries on the upper extremity, excluding the shoulder. Traditionally, the adequacy of the block is assessed by loss of sensory and motor response, a process that is time-consuming, subjective, and dependent on patient cooperation. Objective methods to assess block success involve evaluating sympathetic block and autonomic innervation, which lead to physiological changes such as local vasodilation, increased blood flow, and elevated skin temperature. However, many of these methods require sophisticated equipment or are time-intensive (1,2).

The perfusion index (PI) is a numerical value that represents the ratio of pulsatile to non-pulsatile blood flow, as measured by pulse oximetry. PI values range from 0.02% for weak pulse strength to 20% for strong pulse strength, with variations dependent on physiological conditions, ambient temperature, and monitoring sites (3,4). Given the variability in baseline PI, it is essential for each patient to establish their own baseline at a specific location. To mitigate baseline variability, Abdelnasser et al. introduced the PI ratio, which is calculated by dividing the PI at 10 minutes post-block by the baseline PI (5). This timeframe was chosen because previous studies showed the most significant increase in PI occurred within 10 minutes of block administration.

Previous studies have indicated that increased PI serves as an early marker of peripheral vasodilation following regional anaesthesia, often preceding the sensory effects. Consequently, a failure to observe an increase in PI may indicate anaesthetic failure (6). PI has also been used in neonatal acute care as a reliable indicator of illness severity and peripheral perfusion (7). Despite promising results, baseline PI variability and high cut-off values have led to inaccurate predictions of block success. Our study aims to further explore the utility of PI and PI ratio in predicting the success of ultrasound-guided supraclavicular brachial plexus blocks and establish a more precise cut-off value.

Primary Objective: To assess perfusion index as a reliable and objective predictor of a successful block in terms of complete sensory and motor block of the arm.

Secondary Objective: To provide a cut-off value for the perfusion index and perfusion index ratio for prediction of a successful block.

MATERIAL AND METHODS:

The present study was a prospective observational study conducted on 100 patients of American Society of Anaesthesiologists Physical Status (ASA PS) I or II, who underwent elective hand, wrist, and forearm procedures at JSS Medical College and Hospital, Mysuru, between November 2018 and October 2019. The sample size estimation was performed using MedCalc software at a 99% confidence level and a 90% power of the study. The significance level (α) was set at 0.010, and the area under the ROC curve (AUC) was 0.95, based



on the findings of Abdelnasser et al., which identified the brachial plexus perfusion index (PI) ratio as a predictor of successful block. The estimated sample size was 95, which was rounded up to 100 to ensure sufficient power.

The study included patients aged 18 to 60 years who were classified as ASA PS I or II and were scheduled for elective hand, wrist, or forearm procedures under ultrasound-guided supraclavicular brachial plexus block. Exclusion criteria included contraindications to supraclavicular brachial plexus block, pre-existing abnormal neurological or vascular conditions in either arm (such as stroke, spasticity, peripheral vascular disease, diabetes, arteriovenous fistulas, or extensive burn wounds), crush injuries to the fingers, vascular injuries of the upper limb, morbid obesity, anatomical abnormalities of the neck, and known allergic reactions to local anaesthetics. The study was approved by the Institutional Ethical Committee (IEC), and written informed consent was obtained from all participating patients prior to the procedure.

A thorough pre-anaesthetic evaluation was conducted 24 hours prior to the scheduled surgery, and written informed consent was taken. In the operating room, patients were monitored using electrocardiography, automated non-invasive blood pressure (NIBP) monitoring, and pulse oximetry. Premedication was administered, consisting of Inj. Midazolam 0.02 mg/kg IV and Inj. Fentanyl 1 mcg/kg IV. To measure PI, two MIGHTYSAT pulse oximeters were applied to the index fingers of both the blocked and non-blocked limbs 10 minutes before block administration, and baseline PI values were recorded. The ambient temperature of the operating room was maintained at 23-24°C to control for external factors that might influence PI measurements.

The supraclavicular brachial plexus block was administered by an experienced anaesthesiologist with expertise in performing at least 25 successful supraclavicular brachial plexus blocks. The patient was positioned supine with the head turned away from the side to be blocked, and ultrasound guidance was used to visualize the brachial plexus

above the clavicle. After identification of the brachial plexus, a total volume of 24 ml of local anaesthetic (12 ml of 0.5% Inj. Bupivacaine combined with 12 ml of 2% Inj. Lignocaine with adrenaline at a 1:200,000 concentration) was injected perineurally under direct visualization to surround all identified nerve cords. PI measurements were recorded from 10 minutes before block administration (defined as -10 minutes), 5 minutes before block (-5 minutes, baseline), at the time of block (0 minutes), and at 5-minute intervals after the block for a total of 30 minutes (5, 10, 15, 20, 25, and 30 minutes) on both the blocked and non-blocked limbs.

Block success was assessed every 3 minutes for sensory block and every 5 minutes for motor block. Sensory block assessment involved pinching the dermatomal areas supplied by the four major nerves of the upper limb: the median nerve, ulnar nerve, radial nerve, and musculocutaneous nerve. Motor block was evaluated based on the patient's ability to flex the hand and elbow against gravity. If the patient exhibited complete loss of sensation over the surgical area, the block was considered successful. Conversely, if the patient reported pain at the time of assessment or required supplemental analgesia or conversion to general anaesthesia, the block was deemed a failure. The PI ratio, defined as the ratio of the PI value at 10 minutes post-block to the baseline PI value recorded 5 minutes before block administration, was calculated for both limbs. A comparison of PI values between the blocked and non-blocked limbs was performed for all patients.

Data analysis was carried out using R software version 3.5.2. Both comparative and descriptive statistical analyses were conducted. The Mann Whitney U test was applied to compare baseline PI values and PI ratios between successful and failed blocks. The Wilcoxon rank sum test with continuity correction was used to compare PI values at the time of block application between the blocked and non-blocked limbs, as well as to compare mean PI values at 0 minutes with those at 5 and 10 minutes in both limbs. A p-value of less than 0.05 was considered statistically significant.



To assess the predictive ability of the PI ratio for block success or failure, a receiver operating characteristic (ROC) curve was constructed. The ROC curve compared the ability of the PI at 10 minutes and the PI ratio to differentiate between successful and failed blocks.

RESULTS:

In the study 71% patients were males and 29% patients were females with mean age being $38.01 \pm$

12.74 and BMI being 24.85 ± 3.05 . There was nothing significant in the demographic profile of the patients. Among the 100 blocks performed, 90% of blocks were successful and 10% of blocks were considered a failure. **Average PI Ratio:** In our study, the average PI ratio of the blocked limb 4.7 (1.1-29.2) was significantly higher than that of the non-blocked limb 1(0.78-1.56).

Table 1: Perfusion index at different periods of follow-up

Perfusion index	Blocked Arm	Non-Blocked Arm	P value
Baseline	1.9 (0.22-7)	1.8 (0.19-6)	0.936
5 Min	6.32 (0.35-14)	12.12 (0.2-6.5)	<0.001*
10 Min	9.25 (0.48-20)	1.75 (0.21-6)	<0.001*
15 Min	10 (0.51-22)	1.7 (0.19-5.8)	<0.001*
20 Min	11 (0.56-23)	1.75 (0.2-6.2)	<0.001*
25 Min	11.5 (0.55-24)	1.8 (0.2-6.5)	<0.001*
30 Min	12 (0.56-24)	1.9 (0.23-6.4)	<0.001*

Mann Whitney U test

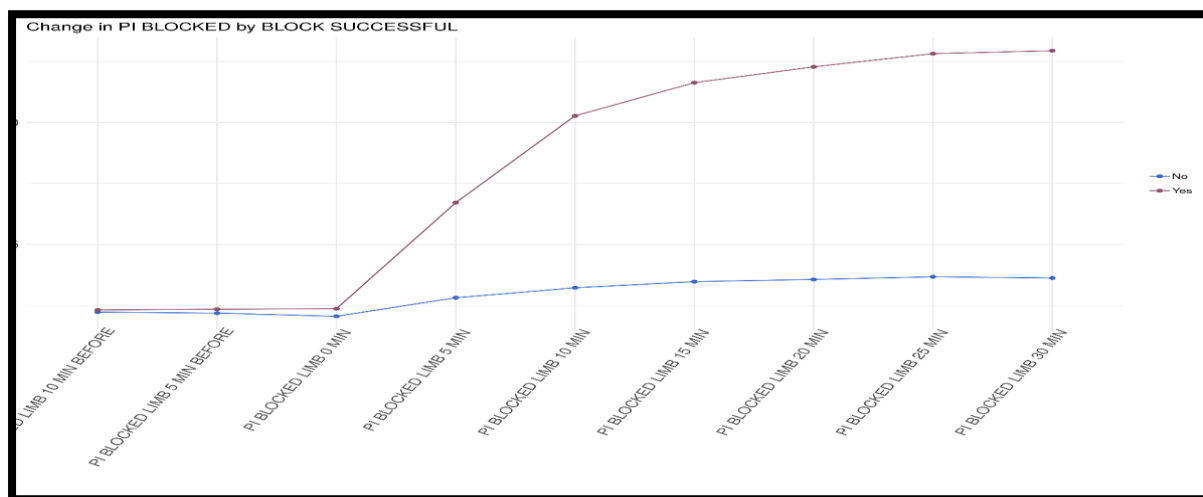


Figure 1: Line diagram showing Change in PI comparison between block successful and block failure group

Area under the for-perfusion index at 10 min to determine successful and a failed block showed the area under the curve was 0.92 and standard error of 0.03 with 95% confidence interval, p value was

<0.0001* for PI at 10 min. The perfusion index at 10 min showed a sensitivity of 73.3% and a specificity of 100% for block success with a cut-off value of 7.2.

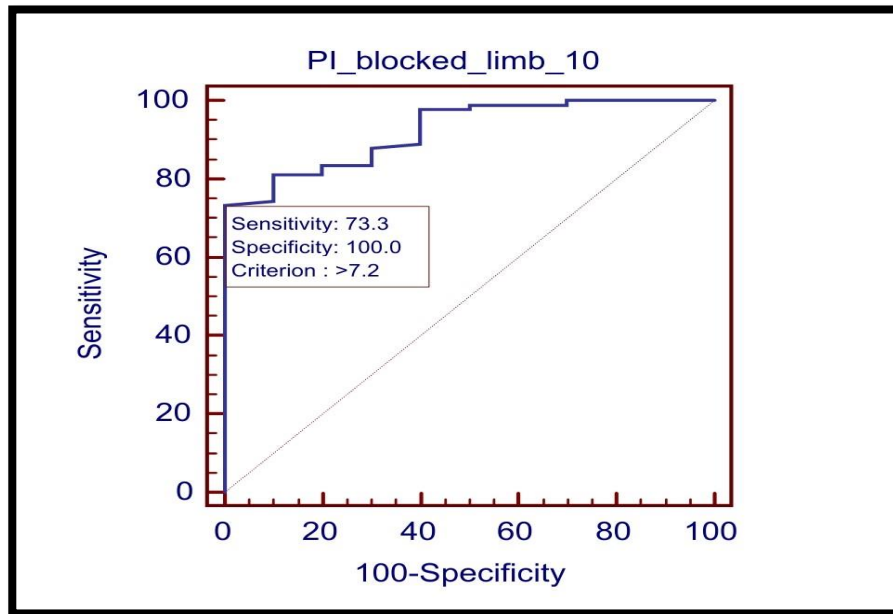


Figure 2: ROC curve to determine the ability of the perfusion index at 10 min to detect a successful and a failed block.

PI Ratio had an area under the curve of 0.95 and standard error of 0.02 with 95% confidence interval, the p value was <0.0001 for PI ratio. The

PI ratio showed a sensitivity of 87.8% and a specificity of 100% for block success at a cut-off value of 2.26.

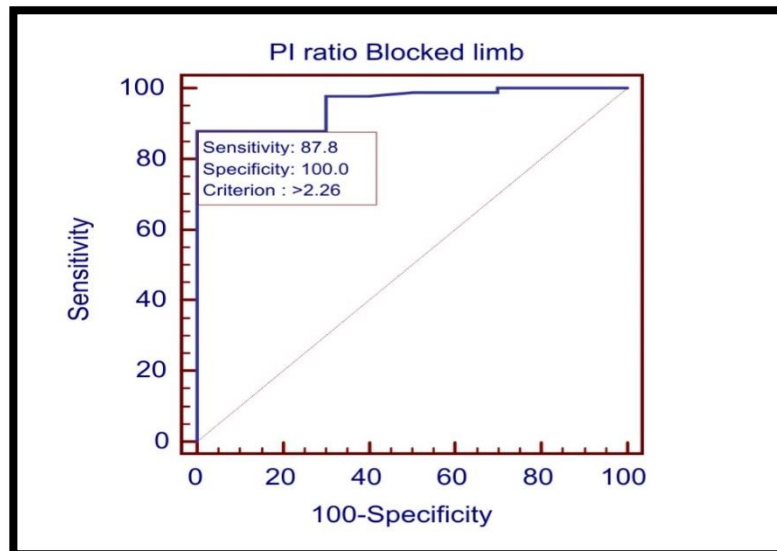


Figure 3: ROC curve to determine the ability of the PI Ratio to detect a successful and a failed block.



DISCUSSION:

The present study was conducted on 100 patients classified as ASA PS I/II who underwent elective hand, wrist, and forearm surgeries under ultrasound-guided supraclavicular brachial plexus block at JSS Medical College and Hospital, Mysuru. The patients' demographics revealed that the majority were male (71 males and 29 females), with an average age of 38.01 years and a mean BMI of 24.85. The demographic data showed no significant differences that could influence the outcomes of the study. The primary aim was to evaluate the efficacy of the PI and PI ratio in predicting the success of the block. Of the 100 blocks performed, 90 were deemed successful, while 10 blocks failed as patients reported pain during the assessment, requiring either supplemental analgesia or conversion to general anaesthesia.

The reasons for block failure can be multifactorial. In regional anaesthesia, failure is often due to the incorrect identification of the target nerve or incomplete coverage of all the necessary nerves for the surgical procedure. The block can be misdirected, where local anaesthetic (LA) is injected into an incorrect fascial or muscular plane, patchy, where some regions of the plexus distribution are not effectively blocked, or incomplete, where the patient experiences numbness but not to a degree sufficient for surgery. Similar findings were reported in the study conducted by Abdelnasser et al., where a failure rate of 10% was observed among 77 patients who underwent ultrasound-guided supraclavicular brachial plexus block, which aligns with the findings in our study (5).

Baseline Perfusion Index (PI): In this study, the baseline PI in the blocked limb was 1.9 (range: 0.22-7), and in the non-blocked limb, it was 1.8 (range: 0.19-6). No significant difference was observed between the baseline PIs of the two limbs. In the study by Abdelnasser et al., the baseline PI was slightly higher, with the blocked limb showing a PI of 2.7 (range: 1.5-4.3) and the non-blocked limb showing a PI of 2.7 (range: 1.5-4.5), which is consistent with our findings (5). The slight increase in baseline PI values in our study could be attributed to local vascular changes following injury, as observed in other studies, including that by Loretta Raj et al., where the baseline PI in the blocked arm was 1.35 (range: 0.3-2.4) and in the non-blocked arm, it was 1.15 (range: 0.2-3.42) (7).

Perfusion Index after Block Application: PI values were recorded at multiple time points (0, 5, 10, 15, 20, 25, and 30 minutes) in both the blocked and non-blocked limbs. In patients with a successful block, PI values in the blocked limb increased significantly from baseline throughout the 30-minute observation period, whereas no significant changes were observed in the non-blocked limb or in the blocked limb of patients with a failed block. The most significant increase in PI values occurred within the first 10 minutes of block application, which suggests that PI can be a reliable early indicator of block success.

At the 5-minute mark, the PI in the blocked limb increased to 6.32 (range: 0.35-14) from the baseline of 1.9 (range: 0.22-7), while in the non-blocked limb, it remained relatively stable at 1.2 (range: 0.2-6.5). In a similar study by Kim et al., the PI at 5 minutes in the blocked limb (non-epinephrine group) increased to 13 (range: 9.4-18) from a baseline of 5.4 (range: 3-7.5), while in the non-blocked limb, it was 4.9 (range: 3-6.1) at 5 minutes with a baseline of 5 (range: 3-6.5) (4). In the epinephrine group, the PI at 5 minutes was 13 (range: 8.5-16) with a baseline of 4.4 (range: 2.6-6.3) in the blocked arm, and in the non-blocked arm, it was 4.7 (range: 3.2-7.3) with a baseline of 3.7 (range: 2.5-6.5). The PI at 5 minutes in Kim et al.'s study was higher than in ours, likely due to the differences in local anaesthetics used.



At 10 minutes, the PI in our study increased to 9.25 (range: 0.48-20) from a baseline of 1.9 (range: 0.22-7) in the blocked limb, while in the non-blocked limb, it remained stable at 1.75 (range: 0.21-6) with a baseline of 1.8 (range: 0.19-6). Abdelnasser et al. reported an increase in PI to 6.8 (range: 3.8-11.7) at 10 minutes from a baseline of 2.7 (range: 1.5-4.3) in the blocked arm, while the non-blocked arm did not show significant changes (5). Similarly, Loretta Raj et al. found that the PI in the blocked arm increased to 8.85 (range: 4.5-15.9) at 10 minutes from a baseline of 1.35 (range: 0.3-2.4), and in the non-blocked arm, it remained at 1.1 (range: 0.3-4.06) with a baseline of 1.15 (range: 0.2-3.42) (7). These results are consistent with our study.

A ROC curve was constructed to assess the ability of the PI at 10 minutes to detect block success, with an area under the curve (AUC) of 0.92, a standard error of 0.03, and a p-value of <0.0001. The PI at 10 minutes demonstrated a sensitivity of 73.3% and a specificity of 100% for block success, with a cut-off value of 7.2. In Abdelnasser's study, the AUC for the PI at 10 minutes post-injection was 1 (range: 0.95-1.00), with a cut-off value of >3.3. The positive predictive value (PPV) was 100% with a 95% confidence interval (CI) of 95-100%, and the negative predictive value (NPV) was 100% with a 95% CI of 57-100% (5). Similarly, in Kim et al.'s study, the AUC for the PI at 5 minutes was 0.89 (95% CI 0.83-0.94), with a cut-off value of >7.7, sensitivity of 0.89 (95% CI 0.83-0.94), and specificity of 0.79 (95% CI 0.69-0.87) (8).

At 15 minutes, the PI in our study increased to 10 (range: 0.51-22) from a baseline of 1.9 (range: 0.22-7) in the blocked limb, while in the non-blocked limb, it remained at 1.7 (range: 0.19-5.8) with a baseline of 1.8 (range: 0.19-6). Abdelnasser et al. reported lower PI values at 15 minutes compared to our study, but Kim et al. found slightly higher but comparable values (5). At 20 minutes, the PI in our study increased to 11 (range: 0.56-23) in the blocked limb, while in the non-blocked limb, it was 1.75 (range: 0.2-6.2). Abdelnasser et al. reported lower values compared to our study, while Kim et al. reported slightly higher but comparable values (5,8). At 25 and 30

minutes, the PI in our study continued to rise, with values of 11.5 (range: 0.55-24) and 12 (range: 0.56-24), respectively, while the non-blocked limb values remained relatively unchanged. These findings were comparable to those reported by Kim et al. (8). **Sensory and Motor Blockade:** In our study, complete sensory blockade was achieved within 6 minutes in 17 patients, 9 minutes in 67 patients, and 12 minutes in the remaining 6 patients, in whom the block was successful. Complete motor blockade was achieved at 5 minutes in 4 patients, 10 minutes in 74 patients, and 15 minutes in 9 patients. These results suggest that the PI at 5 minutes serves as a rapid reference point for determining block success, offering a quicker indication compared to the time required for complete sensory and motor blockade.

Perfusion Index (PI) Ratio: The PI ratio, which is the ratio of the PI at 10 minutes to the baseline PI, was introduced by Abdelnasser et al. to address the variability in baseline PI values and facilitate the accurate estimation of cut-off values for clinical application. In our study, the average PI ratio of the blocked limb was 4.7 (range: 1.1-29.2), which was significantly higher than that of the non-blocked limb (1.0, range: 0.78-1.56). Abdelnasser et al. reported a PI ratio of 2.5 (range: 1.7-3.5) in the blocked limb and 1.0 (range: 0.9-1.1) in the non-blocked limb (5). Similarly, Kim et al. found that the PI ratio at 10 minutes was 2.7 (range: 1.9-4) in the blocked arm and 1.1 (range: 0.9-1.4) in the non-blocked arm in the non-epinephrine group. In the epinephrine group, the PI ratio at 10 minutes was 3.3 (range: 2.2-4.4) in the blocked arm and 1.2 (range: 1.0-1.4) in the non-blocked arm (8).

A ROC curve was constructed to evaluate the ability of the PI ratio at 10 minutes to predict block success, with an AUC of 0.95, a standard error of 0.02, and a p-value of <0.0001. The PI ratio showed a sensitivity of 87.8% and a specificity of 100% for block success, with a cut-off value of 2.26. In Abdelnasser's study, the AUC for the PI ratio was 1 (range: 0.95-1.0), with a cut-off value of >1.4 (5). Similarly, Kim et al. found that the AUC for the PI ratio at 5 minutes was 0.94 (95% CI 0.90-0.98), with a cut-off value of >1.6, a



sensitivity of 0.87 (95% CI 0.79-0.94), and a specificity of 0.89 (95% CI 0.80-0.95) (8).

Variability in PI and PI ratio values following a successful block was higher compared to other studies, necessitating further research on factors affecting PI, including baseline differences, geographical variations, and anaesthetic properties.

Conclusion: The PI and PI ratio are simple, non-invasive and objective tools that can be used for evaluation of a successful usg guided supraclavicular brachial plexus block. PI at 5 mins can provide a quicker indication of a successful block when compared to complete sensory and motor blockade.

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