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ORIGINAL RESEARCH **REGIONAL ANESTHESIA**

Comparative evaluation of pulse oximeter perfusion index and skin temperature as predictors of brachial plexus block success: a prospective observational study

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ABSTRACT

Background & objective: Brachial plexus block (BPB) is a widely utilized regional anesthesia technique for upper limb surgeries, known for its targeted action and ability to reduce the need for general anesthesia. However, predicting its success remains a clinical challenge due to variability in onset times. Reliable predictors such as changes in the perfusion index (PI) and skin temperature (ST) could enable earlier and more accurate identification of successful blocks, thereby preventing unnecessary interventions. This study aimed to compare the diagnostic accuracy of PI and ST in predicting BPB success.

Methods: In this prospective, comparative study conducted between November 2020 and July 2022, 100 patients undergoing elective upper limb surgeries under ultrasound-guided BPB were enrolled at Aarupadaiveedu Medical College, Puducherry, India. PI was measured using a pulse oximeter, and ST was recorded using an infrared thermometer at baseline and at 5, 10, 15, and 20 minutes after block administration. Diagnostic performance, including sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), and overall accuracy, was evaluated for both PI and ST.

Results: The mean time for a successful BPB was 14.5 minutes. PI changes were statistically significant as early as 5 minutes post-block, whereas ST changes became significant only after 10 minutes. At 15 and 20 minutes, PI demonstrated superior diagnostic accuracy, reaching 82% and 98%, respectively, compared to 39% and 62% for ST. At 20 minutes, PI achieved 100% sensitivity, 66.7% specificity, 97.9% PPV, and 100% NPV. In contrast, ST at 20 minutes showed 63.8% sensitivity, 33.3% specificity, 93.8% PPV, and 5.6% NPV.

Conclusions: Perfusion index is a more reliable and earlier indicator of BPB success compared to skin temperature. PI changes were evident as early as 5 minutes post-block, making it a valuable non-invasive tool for real-time evaluation of block efficacy. Incorporating PI monitoring into routine clinical practice can facilitate timely interventions and improve patient outcomes.

Abbreviations: BPB**:** Brachial plexus block, PPV: positive predictive value, NPV: negative predictive value, PI: perfusion index, ST: skin temperature,

Keywords: Brachial Plexus; Perfusion Index; Skin Temperature; Regional Anesthesia; Diagnostic Accuracy; Pulse Oximetry; Ultrasonography; Interventional

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1. INTRODUCTION

Brachial plexus block (BPB) is an integral component of regional anesthesia, particularly for upper limb surgeries. This technique offers several advantages, including targeted pain relief, minimal systemic side effects, reduced opioid use, and superior postoperative analgesia. Despite its widespread use, one of the persistent challenges associated with BPB is the variability in its onset of action, which typically ranges between 10 and 20 minutes. This variability often leaves clinicians uncertain about block success, potentially leading to delays in surgical procedures or unnecessary conversions to general anesthesia. A reliable and objective method to predict block success in real time is essential to address these challenges and optimize clinical workflows.[1,2]

Traditionally, the efficacy of BPB has been assessed using subjective methods such as patient-reported pain relief, sensory testing, and motor blockade assessment. These methods, however, rely heavily on patient cooperation and can be time-consuming, especially in scenarios where patients are sedated, unresponsive, or are under general anesthesia.[3,4] The subjective variability in interpretation among clinicians further complicates the assessment process. These limitations underscore the urgent need for objective, non-invasive, and rapid predictors of BPB success that can be consistently applied across diverse patient populations and clinical settings.

Emerging evidence suggests that physiological changes induced by BPB, such as alterations in vascular tone, can serve as early indicators of block success. The perfusion index (PI), derived from pulse oximetry, measures the ratio of pulsatile to non-pulsatile blood flow and is sensitive to changes in autonomic nervous system activity.[5,6] Successful BPB leads to vasodilation in the blocked limb, which is reflected by a significant increase in PI. Previous studies have demonstrated that PI changes occur rapidly following the administration of local anesthetics, often preceding the onset of sensory or motor blockade. This makes PI a promising tool for early, real-time assessment of BPB efficacy.[7,8]

Similarly, changes in skin temperature (ST) have been explored as a potential predictor of block success. Vasodilation resulting from sympathetic blockade typically leads to an increase in peripheral ST, providing a measurable indicator of autonomic nervous system activity.[9] However, the onset of ST changes is often delayed compared to PI, and its diagnostic accuracy has been reported to be lower in several studies. While ST measurement remains a practical and widely accessible method, its limitations, including sensitivity to environmental factors and patient variability, necessitate a direct comparison with more advanced techniques like PI.[10] Despite the growing interest in these predictors, few studies have comprehensively compared the diagnostic accuracy, sensitivity, and specificity of PI and ST in the context of BPB. The scope of this study is to fill this gap by evaluating these two non-invasive methods in a prospective and comparative framework. By doing so, we aim to provide a robust evidence base to guide clinicians in selecting the most reliable and timely predictor for assessing BPB success.[11,12]

The rationale for this study lies in its potential to address key clinical challenges, including procedural delays, unnecessary use of general anesthesia, and patient discomfort. If PI proves to be a superior predictor, its integration into routine clinical practice could revolutionize the real-time assessment of BPB, reducing reliance on subjective methods and enhancing patient safety. Conversely, validating the utility of ST as a predictor could strengthen its role as a cost-effective alternative for resource-limited settings. By comparing these two methods, this study seeks to provide actionable insights that can improve clinical decision-making and patient outcomes in regional anesthesia.

This study aims to evaluate and compare the predictive accuracy of PI and ST in determining BPB success, with a focus on their diagnostic performance at various time intervals post-block. The findings will have significant implications for improving the efficiency and reliability of BPB assessment, ultimately contributing to better clinical care and resource utilization in anesthesia practice.

2. METHODOLOGY

This study was a prospective, comparative observational study conducted in the Department of Anesthesiology at Aarupadaiveedu Medical College, Puducherry, India, over 20 months from November 2020 to July 2022. The study included 100 adult patients scheduled for elective upper limb orthopedic surgeries under ultrasound-guided brachial plexus block (BPB). Ethical approval was obtained from the institutional ethics committee, and written informed consent was secured from all participants before enrolment.

Eligible participants were adults aged 18 years or older, classified as American Society of Anesthesiologists (ASA) physical status I or II, and undergoing elective upper limb orthopedic procedures. Patients with conditions that could interfere with the use of pulse oximetry or thermal scanning (e.g., vascular compromise, degloving injuries, or significant swelling of the limb) were excluded. Additionally, those with febrile illnesses, hypotension, shock, or requiring emergency surgery were excluded to ensure uniformity in study conditions.

Upon arrival in the operating room, standard monitoring, including non-invasive blood pressure, electrocardiography, and oxygen saturation, was applied. Intravenous access was secured for all patients. Patients were placed in a semi-sitting position with their heads turned away from the side to be blocked. The BPB was performed using a high-frequency linear ultrasound transducer placed over the supraclavicular fossa. Under real-time guidance, a 22-gauge insulated block needle was inserted in-plane, targeting the brachial plexus adjacent to the subclavian artery. A total of 25 mL of local anesthetic (12.5 mL of 0.5% bupivacaine and 12.5 mL of 2% lidocaine) was injected to ensure complete perineural distribution.

2.1. Data Collection

Following block administration, perfusion index (PI) and skin temperature (ST) were measured in the blocked and unblocked limbs. PI was measured using a pulse oximeter applied to the index finger of both limbs, while ST was recorded using an infrared thermometer at specific anatomical sites away from joints or subcutaneous veins. Both measurements were taken at baseline (prior to block administration) and at 5,10,15, and 20 minutes post-block. The ratio of the post-block PI to the baseline PI was also calculated. The contralateral (unblocked) limb served as a control for comparison.

The block was deemed successful based on the clinical onset of motor and sensory blockade, defined by the inability to move the fingers and absence of pinprick sensation in the distribution of the radial, ulnar, median, and musculocutaneous nerves.

2.2. Statistical Analysis

Sample size was determined using power analysis with $\alpha = 0.05$ and power = 0.90, resulting in a calculated sample size of 77. To accommodate potential dropouts, the sample size was increased to 100. Data were analyzed using appropriate statistical tests to compare PI and ST values between the blocked and unblocked limbs at different time intervals. Statistical significance was defined as $P < 0.05$. Sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), and diagnostic accuracy were calculated for PI and ST at 15 and 20 minutes. All statistical analyses were conducted using statistical software, and results were presented as means with standard deviations (SD) or proportions, as applicable.

3. RESULTS

The baseline characteristics of the study population are presented in Table 1. The cohort included 100 patients, predominantly male, with the majority classified as ASA II. Hemodynamic parameters and haemoglobin levels were within normal ranges, indicating a stable population. Baseline characteristics of the study participants, including demographic and clinical data, are summarized in Table 1. The study population was predominantly male, with stable baseline parameters, ensuring uniformity in the assessment of brachial plexus block outcomes.

The distribution of block success timing is presented in Table 2. The majority of successful brachial plexus blocks occurred within 15 minutes of administration, with 51% achieving success by 15 minutes and an additional 31% by 20 minutes. These findings suggest that the 15–20-minute period is critical for assessing block efficacy.

Skin temperature (ST) changes between the blocked and unblocked arms are summarized in Table 3. Significant differences in ST were observed beginning at 10 minutes and became more pronounced at 15 and 20 minutes. These findings indicate that skin temperature is a delayed predictor of block success, with significant changes appearing only after 10 minutes post-block.

Differences in perfusion index (PI) between the blocked and unblocked arms are presented in Table 4. Significant changes were observed as early as 5 minutes after block administration, with highly significant differences persisting up to 20 minutes. The PI showed earlier and more consistent changes compared with skin

Table 1: Baseline parameters of the study population (n = 100)

Variable		Value
Age (years)		44.8 ± 13.2
Gender	Male	61 (61)
	Female	39 (39)
Body Mass Index (BMI, kg/m²)		24.6 ± 5.8
ASA Physical Status		
I		44 (44)
II		56 (56)
Operation Type		
Fracture Fixation		39 (39)
Implant Removal		45 (45)
Others		16 (16)
Hemoglobin (g/dL)		11.3 ± 3.5
Pulse Rate (beats/min)		84.7 ± 12.8
Systolic Blood Pressure (mmHg)		114.3 ± 16.3
Diastolic Blood Pressure (mmHg)		84.6 ± 8.9
Comorbidities		
Diabetes Mellitus (DM)		35 (35)
Hypertension (HTN)		40 (40)
Coronary Artery Disease (CAD)		25 (25)
Smoking		30 (30)

Data presented as mean ± SD or n (%)

Table 2. Time to block (n = 100)

Block Success Timing	Number of Patients (%)
Successful at 10 min	12 (12)
Successful at 15 min	51 (51)
Successful at 20 min	31 (31)
Unsuccessful block	6 (6)

temperature, indicating that it is a more reliable predictor of block success.

The diagnostic accuracy of skin temperature and perfusion index (PI) at 15 and 20 minutes is presented in Table 5. The PI consistently outperformed skin temperature in terms of sensitivity, specificity, and overall accuracy. These results demonstrate the superior diagnostic accuracy and predictive reliability of the perfusion index, supporting its use as a primary indicator of brachial plexus block success.

Table 3: Skin temperature (°C) in blocked and unblocked arms (n = 100)

Time Point	Blocked Arm	Unblocked Arm	P-value
Baseline	30.2 ± 0.8	30.2 ± 0.9	1.000
0 min	30.7 ± 0.9	30.5 ± 0.9	0.118
5 mins	31.0 ± 1.0	30.7 ± 0.9	0.067
10 mins	31.2 ± 1.3	30.8 ± 1.0	0.016*
15 mins	32.4 ± 1.5	30.9 ± 1.0	<0.001*
20 mins	33.1 ± 1.2	31.1 ± 1.1	<0.001*

*Data presented as mean ± SD; *Significant values (P < 0.05).*

Table 4: Perfusion Index (PI) in blocked and unblocked arms (n = 100)

Time Point	Blocked Arm	Unblocked Arm	P-value
Baseline	2.07 ± 1.06	2.14 ± 1.04	0.638
0 min	2.04 ± 1.02	2.13 ± 1.05	0.539
5 mins	4.82 ± 1.81	2.65 ± 1.15	<0.001*
10 mins	6.94 ± 1.51	2.53 ± 1.21	<0.001*
15 mins	7.25 ± 1.17	2.82 ± 1.08	<0.001*
20 mins	7.41 ± 1.33	2.68 ± 1.21	<0.001*

*Data presented as mean ± SD; *Significant values (P < 0.05).*

The baseline comorbidities of the study population are summarized in Table 6. Among the 100 patients, the most common comorbidity was hypertension (40%), followed by diabetes mellitus (35%), smoking (30%), and coronary artery disease (25%). These findings highlight the prevalence of cardiovascular and metabolic conditions in the cohort.

Hypertension and diabetes mellitus constituted the most common comorbidities, underscoring the importance of accounting for these conditions when evaluating predictors of block success.

Implant removal was the most common surgical indication, accounting for 45% of cases, followed by fracture fixation (39%) and other procedures (16%). This distribution reflects a typical case mix for upper limb surgeries requiring brachial plexus block.

Table 5: Diagnostic accuracy of skin temperature and perfusion index

Parameter	Skin Temperature (15 min)	Skin Temperature (20 min)	PI (15 min)	PI (20 min)
Sensitivity (%)	20.6	63.8	100	100
Specificity (%)	70.3	33.3	51.4	66.7
Positive Predictive Value (%)	54.1	93.8	77.8	97.9
Negative Predictive Value (%)	34.2	5.6	100	100
Diagnostic Accuracy (%)	39	62	82	98

Figure 3 provides a comparative view of key baseline comorbidities and the effectiveness of predictors of brachial plexus block success. Among the comorbidities, hypertension (40%) and diabetes mellitus (35%) were the most prevalent, followed by smoking (30%) and coronary artery disease (25%). These conditions highlight the cardiovascular and metabolic risk profile of the study population.

In terms of predictors, Perfusion Index demonstrated an outstanding diagnostic accuracy of 98%, significantly outperforming Skin Temperature, which had a diagnostic accuracy of 62%. This contrast underscores the value of Perfusion Index as an early, reliable, and sensitive indicator of block success.

Hypertension and diabetes mellitus were the predominant comorbidities in the study population, reflecting a cohort with significant cardiovascular risk that may influence block outcomes or procedural considerations. Among the evaluated predictors, the perfusion index (PI) demonstrated markedly higher diagnostic accuracy for assessing brachial plexus block success compared with skin temperature, making it a superior real-time indicator for clinicians. The pronounced difference in predictive accuracy underscores the clinical value of integrating perfusion index monitoring into routine anesthetic practice to enhance the assessment and reliability of block efficacy.

4. DISCUSSION

The study population was characterized by a high prevalence of hypertension (40%) and diabetes mellitus (35%), followed by smoking (30%) and coronary artery disease (25%). These findings reflect a common comorbidity profile among patients undergoing elective upper limb surgeries. Such conditions, particularly hypertension and diabetes mellitus, are known to influence peripheral vascular tone and autonomic regulation. These factors could potentially affect the onset and success of regional anesthesia, such as brachial plexus block (BPB).[13,14]

Hypertension and diabetes mellitus, often associated with endothelial dysfunction and vascular stiffness, may delay or alter the physiological changes expected during a successful BPB, such as vasodilation. Smoking and coronary artery disease further exacerbate these challenges by impairing microvascular circulation and increasing sympathetic activity. Recognizing these underlying factors is critical for anesthesiologists to anticipate variations in block performance and tailor perioperative management accordingly.[15,16]

The procedural mix in this study included a predominance of implant removal (45%) and fractures (39%), with a smaller proportion of other procedures (16%). This distribution reflects typical upper limb surgical indications for BPB. The consistency of procedural types supports the generalizability of the study findings to routine clinical practice.[17,18] Furthermore, the procedural characteristics ensure that the observed trends in predictors, such as perfusion index and skin temperature, are not biased by procedure-specific factors.

The study findings highlight a stark contrast between the diagnostic accuracies of Perfusion Index (PI) and Skin Temperature (ST) in predicting BPB success. Perfusion Index achieved an impressive diagnostic accuracy of 98%, compared to 62% for Skin Temperature. These results reinforce the superiority of PI as an early and reliable indicator of block efficacy.[19,20]

The perfusion index (PI) measures the ratio of pulsatile to non-pulsatile blood flow, reflecting autonomic regulation of vascular tone. During brachial plexus block (BPB), sympathetic blockade induces vasodilation, which is rapidly detected as an increase in PI. In this study, PI showed significant changes as early as 5 minutes post-block, achieving near-complete accuracy by 20 minutes. This sensitivity and rapid responsiveness make PI a valuable tool for real-time block assessment, particularly in sedated or unresponsive patients where sensory and motor evaluations are not feasible. In contrast, skin temperature (ST) changes also result from peripheral vasodilation secondary to sympathetic blockade but typically appear later, around 10 to 15 minutes post-block. Its delayed onset, lower specificity, and susceptibility to external factors such as ambient temperature and individual vascular variability limit its reliability as a standalone predictor compared with PI.

The interplay between baseline comorbidities and predictor performance is particularly noteworthy. Conditions such as diabetes and hypertension, which impair vascular responsiveness, may attenuate the expected changes in PI and ST during BPB. Despite this, PI remained a robust predictor across the study population, suggesting its resilience to confounding factors. In contrast, ST's lower accuracy could partially be attributed to its greater susceptibility to these comorbid influences.[21,22]

The perfusion index (PI) offers distinct clinical advantages as an early predictor of block success, with measurable changes detectable within 5 minutes of block administration. This enables timely identification of effective blocks and early intervention in cases of failure, thereby minimizing delays in surgical workflow. Both PI and skin temperature (ST) are non-invasive monitoring tools; however, the superior accuracy and earlier onset of PI make it the preferred choice in settings where efficiency and reliability are critical. Patient-specific factors should also be considered when selecting monitoring modalities, as individuals with diabetes mellitus or cardiovascular comorbidities may demonstrate more consistent results with PI than with ST. Moreover, while pulse oximeters capable of measuring PI may require an initial investment, their ability to streamline block assessment and reduce the need for additional anesthetic interventions underscores their cost-effectiveness and value in perioperative monitoring.[23,24,25]

5. LIMITATIONS

This study's key strength lies in its comprehensive comparison of two non-invasive predictors, perfusion index (PI) and skin temperature (ST), which provides robust evidence to guide clinical decision-making. The inclusion of patients with diverse comorbidities further enhances the generalizability of the findings. However, certain limitations should be acknowledged. Environmental factors influencing skin temperature were not fully controlled, which may have affected its accuracy, and the absence of long-term follow-up limited the assessment of how these predictors correlate with postoperative outcomes.

6. CONCLUSION

This study underscores the clinical value of Perfusion Index as a superior predictor of brachial plexus block success compared to Skin Temperature. Its early onset, high accuracy, and resilience to comorbid influences make it a reliable tool for real-time block assessment. These findings highlight the importance of incorporating PI into routine anesthesia practice, particularly for patient populations with significant cardiovascular and metabolic risk profiles. Future research should focus on conducting multicenter trials with larger sample sizes to validate these findings across diverse clinical settings. Investigating the combined use of perfusion index (PI) and skin temperature (ST) may further improve diagnostic accuracy, especially in challenging or equivocal cases. Additionally, advancements in portable and cost-effective technologies for real-time PI measurement could promote wider adoption of this monitoring approach in resource-limited environments.

7. Data availability

The numerical data generated during this research are available from the authors.

8. Ethical Considerations

This study adhered to the Declaration of Helsinki guidelines for research involving human participants. Ethical approval was obtained from the Institutional Ethics Committee of Aarupadaiveedu Medical College, Puducherry, India, and all participants provided written informed consent. The confidentiality of participant data was maintained throughout the study.

9. Funding

No external funding was received for this study.

10. Conflicts of Interest

The authors declare no conflicts of interest.

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