Original Article

DOI: 10.7860/JCDR/2026/79409.22200

Anaesthesia Section

Evaluation of Perfusion Index as a Tool for Early Detection of Ulnar Nerve Sparing after Brachial Plexus Block Through Supraclavicular Approach: A Prospective Observational Study

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ABSTRACT

Introduction: Supraclavicular Brachial Plexus Block (SPB) is a common anaesthesia method for upper limb surgeries. However, ulnar nerve sparing can occur, leading to patient discomfort and surgical delays. Traditional assessment methods are subjective and time-consuming. The Perfusion Index (PI) has been shown to be an effective, objective, non-invasive tool for assessing peripheral nerve blocks.

Aim: To evaluate PI as a tool for early detection of ulnar nerve sparing after SPB.

Materials and Methods: This prospective observational study included 60 patients undergoing upper limb orthopaedic surgery under SPB. PI readings were taken at the index and little fingers at baseline and at regular intervals after the block for 30 minutes. Clinical assessment of the block was also performed. Data normality was tested using the Shapiro-Wilk test, and categorical data were compared using the Chi-square test.

Results: Out of 60 patients, 44 (73.33%) had successful blocks, and 16 (26.67%) had ulnar nerve sparing. Demographic characteristics (age, weight, height, sex, ASA grade, and type of surgery) as well as baseline PI at the index and little fingers were comparable between patients with successful blocks and those with ulnar nerve sparing. PI at the little finger was significantly higher in successful blocks compared to ulnar sparing cases from two minutes onwards, reaching a maximum at 30 minutes (7.39±0.80 in successful block vs 1.68±0.27 in ulnar sparing, p<0.001). The PI ratio at the little finger showed statistically significant differences from one minute onwards, also reaching a maximum at 30 minutes (6.08±1.63 in successful block vs 1.52±0.30 in ulnar sparing, p<0.001). In ulnar sparing cases, PI and PI ratio were significantly higher at the index finger compared to the little finger (Mean PI at 30 minutes: index finger 9.22±1.71 vs little finger 1.68±0.27, p<0.001; Mean PI ratio at 30 minutes: index finger 8.08±1.15 vs little finger 1.52±0.30, p<0.001). The area under the Receiver Operating Characteristic (ROC) for PI at the little finger reached 1.0 at seven minutes, demonstrating 100% sensitivity and specificity for detecting ulnar sparing.

Conclusion: PI measured at the little finger is a highly reliable, non-invasive tool for early detection of ulnar nerve sparing following SPB. It provides objective, real-time monitoring and can detect ulnar sparing as early as seven minutes post-block with high accuracy. Incorporating PI monitoring into routine anaesthesia practice can improve early detection of failed blocks, reduce surgical delays, and enhance patient comfort.

Keywords: Peripheral nerve locator, Pulse oximetry, Regional anaesthesia, Segmental nerve sparing, Upperlimb surgeries

INTRODUCTION

The SPB is the most commonly performed mode of anaesthesia for upper limb surgeries, especially after the invention of peripheral nerve locators and ultrasound guidance. The supraclavicular approach to the brachial plexus provides a rapid onset and higher success rate, as the brachial plexus is compactly arranged at this location [1].

Despite representing the most compact cross-sectional part of the entire brachial plexus, the supraclavicular region is notorious for segmental sparing of the C8-T1 nerve components (ulnar nerve). This occurs because the sub-compartment fascial divisions are thickest at this point [2]. Ulnar nerve sparing leads to dissatisfaction among patients and surgeons, as patients often require supplemental analgesia and sedation to complete surgery, which can be cumbersome and prolong surgical time [3].

The success of peripheral nerve blocks is usually assessed by evaluating sensory and motor function; however, these are subjective methods. They cannot be reliably used in patients under general anaesthesia or deep sedation and are also time-consuming [4]. Various objective methods have been introduced for block assessment [5-7], such as thermographic temperature measurement, laser Doppler perfusion imaging, and skin electrical resistance. These methods assess sympathetic blockade and resultant physiological changes, including vasodilation, blood flow, and skin temperature changes [8]. However, most of these objective methods require sophisticated and expensive equipment.

The PI is an easy, objective, and non-invasive method for assessing peripheral nerve blocks. PI represents the ratio between pulsatile and non-pulsatile blood flow, measured using co-oximetry technology [9]. PI is influenced by the balance of the sympathetic and parasympathetic nervous systems [10] and increases due to vasodilation caused by sympathetic blockade induced by peripheral nerve block. Therefore, PI can be used as a predictor for successful nerve blocks, particularly in SPB [11].

Several studies have evaluated PI as a tool for early detection of block success [11-13]. However, a single measurement of PI at the index finger may fail to detect ulnar nerve sparing, as selective changes in PI occur according to the blocked dermatome due to the segmental distribution of sympathetic nerve supply in the upper limb [14,15]. Very few studies [16-18] have evaluated PI as a tool to detect segmental sparing of the ulnar nerve. Hence, the present study aimed to evaluate PI as a tool for early detection of ulnar nerve sparing following SPB.

MATERIALS AND METHODS

This prospective observational study was conducted in the orthopaedic operation theater of Dhiraj General Hospital, Sumandeep

Vidyapeeth, Waghodia, Vadodara, Gujarat, from August 2024 to January 2025. Ethical clearance was obtained from the Institutional Review Board (SVICE/on/Medi/RP/July/24/67). The study was registered in the Clinical Trial Registry-India (CTRI) with registration number CTRI/2024/12/077542. Patient recruitment was performed only after CTRI registration. The purpose of the study was explained to all participants, and written informed consent was obtained.

Inclusion criteria: Adult patients aged 18-60 years, of either gender, with American Society of Anaesthesiologists (ASA) status I or II, undergoing upper limb orthopaedic surgery under SPB were included in the study.

Exclusion criteria: Patients with known contraindications to peripheral nerve block, such as coagulopathy, infection at the local site, or allergy to local anesthetic, were excluded. Patients with diabetic neuropathy, peripheral neurological deficits, or peripheral vascular disease of the same upper limb, as well as those with injuries to the index or ring finger that would prevent pulse oximeter application, were also excluded from the study.

Sample size calculation: Sample size was calculated using MedCalc Software version 23.1.7. Considering an Area Under the Receiver Operating Characteristic (AUROC) curve of 0.80 with a null hypothesis AUROC of 0.5, and assuming the rate of ulnar nerve sparing would not exceed 15%, a minimum of 51 patients (with at least 7 failed blocks) was required for a study power of 80% and α error of 0.05. For this study, 60 patients were recruited.

Study Procedure

Patients were kept nil by mouth for six hours for solid food and two hours for clear liquids. After being brought into the operation theater, a 20-gauge intravenous cannula was inserted, and Ringer lactate infusion was started. Standard multiparameter monitoring, including electrocardiography leads, automated non-invasive blood pressure cuff, and pulse oximetry probe, was applied.

After taking proper aseptic and antiseptic precautions, the supraclavicular block was administered by an experienced anesthesiologist using a peripheral nerve locator. All patients received 15 mL of 2% lignocaine with adrenaline (1:200,000) and 15 mL of 0.5% bupivacaine, for a total volume of 30 mL.

Clinical assessment of the block was performed by the same anesthesiologist who administered it. For motor block assessment, patients were asked to:

- Flex the arm at the elbow against resistance (musculocutaneous nerve)
- Actively extend the wrist (radial nerve)
- Oppose the index finger (median nerve)
- Flex the distal interphalangeal joint of the little finger (ulnar nerve)

For sensory block assessment, ice and pinprick stimuli were applied in the dermatomal distributions of the musculocutaneous, radial, median, and ulnar nerves. Assessments were repeated every five minutes for 30 minutes.

PI readings were taken using two pulse oximeter probes—one at the index finger and one at the little finger. Readings were obtained by an anesthesiologist blinded to the clinical block assessment. Measurements were recorded at baseline, every minute for 10 minutes after SPB, and then every five minutes for the next 20 minutes. The PI ratio was calculated at each time point as: PI / Baseline PI [16].

A block was considered failed if any supplemental analgesia, sedation, or general anaesthesia was required to complete surgery. Ulnar nerve sparing was defined as the presence of sensation in dermatomes supplied by the ulnar nerve, while other regions of the upper limb were anesthetised. Patients with ulnar nerve sparing received an ulnar nerve block at the elbow to achieve complete anaesthesia. The orthopaedic surgeon was not allowed to start the surgery until all PI readings were completed.

The primary outcome was to evaluate the ability of PI and PI ratio for early detection of ulnar nerve sparing. PI and PI ratio at the little finger were compared between patients with successful blocks and those with ulnar nerve sparing. In patients with ulnar nerve sparing, PI and PI ratio at the index and little fingers were also compared. The secondary outcome was to determine the earliest time at which PI reached its optimal predictive value. The AUROC curve was generated, and sensitivity, specificity, Positive Predictive Value (PPV), and Negative Predictive Value (NPV) were calculated.

STATISTICAL ANALYSIS

Data were collected and organised using Microsoft Excel 2010. Categorical data were presented as percentages and frequencies (%), while continuous data were presented as mean±Standard Deviation (SD). Data normality was assessed using the Shapiro-Wilk test. Comparison of categorical data was performed using the Chi-square test. Comparison of PI and PI ratio at the little finger between patients with successful blocks and patients with segmental ulnar sparing, and comparison of PI and PI ratio at the little and index fingers in patients with ulnar nerve sparing, were performed using the Mann-Whitney U test. The ROC curve was generated to assess the ability of PI to detect segmental ulnar sparing. The ROC curve classifies a patient's disease state as either positive or negative based on test results and helps identify the optimal cut-off value with the best diagnostic performance [19]. The optimal cut-off was determined using the Youden index (Youden's J statistic), which evaluates diagnostic test performance by maximising the difference between true positive and false positive rates [20]. Sensitivity, specificity, PPV, and NPV were calculated for PI in detecting segmental ulnar sparing. A p-value <0.05 was considered significant, and p<0.001 was considered highly significant.

RESULTS

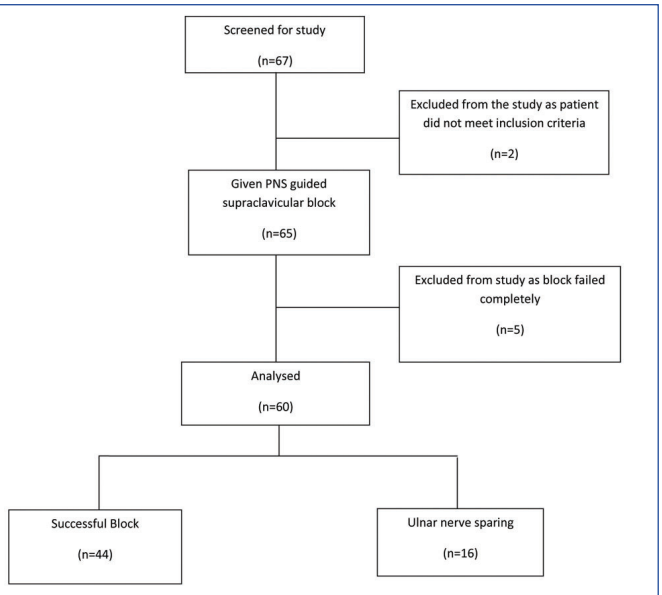
Sixty-seven patients undergoing upper limb surgery under SPB were assessed for the study, of whom two patients were excluded as they did not meet the inclusion criteria. Therefore, 65 patients received Peripheral Nerve Stimulator (PNS)-guided SPB. Among these, five patients were excluded due to complete block failure. Consequently, 60 patients were analysed, of whom 44 (73.33%) had a successful block and 16 (26.67%) exhibited ulnar nerve sparing [Table/Fig-1].

Demographic characteristics, including age, weight, height, sex, ASA grade, and type of surgery, as well as baseline PI at the index and little fingers, were comparable between patients with successful blocks and those with ulnar nerve sparing [Table/Fig-2].

As shown in [Table/Fig-3], PI at the little finger in patients with successful blocks was higher compared to those with ulnar nerve sparing from two minutes onwards. The differences were statistically significant at the 2nd and 3rd minutes (p=0.003, p=0.002, respectively) and became highly significant from four minutes onward (p<0.001), reaching a maximum at 30 minutes (7.39±0.80 in successful block vs 1.68±0.27 in ulnar sparing, p<0.001).

[Table/Fig-4] shows the PI ratio at the little finger for patients with successful blocks and ulnar nerve sparing. PI ratio was higher in the successful block group from one minute onward, and the differences were highly significant at all time points (p<0.001), reaching a maximum at 30 minutes (6.08±1.63 in successful block vs 1.52±0.30 in ulnar sparing, p<0.001).

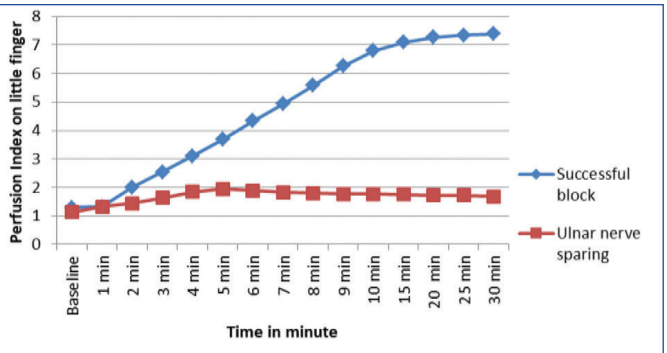
[Table/Fig-5,6] shows PI and PI ratio at the index and little fingers in patients with ulnar nerve sparing. Both PI and PI ratio were higher at the index finger than at the little finger. Differences were statistically significant at one minute (p=0.03, p=0.04, respectively) and highly significant from two minutes onward (p<0.001). At 30 minutes, mean PI was 9.22±1.71 at the index finger versus 1.68±0.27 at the



[Table/Fig-1]: Patient enrollment flow diagram.

Particulars		Successful block (n=44)	Ulnar sparing (n=16)	p-value
Age (years)		38.98±12.44	40.75±8.26	0.53
Sex	Male	28 (63.6%)	10 (62.5%)	0.94
	Female	16 (36.4%)	6 (37.5%)	
weight (kg)		60.45±8.01	56.56±6.14	0.08
Height (cm)		156.3182±6.99	155.875±6.59	0.79
ASA grade	I	25	7	0.39
	II	19	9	
Type of surgery	ORIF and Platting for DER	19 (43.18%)	9 (56.25%)	0.79
	TBW for olecranon fracture	8 (18.18%)	3 (18.75%)	
	Implant removal from radius and ulna	9 (20.46%)	2 (12.5%)	
	Tendon repair	8 (18.18%)	2 (12.5%)	
Index finger Baseline PI		1.30±0.30	1.16±0.25	0.09
Little finger Baseline PI		1.29±0.32	1.13±0.26	0.08

[Table/Fig-2]: Demographic characteristic and Baseline PI on index and little finger.
(Unpaired t-test for continues data and Chi-square test for categorical data)
ORIF: Open Reduction Internal fixation; DER: Distal End Radius fracture; TBW: Tension Band Wiring



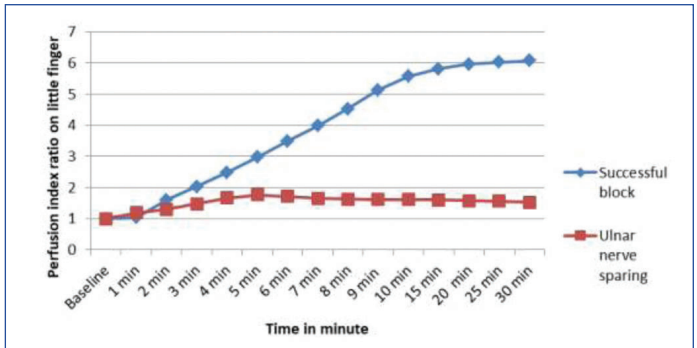
[Table/Fig-3]: Perfusion Index (PI) on little finger of patients with successful block and patients with ulnar nerve sparing.
(Mann-Whitney U test)

little finger (p<0.001), and mean PI ratio was 8.08±1.15 at the index finger versus 1.52±0.30 at the little finger (p<0.001).

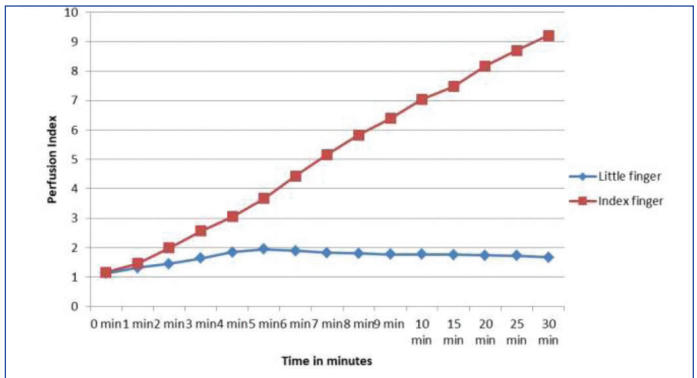
As shown in [Table/Fig-7], the AUROC reached its highest value at seven minutes, and the sensitivity of PI to detect ulnar nerve sparing reached 100% at seven minutes.

DISCUSSION

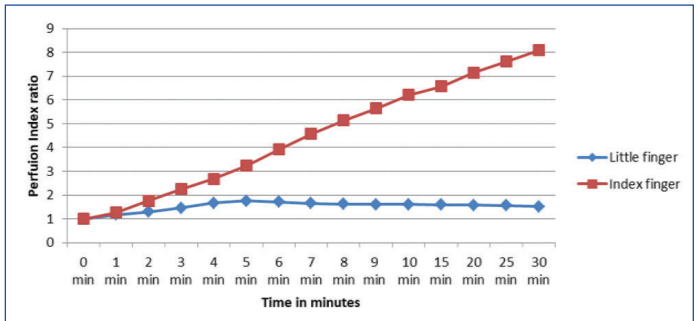
This prospective observational study evaluated PI as an early detection tool for ulnar nerve sparing following SPB. Among the



[Table/Fig-4]: Perfusion Index (PI) ratio on little finger of patients with successful block and patients with ulnar nerve sparing.
(Mann-whitney U test)



[Table/Fig-5]: Perfusion Index (PI) on little finger and index finger in patients with ulnar nerve sparing
(Mann-whitney U test)



[Table/Fig-6]: Perfusion Index (PI) ratio on little finger and index finger in patients with ulnar nerve sparing.
(Mann-whitney U test)

Time	AUROC	Sensitivity	Specificity	PPV	NPV	Optimal Threshold
1 min	0.5	43.1818	68.75	79.1667	30.5556	1.5
2 min	0.879261	70.4545	100	100	55.1724	1.9
3 min	0.901278	77.2727	100	100	61.5385	2.3
4 min	0.93821	86.3636	100	100	72.7273	2.6
5 min	0.981534	95.4545	100	100	88.8889	2.5
6 min	0.990057	95.4545	100	100	88.8889	3
7 min	1	100	100	100	100	2.5
8 min	1	100	100	100	100	3
9 min	1	100	100	100	100	4.8
10 min	1	100	100	100	100	4.9
15 min	1	100	100	100	100	5.2
20 min	1	100	100	100	100	5.5
25 min	1	100	100	100	100	5.6
30 min	1	100	100	100	100	5.7

[Table/Fig-7]: Predictive ability of PI at little finger to detect ulnar nerve sparing.
(AUROC: Area under the receiver operating characteristic; PPV: Positive predictive value, NPV: Negative predictive value)

60 patients analysed, 16 (26.67%) exhibited ulnar nerve sparing. Patients with ulnar nerve sparing were comparable to those with successful blocks in terms of demographic characteristics, including

age, weight, height, ASA grade, and type of surgery (p>0.05). Baseline PI and PI ratio at both the little and index fingers were also comparable (p>0.05).

The findings demonstrate that PI measured at the little finger can effectively distinguish between a successful block and ulnar nerve sparing as early as 2-3 minutes post-block, with statistical significance at the 2nd and 3rd minutes and highly significant differences from the 4th minute onward. Additionally, the PI ratio at the little finger was consistently higher in the successful block group compared to the ulnar nerve sparing group. The AUROC curve reached 1.0 at seven minutes, indicating 100% sensitivity and specificity in detecting ulnar sparing.

Furthermore, in patients with ulnar nerve sparing, PI measurements at the little finger were consistently lower than those at the index finger, highlighting the segmental nature of the block. These results suggest that PI can serve as an early and reliable predictor of ulnar nerve sparing, providing an objective, non-invasive alternative to traditional sensory and motor testing, which can be subjective, delayed, or impractical in sedated patients.

The study's findings are consistent with those of Abdelhamid B et al., who also investigated PI in detecting segmental ulnar nerve sparing following supraclavicular block [16]. In their study, the PI ratio at the little finger was significantly higher in patients with a successful block, whereas PI at the index finger showed poor predictive ability. They reported an AUROC value of 0.96 at seven minutes, similar to our findings (AUROC 1.0 at seven minutes). Their optimal cut-off PI ratio was ≤1.35 at seven minutes, whereas our study identified an optimal threshold of 2.5-3.0 at seven minutes, reinforcing the predictive power of PI for detecting ulnar sparing. Additionally, Abdelhamid et al., reported that a 71% increase in PI at the little finger at five minutes could effectively rule out ulnar sparing. Our study expands on this by demonstrating that PI reaches peak predictive accuracy at seven minutes and maintains 100% sensitivity and specificity beyond ten minutes, further supporting the use of early PI monitoring in clinical practice.

The segmental nature of ulnar sparing has also been emphasised in prior research. For instance, Lange KHW et al., demonstrated that vasodilation changes following nerve blocks are highly localised to specific dermatomes, which explains why PI at the little finger—but not the index finger—accurately reflects ulnar nerve sparing [15]. Our study further supports this concept, as PI measurements at the index finger remained consistently higher than those at the little finger, making index finger PI an unreliable indicator of ulnar sparing.

Several other studies have examined PI as a predictor of nerve block success in SPB as well as at other anatomical locations. Karthik L et al., evaluated PI as a predictor of successful SPB [21]. They found that PI increased in the blocked arm after five minutes compared with the unblocked arm and also relative to its baseline value. Both PI and PI ratio in the blocked arm were significantly lower than unblocked arm. They concluded that PI can be considered a useful tool for evaluating the success of supraclavicular blocks.

Sriramatr D et al., also studied the role of PI as an early predictor of successful supraclavicular block [22]. Their results showed that PI continuously rose from baseline in successfully blocked patients. PI at three minutes after local anesthetic injection indicated block success at a cut-off value of 3.6. They concluded that successful block could be determined early by monitoring the increase in PI from baseline.

Galvin EM et al., demonstrated that PI is a simple, reliable, objective, and early indicator of regional block success in axillary and sciatic nerve blocks [7]. Kus A et al., found that PI could effectively predict successful infraclavicular brachial plexus blocks and that PI monitoring provides a highly valuable tool to quickly evaluate the success of regional anaesthesia of the upper extremity in clinical practice [23].

Sebastiani A et al., showed that PI increases after successful interscalene nerve blockade and may be used as an indicator of successful block placement [8]. Buono RD et al., evaluated PI for early detection of nerve blocks, including sciatic nerve block, brachial plexus block, and spinal anaesthesia. They found that a tripling of PI within five minutes of performing regional anaesthesia reliably indicated block success [12]. Yamazaki H et al., evaluated PI via pulse oximetry to determine the efficacy of Stellate Ganglion Block (SGB) [24]. They found that PI increased in the earlobe and upper limbs on the treated side in patients who received an effective SGB. The positive correlation between changes in PI and both clinical signs and skin microcirculatory blood flow suggests a sympatholytic effect, indicating that PI could be useful in determining the efficacy of SGB.

Our study builds upon these findings and further emphasises the importance of selecting the appropriate anatomical site for PI measurement. Since PI is segment-dependent, our results confirm that the little finger is the ideal site for detecting ulnar sparing, and the index finger should not be relied upon for block assessment. In patients with ulnar nerve sparing, PI readings at the index finger may appear normal, falsely suggesting a successful block, while the patient may still experience pain due to incomplete ulnar nerve anaesthesia.

Early detection of ulnar nerve sparing is essential in regional anaesthesia practice. Traditionally, sensory and motor block assessments rely on subjective patient feedback and delayed evaluation methods, which may be unreliable in sedated or non-cooperative patients. Our study reinforces the clinical utility of PI as an objective, real-time monitoring tool for early detection of ulnar nerve sparing.

The current study's findings suggest that PI at the little finger should be monitored in all patients undergoing SPB, as it provides early and highly accurate detection of block success. The optimal PI ratio thresholds derived from our study can serve as practical guidelines for clinicians:

- A PI ratio of 2.5 at seven minutes ensures 100% predictive accuracy in ruling out ulnar nerve sparing.
- PI can begin providing reliable predictions from two minutes onward, allowing early intervention in cases of partial or failed blocks.
- Continuous PI monitoring can help reduce surgical delays by enabling early identification of segmental nerve sparing and prompt corrective action, such as supplemental nerve blocks or conversion to general anaesthesia.

Moreover, PI monitoring offers additional advantages over traditional sensory assessments, including:

- Non-invasiveness: Unlike pinprick or ice tests, PI monitoring does not require patient cooperation.
- Applicability in sedated patients: PI can be used in patients under moderate sedation or general anaesthesia. Ceylan A et al., conducted a study to evaluate the success of supraclavicular block performed under general anaesthesia using PI and concluded that block success can be reliably assessed with PI [25].
- Standardisation: PI provides an objective measurement, reducing inter-observer variability.
- Assessment in children: PI can also be used to assess block success in pediatric patients, where subjective methods are not feasible. Demi Rci Ç et al., investigated the correlation of block success with PI measurements in pediatric patients undergoing surgery under caudal epidural block anaesthesia [26]. They concluded that PI is a valuable and objective measure for assessing block success in pediatric patients, offering advantages in speed and reliability over traditional monitoring methods.

- Assessment in critically ill patients: PI can be used in critically ill, non-intubated patients undergoing upper limb surgery. Hasanin A et al., evaluated PI as a tool for pain assessment in critically ill patients [10]. They found that the application of a painful stimulus was associated with a decrease in PI, with good correlation between changes in PI and the Behavioral Pain Scale for Non-Intubated (BPS-NI) values after the stimulus.

Future studies should explore the potential of PI monitoring in other regional anaesthesia techniques, such as infraclavicular, axillary, and interscalene blocks, to determine whether similar segmental differences in PI can be used for block assessment at these sites.

Limitation(s)

Despite the strong predictive value of PI demonstrated in this study, several limitations exist: it was a single-center study and high-risk populations were excluded. Factors such as ambient temperature, systemic blood pressure, and individual autonomic tone can influence PI readings. Future studies should control for these variables to enhance the accuracy of PI as a predictive tool.

CONCLUSION(S)

This study confirms that PI at the little finger is a highly reliable, non-invasive tool for early detection of ulnar nerve sparing following SPB. Incorporating PI monitoring into routine anaesthesia practice can improve early detection of failed blocks, reduce surgical delays, and provide an objective, standardised measure of block success. Given these advantages, we recommend incorporating PI monitoring into routine clinical practice, particularly focusing on the little finger for detecting ulnar nerve sparing. Future research should validate these findings in larger patient populations and explore PI's applicability in other regional anaesthesia techniques.

Acknowledgement

We acknowledge the Institutional Ethical Committee for approving this study, the orthopaedic department, and all the patients who willingly participated in this study.

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PLAGIARISM CHECKING METHODS: [Jain H et al.]
- Plagiarism X-checker: Apr 01, 2025
- Manual Googling: Aug 16, 2025
- iThenticate Software: Aug 19, 2025 (17%)

ETYMOLOGY: Author Origin

EMENDATIONS: 7

AUTHOR DECLARATION:
- Financial or Other Competing Interests: None
- Was Ethics Committee Approval obtained for this study? Yes
- Was informed consent obtained from the subjects involved in the study? Yes
- For any images presented appropriate consent has been obtained from the subjects. Yes

Date of Submission: **Mar 17, 2025**
Date of Peer Review: **Jul 12, 2025**
Date of Acceptance: **Aug 22, 2025**
Date of Publishing: **Jan 01, 2026**