Section: Anaesthesiology

Original Research Article

PULSE OXIMETRY PERFUSION INDEX AND PERFUSION INDEX RATIO AS A PREDICTOR OF SUPRACLAVICULAR BRACHIAL PLEXUS BLOCK EFFICACY: A PROSPECTIVE OBSERVATIONAL STUDY

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ABSTRACT

Background: The supraclavicular brachial plexus block is a cornerstone of regional anaesthesia for upper limb procedures, prized for its dense and rapid onset. However, traditional metrics for determining block success such as sensory and motor testing are often subjective, time-intensive, and reliant on active patient participation. Since sympathetic blockade and subsequent vasodilation often precede sensory loss, we evaluated whether the perfusion index (PI), a real-time marker of peripheral perfusion could serve as a superior predictor of block success. **Aim:** The aim of this study is to investigate the utility of the perfusion index (PI) and perfusion index ratio (PIR) as an objective, non-invasive alternative for predicting block efficacy. Our primary objective was to establish a definitive PI and PIR cut-off value that accurately identifies successful ultrasound-guided supraclavicular blockade. **Materials and Methods:** The study included 60 patients undergoing elective orthopaedic upper limb procedures via ultrasound-guided supraclavicular nerve block. Following local anaesthetic administration, sensory block onset was evaluated via pinprick, while motor block was assessed by testing elbow and hand flexion. Perfusion Index (PI) was tracked at baseline and at 10, 20, and 30-minute intervals in both the blocked and non-blocked limbs. The PI ratio was defined as the 10-minute post-injection PI relative to baseline. A PI of >3.3 at 20 minutes and a PI ratio of >1.4 intra-operatively were accurate predictor for block success. **Result:** The blocked limb consistently demonstrated a higher perfusion index (PI) and PI ratio than the untreated side. At the 20-minute mark, a PI of > 3.3 and a PI ratio of > 1.4 served as definitive diagnostic thresholds, predicting block success with 100% sensitivity and specificity. **Conclusion:** PI and PI ratio are simple, inexpensive, non-invasive, highly accurate, early predictors of successful ultrasound-guided supraclavicular blocks. A PI ratio of > 1.4 is a good predictor for block success.

INTRODUCTION

Regional anaesthesia is a cornerstone of modern surgical care, offering distinct advantages for patients, surgeons, and anaesthesiologists by offering a simplified alternative to general anaesthesia. By preserving consciousness and avoiding airway instrumentation, it ensures a rapid recovery and superior postoperative analgesia while bypassing the systemic side effects of general anaesthesia. The brachial plexus block is a premier alternative for upper limb procedures. While it can be performed via interscalene, infraclavicular, or axillary routes, the supraclavicular approach is particularly favoured; as at this level, the plexus is compact and superficial, making it highly accessible. [1-4]

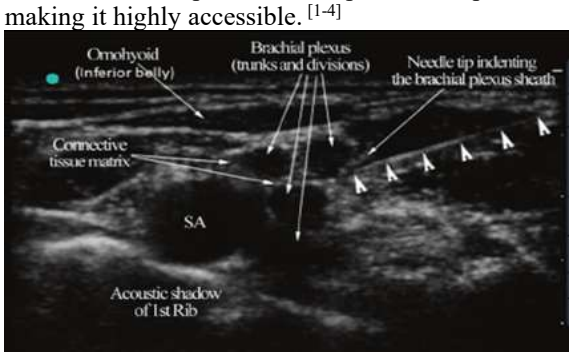

Figure 1: USG image of supraclavicular block

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The integration of ultrasound guidance has further refined these blocks [Figure 1], for enabling dense anaesthesia with lower and minimal local anaesthetic doses and faster onset times.[5] Traditionally, clinicians assess the success of a peripheral nerve block success via neurological of sensory and motor testing.[6-10] However, this subjective approach is often time-consuming, dependent on sophisticated equipment and relies heavily on patient cooperation,[9] and perception,[10,11] making it impractical for sedated patients or those with communication barriers. A successful block triggers a sympathetic fiber blockade, resulting in vasodilation, increased local blood flow,[6,7] and a rise in skin temperature.[8] To modernize assessment, various objective markers have been explored, including skin temperature measurement,[12] skin electrical resistance,[13,14] tissue oxygen saturation and laser doppler perfusion imaging.[6,8] Among these, the Perfusion Index (PI)—derived from pulse oximetry stands out as a simple, non-invasive and rapid tool for interpreting block success.[15,16] The PI is a numerical value for the ratio between pulsatile and non-pulsatile blood flow measured by a special pulse oximeter.[17] Its usage has been increased progressively in many institutes. A successful block triggers sympathetic blockade mediated vasodilation, leading to a significant increase in PI in the blocked limb compared to the unblocked side. [18-20] By calculating the Perfusion Index Ratio (PIR), [8,9] which is the ratio between perfusion index (PI) at a point of time to the baseline perfusion index (PI), between the blocked and unblocked limbs. Anaesthetist can use the resulting vasodilation as a reliable, objective physiological marker of a successful supraclavicular block.[21] This study assesses the utility of the Perfusion Index (PI) and PI Ratio (PIR) as reliable markers for forecasting onset, success, and efficacy of supraclavicular brachial plexus block.[21,22]

Aim

To assess whether the perfusion index (PI) can foretell the success of supraclavicular brachial plexus block under ultrasound guidance in comparison to neurological assessment, and to determine the best cutoff value for the PI and PIR in detection of block efficacy.

Primary objectives

To evaluate the PI and PI ratio as predictors of successful supraclavicular nerve block

Secondary objectives

To determine the best cutoff value for the PI and PIR in detection of block efficacy such as sensory and motor blockade.

MATERIALS AND METHODS

This prospective observational study was conducted in sixty patients undergoing elective upper limb orthopaedic procedures under ultrasound-guided supraclavicular nerve block at Madras Medical College and Rajiv Gandhi Government General Hospital in orthopaedic theatre from September 2019 to February 2020. After obtaining institute ethics committee approval and written informed consent, sixty patients posted for elective upper limb surgeries were included in the study. The inclusion criteria were age between 18 years and 60 years, with Body Mass Index <35 coming under American society of Anaesthesiologists ASA Physical status I and II and posted for elective upper limb surgery (elbow/below elbow surgery). The exclusion criteria were patient refusal, allergy to local anaesthetic drugs, patients with severe cardiovascular, endocrine, respiratory, renal, hepatic, psychiatric diseases, peripheral vascular disease and coagulopathy. A comprehensive pre-anaesthetic assessment was performed for all participants and the patients were explained about the study protocol and written informed consent was taken. The patients were kept nil per oral for six hours before surgery. Patients were given IV pantoprazole 40 mg the previous night and IV ondansetron 4 mg on the day of surgery. Standard ASA monitors such as an electrocardiogram (ECG), non-invasive blood pressure (NIBP), and pulse-oximeter were connected, and baseline vitals like heart rate (HR), systolic (SBP), diastolic (DBP), mean arterial pressure (MAP), oxygen saturation (Spo2), respiratory rate (RR) were recorded. IV Ringer lactate was started at a maintenance rate of 10 ml/kg/hr through an 18G peripheral venous cannula. Perfusion Index Measurement done in both upper limbs, base line recording done. Inj. Midazolam (0.03 mg/kg) given intravenously as premedication.

Patient made to lie in supine position with the head of the patient turned away from the side to be blocked. The supraclavicular nerve block was performed under ultrasound guidance with high frequency linear transducer over the supraclavicular fossa in the coronal oblique plane immediately superior to the midclavicular point.[23] The block was performed using a 22-gauge 5 cm insulated block needle, which was inserted in-plane (lateral to medial) to the ultrasound probe. The brachial plexus was identified as a compact group of nerves, hypo-echoic, round or oval, located lateral and superficial to the pulsatile subclavian artery and superior to the first rib. A volume of 25 ml of local anaesthetic (bupivacaine 0.5% 12.5 ml and lidocaine 2%, 12.5 ml) was injected perineurally under vision to surround all the neural plexus.

Perfusion index (PI) was measured using Masimo set,[17] pulse oximetry [Figure 2] applied on the index finger after local anaesthetic injection in both blocked and unblocked arm using two separate oximeters at baseline, 10 minutes 20 minutes ,30 minutes. Perfusion index ratio (PIR) was calculated as a ratio between the PI at 10 and 20 mins after injection and the baseline PI. In every patient a comparison between the blocked and the unblocked limb is performed.

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Figure 2 – Masimo pulse oximeter

Sensory and motor block was assessed for the patients to identify the success of the block. Sensory block was assessed in dermatomal areas supplied by the four main nerves (median nerve, radial nerve, ulnar nerve, and musculocutaneous nerve) using 23G hypodermic blunt needle on a 3-point scale (0 - normal sensation, 1 -loss of sensation of prick [analgesia] and 2 -loss of sensation of touch [anaesthesia]) and compared to same stimulation on contralateral arm.[24] Assessment of motor block assessed by Modified Bromage 3 - point score (0- normal motor function with full flexion and extension of elbow, wrist and fingers, 1- decreased motor strength with ability to move fingers and/or wrist only and 2-complete motor blockade with inability to move fingers.[25] The supraclavicular nerve block was considered successful with regard to neurological examination when brachial plexus dermatomes (C5–T1) were completely blocked. The standard for unsuccessful block was taken as the need for conversion to general anaesthesia because of pain sensation at the site of the operation.

Sample size: Sample size was calculated using open epi version using master article for PI and PI ratio at 10 minutes for a cut off 3.3 and 1.4, respectively. To detect a positive correlation a sample of 60 subjects was calculated to provide 80% power.

Statistical Analysis: The collected data was entered in Microsoft Excel and transferred to SPSS software for analysis (version 22). Pearson correlation coefficient was used to analyse the association between two continuous variables. Repeated measures ANOVA was used to analyse the change in mean over time at various time intervals. Receiver operator characteristic curve was used to identify the use of perfusion index and perfusion index ratio in predicting the success of the block. The positive predictive value and negative predictive value were calculated for both the PI at 10 and 20 min and the PI ratio and compared with neurological examination for prediction of block success. For all tests of statistical significance p value of <0.05 was taken as significant.

RESULTS

Sixty eligible patients successfully received an ultrasound-guided supraclavicular nerve block (100% success rate). Patient demographics are summarized in [Table 1]. The study population had a mean age of 37.83 ± 11.28 years (range: 18–60 years), with a predominance of males (78%) and patients in the 18–30 age bracket. Perfusion index (PI) was monitored using a Masimo set pulse oximeter [Figure 2]. The Perfusion Index Ratio (PIR) was defined as the ratio of the PI at 10 minutes to the baseline value. While factors such as vascular elasticity and blood volume influence peripheral PI, it is primarily driven by changes in peripheral vascular resistance regulated by the autonomic nervous system. Consequently, a higher PI indicates increased digital blood flow, whereas a lower PI suggests reduced perfusion.

Table 1: Demographic variation

Characteristic	Mean± SD
AGE	37.83±11.28
BMI	24.38±2.57
SEX	M-47, F-13
ASA	I – 39 (65%), II – 21 (35)

Perfusion Index of Blocked and unblocked Limb

The Perfusion Index (PI), derived from pulse oximetry, provides a continuous and non-invasive assessment of peripheral perfusion. It is defined as the ratio of pulsatile blood flow to non-pulsatile flow. In the present study, baseline PI values were comparable across both limbs. However, successful neural blockade was characterized by a significant increase in PI within the blocked limb relative to the contralateral control at 10, 20, and 30-minutes post-injection. [Table 2,3. Figure 3,] Throughout the study, the perfusion index in the blocked arm remained significantly higher than baseline values across all measurement intervals. These results align with observations by various studies [27,28]. Furthermore, we observed a linear increase in the perfusion index from 10 to 30 minutes, a trend that mirrors the findings from literature.[29] Similarly, some studies [32] reported an increase in perfusion index after 5 minutes. Past studies have also found similar incremental change in perfusion index in the blocked arm[21,33].

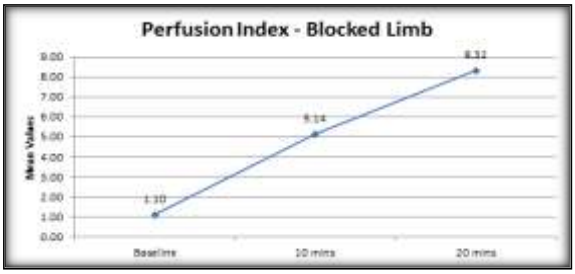

Figure 3: Perfusion index of blocked limb.

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Table 2: Perfusion index of blocked limb

Perfusion Index - Blocked Limb	Baseline	10 mins	20 mins
Mean	1.10	5.14	8.32
SD	0.50	1.41	1.72
P value	<0.001 (significant)		
Paired t Test	<0.001 (significant)		

Table 3: Perfusion index of blocked and unblocked limb

Perfusion Index		Baseline	10 mins	20 mins
Unblocked Limb	Mean	1.07	1.06	1.07
	SD	0.49	0.47	0.49
Blocked Limb	Mean	1.10	5.14	8.32
	SD	0.50	1.41	1.72
P value Unpaired t Test		0.739	<0.001 (significant)	<0.001 (significant)

Perfusion Index Ratio

The Perfusion Index Ratio (PIR) serves as a more robust clinical metric than the Perfusion Index (PI) alone, as it effectively accounts for confounding variables. While PI is susceptible to fluctuations in vascular elasticity, intravascular volume, and instrumental calibration errors, the PIR normalizes these internal and external factors. In this study, the PIR in the blocked limb was significantly higher than in the unblocked limb at both 10 minutes [5.23(2.28)] vs. [0.99(0.10)] and 20 minutes [8.32(1.72)], demonstrating statistical significance ($p<0.05$) [Figure 4, Table 4]. These results also align with findings by few studies, [27,28] who have reported significantly elevated PIR in the blocked extremity (PIR of > 2.5).

Figure 4: Perfusion Index Ratio.

Table 4: Perfusion Index Ratio

Perfusion Index Ratio	Unblocked Limb	Blocked Limb	
		10 mins	20 mins
Mean SD	0.99 0.10	5.23 2.28	8.32 1.72
P value Unpaired t Test		<0.001 (significant)	

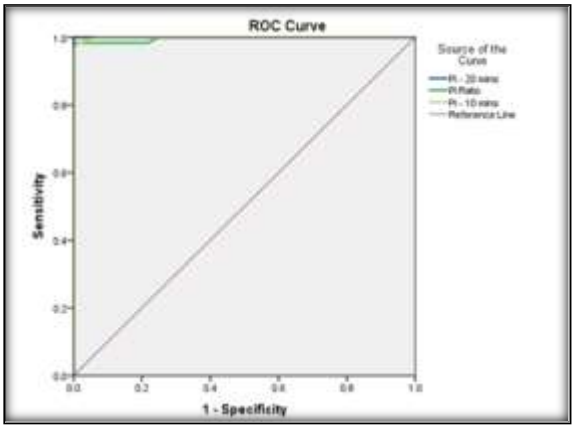

Figure 5: AUROC curve

AUROC curve

The AUROC curve for the PI ratio was 1 (0.95–1.00), with a cut-off value >1.4. [Table 5, Figure 5]. In studies focusing on PI for sensory block in supraclavicular blocks, a higher AUROC might suggest a stronger correlation between higher PI values and successful sensory block In the present study, Area Under Receiver Operator Curve (AUROC) for perfusion index was 0.84 at 30 minutes. The positive predictive value of 100% with a 95% confidence interval of 95–100% and negative predictive value of 100% with a 95% confidence interval of 57–100% were calculated for the PI as a predictor of block success.

Table 5: Perfusion Index and Perfusion Index Ratio Analysis

Accuracy Analysis	Perfusion Index - 10 mins	Perfusion Index - 20 mins	Perfusion Index Ratio
Cut Off	>3.3	>3.3	>1.4
Sensitivity (%)	100	100	100
Specificity (%)	100	100	100
PPV (%)	100	100	100
NPV (%)	100	100	100
AUC	0.999	1.000	0.996
P value	<0.001	<0.001	<0.001

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The PI increased in the blocked limb at 10, 20, and 30min compared with the baseline reading [Table 5 and Figure 5]. The AUROC curve for the PI ratio was 1 (0.95–1.00), with a cut-off value >1.4 [Table 5]. The positive predictive value of 100% with a 95% confidence interval of 95–100% and negative predictive value of 100% with a 95% confidence interval of 57–100% were calculated for the PI as a predictor of block success. None of patients with a successful block according to neurological examination needed general anaesthesia; thus, sensitivity of 100% and specificity of 100% were calculated for neurological examination for detection of successful block by the PI.

Perfusion Index - 10 mins @ >3.3

- Sensitivity of Perfusion Index - 10 mins @ >3.3 to detect block success is high,
- Specificity of Perfusion Index - 10 mins @ >3.3 to detect block failure is high,
- Positive predictive value of Perfusion Index - 10 mins @ >3.3 to detect block success is high,
- Negative predictive value of Perfusion Index - 10 mins @ >3.3 to detect block failure is high,

Perfusion Index - 20 mins @ >3.3

- Sensitivity of Perfusion Index - 20 mins @ >3.3 to detect block success is very high, meaning that 100% of successful blocks will be detected by this test at this cut off
- Specificity of Perfusion Index - 20 mins @ >3.3 to detect block failure is very high, meaning that 100% of unsuccessful blocks will be detected by this test at this cut off
- Positive predictive value of Perfusion Index - 20 mins @ >3.3 to detect block success is very high, meaning 100% of individuals with positive test will actually have successful blocks
- Negative predictive value of Perfusion Index - 20 mins @ >3.3 to detect block failure is very high, meaning 100% of individuals with negative test will actually unsuccessful blocks

Perfusion Index ratio @ >1.4

- Sensitivity of Perfusion Index Ratio @ >3.3 to detect block success is very high, meaning that 100% of successful blocks will be detected by this test at this cut off
- Specificity of Perfusion Index Ratio @ >3.3 to detect block failure is very high, meaning that 100% of unsuccessful blocks will be detected by this test at this cut off
- Positive predictive value of Perfusion Index Ratio @ >3.3 to detect block success is very high, meaning 100% of individuals with positive test will actually have successful blocks
- Negative predictive value of Perfusion Index Ratio @ >3.3 to detect block failure is very high, meaning 100% of individuals with negative test will actually unsuccessful blocks.

DISCUSSION

Upper limb regional anaesthesia provides targeted anaesthesia from the shoulder to the fingertips, serving as a robust alternative to general anaesthesia. By minimizing opioid consumption and providing superior postoperative pain relief, brachial plexus blockade has become a cornerstone of modern perioperative care. Among the various approaches—interscalene, supraclavicular, infraclavicular, and axillary, [8,20,21] the ultrasound-guided supraclavicular block is often preferred method for direct visualization and localization of the targeted nerve for procedures involving the arm and hand. Its primary advantage lies in the compact anatomy of the plexus at this level, which facilitates a rapid onset of dense anaesthesia using low volumes of local anaesthetics. Current literature identifies ultrasound guidance as the standard of care, correlating with enhanced patient and surgeon satisfaction, prolonged analgesic duration, and a reduction in procedure-related complications. Reported success rates for surgical anaesthesia typically range between 90% and 97%. Notably, few researches [26] suggests that supplemental nerve stimulation does not improve block efficacy, indicating that eliciting paraesthesia or motor responses is no longer the "gold standard" for confirming successful needle placement.

While the success of peripheral nerve blocks is traditionally assessed through sensory and motor testing, these methods remain subjective, time-consuming, and reliant on patient cooperation [6-8]. Although alternative objective metrics exist, many are hindered by their complexity or the need for specialized equipment. This study evaluates the utility of the Perfusion Index (PI) and the Perfusion Index Ratio (PIR) as objective, non-invasive indicators of successful supraclavicular blockade [27,28]. We aim to establish a definitive cut-off value for PI and PIR to accurately predict block success, thereby streamlining the clinical assessment process. Early and accurate detection of peripheral nerve block success facilitates prompt intervention—either through block supplementation or a transition to general anaesthesia—thereby optimizing operating room efficiency and enhancing patient satisfaction. In this study, we utilized the Perfusion Index (PI) ratio (defined as the 10-minute PI relative to baseline) to quantify the rate of increase following a successful block.[29] This approach was chosen to account for the significant skewness and inter-individual variability in baseline PI, a phenomenon previously documented in literature.[30,31]

Our prospective observational data demonstrated that the PI was significantly higher in the blocked limb at all measured intervals.[29] Furthermore, the PI ratio remained consistently elevated in the blocked limb compared to the contralateral control limb.[32] Given the inherent variability of absolute values, our findings suggest that dynamic changes in PI serve as a more robust indicator of block success.[33] We

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identified a PI cut-off of > 3.3 at 10 and 20 minutes and a PI ratio of > 1.4 as definitive markers of success,[35] with both metrics yielding a sensitivity and specificity of 100%[27,34] .

The diagnostic effectiveness or diagnostic accuracy in relation to Perfusion Index and Perfusion index ratio test is

- Perfusion Index - 10 mins @ >3.3 - with high specificity and PPV suggesting that false positives are very rare. It is also a very good screening test with very high sensitivity and NPV suggesting that false negative tests will occur rarely.
- Perfusion Index - 20 mins @ >3.3 - An excellent case finding or diagnostic test with very high specificity and PPV suggesting that false positives are very rare. It is also a very good screening test with very high sensitivity and NPV suggesting that false negative tests will occur rarely. On the whole it is an excellent combined diagnostic and screening tool with very high clinical utility to predict block success
- Perfusion Index Ratio @ >1.4 - An excellent case finding or diagnostic test with very high specificity and PPV suggesting that false positives are very rare. It is also a very good screening test with very high sensitivity and NPV suggesting that false negative tests will occur rarely. On the whole it is an excellent combined diagnostic and screening tool with very high clinical utility to predict block success

But among the three Perfusion Index - 20 mins @ >3.3 is the much better and robust test with very high clinical utility to predict block success because of higher area under the receiver operating characteristics value.

CONCLUSION

The Perfusion Index (PI) serves as a rapid, non-invasive, and cost-effective predictor of supraclavicular nerve block success. Our findings suggest that a PI > 3.3 at the 10- and 20-minute marks, and an intra-operative PI ratio > 1.4, provides a reliable objective measure of Ultrasonography guided supraclavicular block efficacy. Integrating PI monitoring into clinical practice allows anaesthesiologists to validate block onset early, optimize analgesic dosing, and implement timely interventions when necessary.

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