Original Article

Perfusion Index as a Parameter for Effectiveness of Ultrasound-guided Supraclavicular Brachial Plexus Block

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Abstract:

Background: *Ultrasound-guided (USG) supraclavicular brachial plexus block (SCBPB) in upper extremity surgery is a popular approach. Conventional methods for the evaluation of block success are time-consuming and need the patient's cooperation. The perfusion index (PI) is an oximetry reliability indicator, available on many monitors as a non-invasive parameter, indicating the ratio of arterial blood flow (pulsatile flow) to venous, capillary, and tissue blood flow (non-pulsatile blood flow), which is a more sensitive and earlier indicator of sympathetic blockade than temperature measurement. The main objective of this study is to evaluate the success of the supraclavicular block by using the perfusion index (PI) as a parameter.*

Methods: *This study was carried out between January, 2021 and January, 2022 at Dhaka Medical College in the orthopedics operation theatre. Patients received a total of 20 ml of 0.5% Bupivacaine for ultrasound guided supraclavicular brachial plexus block (SCBPB). Perfusion index was recorded on the index finger before & just after performance of SCBPB, after achieving complete sensory & motor block, after performance of SCBPB and at the time of the end of surgery. Comparison was done between the PI before SCBPB and just after SCBPB, after complete loss of sensory & motor function, and at the time of the end of surgery. Chi-square test was done for qualitative variables, and t-test was done for quantitative variables. A receiver operating characteristic (ROC) curve was used to determine the sensitivity and specificity of PI and to determine the cut-off point.*

Results: *A total of 90 patients were enrolled in the study. Considering PI just after SCBPB, at the time of complete sensory block, at the time of complete motor block, and at the time of the end of surgery with baseline PI, it was found statistically significant as $p<0.05$. While the area under the curve (95%CI) = 0.924(0.9-1.0) of PI at the time of complete motor block was greater than AUC (95%CI) = 0.913(0.9-1.0) of PI at the time of complete sensory block in the ROC curve. Perfusion index at the time of complete motor block has a higher 95.74% sensitivity and 97.3% specificity with 97.8% positive predictive value and 94.7% negative predictive value. Accuracy value 97.6%. And the cutoff value was >5.43. Where PI at the time of complete sensory block has 92.74% sensitivity and 97.56% specificity with 98.3% positive predictive value and 87.5% negative predictive value. Accuracy value 94%. And the cut off value was > 4.23. Mean PI value at the time of complete motor block 6.47±1.42 with percentage (%) change of PI from base line 197.6±18.6% was higher than mean PI value at the time of complete sensory block 5.47±1.12 and percentage (%) change of PI from base line 169.8±16.7%.*

Conclusion: *PI provides a real-time, objective, and continuous display, unlike intermittent, subjective clinical testing. It enables early identification of successful blocks, reducing operating time spent on sensory/motor assessments. So, PI can be used as a parameter of successful SCBPB.*

Keywords: *Brachial plexus block, Perfusion index, Monitoring, Accuracy, Sensitivity, Specificity.*

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Introduction:

Brachial plexus block, alone or in combination with general anaesthesia, has become one of the most important anaesthesia techniques for surgeries in the upper limb or shoulder. It provides excellent analgesia and muscle relaxation and considerably decrease the peri and postoperative opioid requirements[1]. In recent times, the use of brachial plexus block has been increasing in developing countries due to the growing expertise and confidence as well as improved access to ultrasound machine and nerve stimulators. The application of ultrasound technique for exact localization of nerves/plexus has revolutionized the regional anaesthesia field where in ultrasound probes with suitable frequencies have been successfully tried[2].

However, a successful peripheral nerves block is usually evaluated by assessment of sensory and motor function. The traditional method of assessing the degree of anaesthesia produced by brachial plexus block is based on the repeated use of a painful stimulus, usually pinprick. If sensation is intact, this may be unpleasant and may rapidly destroy the patient's confidence. Pin prick method is subjective, time consuming, and depends on patient cooperation and cognition[3].

Various objective methods are used for evaluation of block success. These are evaluation of the sympathetic block and consequent physiological changes, such as vasodilation and changes in blood flow and skin temperature. However, most of the objective methods require more time or dependent on sophisticated equipment[4].

The patient's response to pinprick is evaluated to determine whether an effective and successful block is adequate[5]. In traditional methods, evaluation of the loss of sensory responses to stimuli and communication with the patient should be very good. Furthermore, results vary from person to person. Quantitative methods are therefore needed to be able to make more objective evaluations. These quantitative methods evaluate local vasodilatation, increase blood flow and increase skin temperature as a result of sympathetic nerve blockade in the blocked area after a successful block. Increased blood flow is detected in the area, where the block is provided, by laser Doppler applications. However, the clinical use of this method is remain limited since it is not a cost effective method and application of which is difficult. As an alternative method, the sympathetic block is evaluated by measuring the change of the skin electrical resistance. In terms of clinical use; fast responses cannot be obtained with these methods under intensive operating room conditions and in urgent cases where time is important. Therefore, the perfusion index (PI) used to evaluate the success of peripheral blocks has become popular in recent years[6].

A successful supraclavicular nerve block for limb surgery is associated with vascular dilatation[7]. Perfusion index (PI), which is automatically calculated by pulse oximetry, provides an indication of peripheral perfusion at the sensor site. The Perfusion Index reflects the ratio between pulsatile and non-pulsatile blood flow and is a measure for the level of vascular dilatation. It was also emphasized that hypovolemia can be predicted by PI without a reduction of stroke volume by more than 20%. The increase in perfusion index is a good predictor for block success and can be used as an alternative for sensory or motor function tests[6].

It is affected by changes in intravascular volume, elasticity, and intravascular pulse pressure. Therefore, it corresponds to changes in blood volume and varies in values depending on the distensibility of vascular walls and pulse pressure. The blockade of sympathetic nerve fibers after successful nerve block results vasodilation and increased local blood flow, eventually increasing the PI. Several studies have investigated the utility of the PI for assessing regional anaesthesia success and reported that the PI can be used to determine the success of peripheral nerve blocks[8,9]. The traditional methods (Pin-prick test and Modified Bromage Scale) are subjective, and they depend on patients' cooperation but PI is the objective measurement of the succeccful block. Thus, the aim of this study was to evaluate the usefulness of perfusion index as parameter for determining the success of US-guided supraclavicular block in patients undergoing upper extremity surgery by using PI as parameter.

Methods:

This observational study was carried out in the Department of Anaesthesia, Analgesia, Palliative and Intensive Care in collaboration with the

Orthopaedics & Traumatology Department at Dhaka Medical College Hospital, Dhaka, from January 2021 to January 2022. Prior to the commencement of this study, the research protocol was approved by the Ethical Review Committee [ERC-DMC/ECC/2021/386(R)]. Assuming a 95% confidence interval and a study power of 80%, with anticipating 5% dropout, the total sample size was 90. Adult patients aged 18-60 years with American Society of Anaesthesiologist (ASA) grade I and II scheduled for elective upper limb surgery who required supraclavicular brachial plexus block under ultrasound guidance were included in this study. Patients who have a psychiatric illness, peripheral neuropathy, a history of peripheral vascular disease, morbid obesity (BMIe"40), block failure, and whose PI signal was lost during measurements were excluded from this study.

Study procedure

All the patients were informed about the study objective, procedure, advantage & disadvantages. Then they were examined during the preoperative visit on the day prior to surgery. They were kept nothing per orally for 6 hours before the scheduled time of surgery and were premedicated with intravenous omeprazole (40mg) and midazolam (0.02mg/kg)[10] two hours before surgery.

On arrival in the operating theatre, standard monitors including electrocardiogram, noninvasive blood pressure (NIBP), pulse rate, and pulse oximetry were applied. To avoid the influence of any change in blood flow, the NIBP was measured at the contralateral arm; the temperature in the block room was kept constant (25 °C) to minimize the impact from the environment.

Supraclavicular brachial plexus block was performed by one expert anesthesiologist with extensive prior experience in performing regional anesthesia. Patients were placed in a semi-fowler's position with the head turned to the opposite side of the surgical area. Chlorhexidine gluconate 0.5% + 70% Isopropyl alcohol used for skin sterilization. After skin infiltrate with 2 ml of 1% lidocaine, a high-frequency linear transducer (6–13 MHz; X-porte; SonoSite, Bothell, Washington) was used to identify the brachial plexus in the supraclavicular fossa. A 22-G needle for peripheral nerve blocks (B. Braun Melsungen AG, Germany) was inserted following a lateral to medial direction using the in-plane technique. The needle was advanced to the intersection of the first rib and the subclavian artery (i.e., the corner pocket). After confirming that the aspirations test was negative, 2 ml of prepared solution of 0.5% bupivacaine was injected. Then the needle was reposition in the neural cluster the remaining 18 ml of 0.5% bupivacaine was injected. Total 20 ml of 0.5% bupivacaine was injected.

After the completion of the SCBPB procedure, the degree of sensory and motor blocks assessed just after SCBPB, at the time of achieve complete sensory & complete motor block. The sensory block was evaluated in the distributions of the radial, median, ulnar, and musculocutaneous nerve dermatomes with the pinprick test using a blunt-tip needle with a three-point scale (2 = normal sensation, 1 = loss of sensation to pinpricks, and 0 = loss of sensation to light touch). The motor block was tested according to the distribution of nerves as follows: radial (thumb abduction), median (thumb opposition), ulnar (thumb adduction), and musculocutaneous (elbow flexion) with grading on a three-point scale (2 = no loss of force, 1 = decreased force compared with the contralateral arm, and 0 = incapacity to overcome gravity)[11]. The block onset time was defined as the time from the completion of the injection of the study drug until a sensory score of 0 was reported, which was indicated the complete loss of sensory function in the radial, median, ulnar, and musculocutaneous nerves. Block success was defined as the complete loss of sensory function of the mentioned nerve distribution after completion of the SCBPB.

Block failure was defined by a sensory region involved in the surgery is not completely anesthetized or if there was pain at the surgical site, the block was considered as a failed block and supplemental analgesia or conversion to general anaesthesia was considered as per requirement of the patient and they were excluded from the study. Two patients were excluded considered as a failed block.

Perfusion index assessment

A pulse oximeter (Radical-7®; Masimo Corporation, Irvine, CA, USA) was used to monitor the PI. The machine applied to the index finger of operative hand to measure the PI. The PI record at the

following events of time: before the SCBPB (baseline), just after the SCBPB, at the time of complete sensory block (0 = loss of sensation to light touch), at the time of complete motor block (Modified Bromage scale >3) and at the time of end of surgery. Then the PI were compaired among the different events of time. If the pulse oximeter reading was lost in any patients during that period,they were also excluded from the study. Four patients were excluded considered as lost pulse oximeter reading.

The same surrounding environment was maintain until all parameter measurements were completed and to prevent changes in the PI.

Other data like SpO2, SBP, DBP, MAP and PR were measured before block performance and follow up data were recorded before the SCBPB, after the SCBPB , at the time of complete sensory block, at the time of complete motor block and at the time of end of surgery. All data were collected in separate data form and patients demographic data were collected from hospital record file.

The Primary outcome was to observe relation between perfusion index and the success of ultrasound-guided Supraclavicular Brachial Plexus Block by using the Receiver Operating Characteristic (ROC) curve. The Secondary outcome was to calculate the sensitivity (%) and specificity (%), positive predictive value (%) and negative predictive value (%) of perfusion index for determining the success of ultrasound-guided Supraclavicular Brachial Plexus Block.

Statistical analysis:

Data were statistically described in terms of mean ± standard deviation (±SD), or frequencies (number of cases) and percentages when appropriate. Comparison of numerical variables among the study patients were done using Student t- test for independent samples. For comparing categorical data, Chi square (÷2) was performed. ANOVA was used for multiple comparisons among the variable. Receiver operating characteristic (ROC) curve was used to determine the sensitivity and specificity of PI and to determine the cut off point. P values less than 0.05 was considered statistically significant. All statistical calculations were done using computer programs SPSS (Statistical Package for the Social Science; SPSS Inc., Chicago, IL, USA) version 25 for Microsoft Windows.

Results:

A total of 90 patients who were scheduled for upper limb surgery under SCBPB were selected for this study. During perioperative period four patient had lost signal from the pulse oximeter and two patient had block failure. So they were exclueded from the study. Then finally data were calculated for 84 patients who were fulfilled both inclusion and exclusion criteria. All the data were compared and expressed with table, graph and diagram (ROC curve).

Table-I: *Demographic characteristics of the patients (n=84)*

Characteristics		Value
Age (years)		34.68±12.76
Height (cm)		158.45±9.65
Weight(Kg)		61.83±6.43
BMI (kg/m^2)		23.74±2.93
Hemoglobin (g %)		12.38±1.57
Gender	Male	47 (57.3%)
	Female	35 (42.7%)
ASA	I	54 (65.9%)
	II	28 (34.1)

Data were expressed as mean±SD and percentage within the parenthesis.

Table I demonstrates the demographic characteristics of the patients. The mean age of the patient was 34.68±12.76 yrs, mean BMI was 23.74±2.93 and Hemoglobin (gm%) was 12.38±1.57. Maximum patient was ASA Class I (65.9%). On consideration of gender most of the patients was male in gender (57.3%).

Considering type of upper limb surgeries among patients such as elbow deformity (4.7%), forearm deformity (3.5%), hand deformity (7.1%), humerus fracture (21.4%), radius fracture (26.2%), ulna fracture (25.0%) and wrist deformity (11.9%). Table II showed the type of upper limb surgeries among the patients.

Table II. *The type of upper limb surgeries among the patients*

Diagnosis	Number of patients	Percent
Elbow fracture	4	4.7%
Forearm fracture	3	3.5%
Hand deformity	6	7.1%
Humerus fracture	18	21.4%
Radius fracture	22	26.2%
Ulna fracture	21	25.0%
Wrist deformity	10	11.9%

Values are expressed as percentage (%) over column in total.

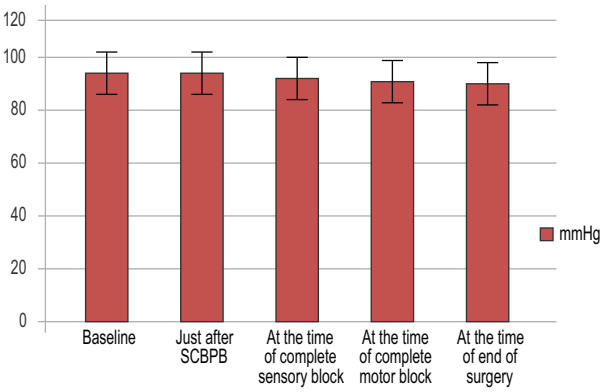

Figure 2: *Mean arterial pressure during perioperative periods among the patients*

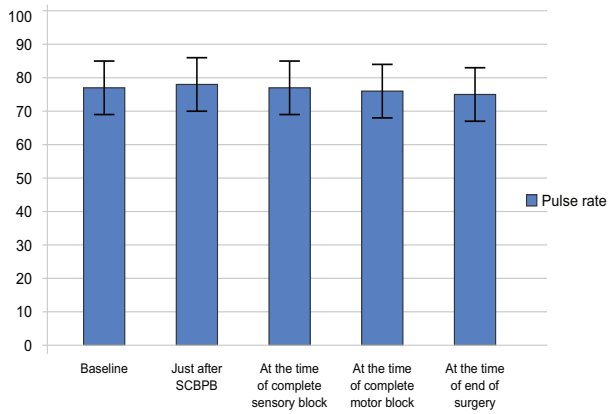

Figure 1: *Mean pulse rate during the perioperative periods among the patients.*

Figure 1 and 2 demonstrates no significant change in pulse rate and mean arterial pressure (MAP) during perioperative periods among the patients.

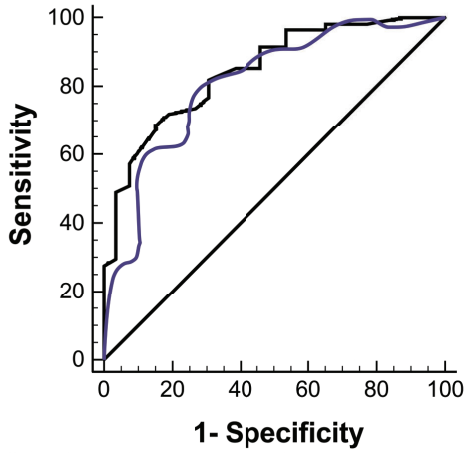

Figure 3: *ROC curve of PI at the time of complete sensory block, at the time of complete motor block. (Blackline- at the time of complete motor block Blue line – at the time of complete sensory block.)*

Table III. *Comparison of perfusion index (PI) values measured at different events*

Points of time	Mean±SD	% change of PI from baseline	p* value
Baseline(Before SCBPB)	3.23±0.75		
Just After SCBPB	4.12±0.96	128.5±7.4	0.0028
At the time of complete sensory block	5.47±1.12	169.8±16.7	0.0023
At the time of complete motor block	6.47±1.42	197.6±18.6	0.0021
At the time of end of surgery	6.12±1.68	186.9±20.5	0.0024

ANOVA was used for multiple comparisons and dependent t-test was used for binary comparisons.

Table III described that there had statistically significant difference in different time of interval while considered PI.

The ROC curve had shown that AUC (95% CI) = 0.913(0.9-1.0) in case of PI at the time of complete sensory block. While AUC (95%CI) =0.924(0.9-1.0) of PI at the time of complete motor block. (Figure 3)

Table IV: *Cross tabulation showing percentage change of perfusion index at the time of complete sensory block (N=84)*

The change of perfusion index at the time of complete sensory block	The perfusion index		P-value
	Change of PI (>50%)(n=55)	Change of PI (<50%)(n=29)	
Cut off value >4.23%	51 (TP)	1 (FP)	<0.05
Cut off value d" 4.23	4 (FN)	28 (TN)	<0.05
Total	55	29	

True positive (TP) =51, False positive (FP) = 1, False negative (FN) = 4, True negative (TN) =28.

From the values of the above table, sensitivity, specificity, positive predictive value and negative predictive value of perfusion index at the time of complete sensory block were 92.74%, 97.56%, 98.3%, and 98.3%, respectively. The accuracy value at the time of complete sensory block was 94%.

Table V: *Cross tabulation showing percentage change of perfusion index at the time of complete motor block (N=84)*

The change of perfusion index at the time of complete motor block	The perfusion index		P-value
	Change of PI (>50%)(n=47)	Change of PI (<50%)(n=29)	
Cut off value >5.43	45 (TP)	1 (FP)	<0.05
Cut off value d"5.43	2 (FN)	36 (TN)	<0.05
Total	47	37	

True positive (TP) =45, False positive (FP) = 1, False negative (FN) = 2, True negative (TN) =36.

The sensitivity and specificity of PI at the time of complete motor block are 95.74% and 97.3% respectively. Similarly, the positive predictive value and negative predictive value of perfusion index at the time of complete motor block are 97.8% and 94.7% respectively. The accuracy value at the time of complete motor block was 96.4%.

Perfusion index at the time of complete sensory block has 92.74% sensitivity and 97.56% specificity with 98.3% positive predictive value, 87.5% negative predictive value & accuracy value was 94%. Where the cutoff value was >4.23. But the PI at the time of complete motor block has higher 95.74% sensitivity and 97.3% specificity with 97.8% positive predictive value 94.7% negative predictive value & accuracy value was 96.4%. Where the cutoff value was >5.43. (table VI)

Table VI: Ability of PI at the various point of time to predict block success.

Parameter	Sensitivity (%)	Specificity (%)	Positive predictive value (%)	Negative predictive value (%)	Accuracy value %	AUROC (95%CI)	Cut-off Value
PI At the time of complete sensory block	92.74%	97.56%	98.3%	87.5%	94%	0.913(0.9-1.0)	>4.23
PI At the time of complete motor block	95.74%	97.3%	97.8%	94.7%	97.6%	0.924(0.9-1.0)	>5.43

AUROC=area under the receiver operating characteristic curve; CI= confidence interval; PI=perfusion index

Discussion

A successful peripheral nerve block (PNB) results in the blockade of sympathetic nerve fibers cause some physiological changes. These changes can be measured by some conventional methods & some modern methods. Among them, perfusion index (PI) has been studied more commonly in the last two decades as it is simple, rapid, noninvasive, and easy to measure and interpret. The role of PI in predicting the success of various peripheral nerves block, as a parameter for fluid responsiveness and early detection of blood loss and post spinal hypotension has been evaluated in literature[12,13,14].

The results of the current study shown that PI is a good predictors of successful SCBPB. After administration of LA drug patients with SCBPB blocks had showed increase in PI values suggesting that increase in PI values is associated with sympathetic blockade. Here calculated cut off value of PI 4.23 at the time of complete sensory block and cut-off value of PI 5.43 at the time of complete motor block. However, the ROC curve had showed that AUC (95%CL) = 0.913(0.9-1.0) in case of PI at the time of complete sensory block, while AUC (95%CI) =0.924(0.9-1.0) in case of PI at the time of complete motor block.

Similarly, the positive predictive value (PPV) of 98.3% for PI at the time of complete sensory block and PPV of 97.8% at the time of complete motor block indicate that almost all predicted number of successful blocks actually turned out to be successful. While negative predictive value (NPV) 87.5% for PI at the time of complete sensory block and NPV 94.7% for PI at the time of complete motor block. These indicate that the predicted number of successful blocks actually a good options for prediction of block success. This means that PI is very accurate in assessing efficacy of ultrasound guided supraclavicular brachial plexus block. Finally, the outcome value of PI at the time of complete sensory block was 92.74% sensitivity and 97.56% specificity, where PI at the time of complete motor block was higher 95.74% sensitivity and 97.3% specificity. Accuracy value at the time of complete sensory block was 94% & accuracy value at the time of complete motor block was 96.4%. So, PI is an acceptable parameter of assessing efficacy of ultrasound guided supraclavicular brachial plexus block. This is because the value of sensitivity indicate that all the successful blocks were correctly identified as successful and a value of specificity indicate that none of the successful blocks were incorrectly identified as unsuccessful. Similar results were presented by Abdelnasser et al., (2017)[15] who also tested the use of PI to predict and provide a cut-off value for ultrasound-guided supraclavicular brachial plexus nerve block success and reported higher PI in the blocked limb at all three-time intervals when compared with the unblocked limb. Further, after injection, the PI at 10 minutes showed a sensitivity and specificity of 100% for block success at cut-off values of 3.3 and 1.4, respectively as was registered in the present research. This similarity in the cut-off value between the two studies despite the methodological differences in the site (supraclavicular nerve block vs axillary and sciatic nerve block) technique (ultrasound vs nerve stimulator), and drug (bupivacaine and lidocaine vs mepivacaine) would be a clue to reach a definitive cut-off value[6].

Candan et al. (2018)[16] used 1 mg/kg 0.5% bupivacaine + 5mg/kg 2% prilocaine and 0.09 % NaCl to complete it to 45 ml in their study about infraclavicular block. The results of the study showed a 132% increase in perfusion index when the 5th minute PI value compared to baseline PI value. As a result, the PI in the infraclavicular block was defined as a sensitive test that predicts block success more quickly than traditional methods. In our study we have also found 169% increase in the ratio of PI values at the end of sensory block to base line PI values. We have used the same local anesthetics but in lower volumes. Higher volumes of local anesthetics used in the supraclavicular block can cause Horner syndrome[16].

In other studies using PI, Galvin,et al. (2006)[6] used 1.5% mepivacaine and found 155% increase in PI at the 10th minute of axillary block and at the 12th minute of the sciatic block. Kuº et al. (2013)[17] found an increase of 120% in PI at the 10th minute of infraclavicular block using 20 ml of levobupivacaine + 10ml lidocaine. Yamazaki et al. (2012)[18] found that an increase of 61.4% in PI in the 5th minute of stellate ganglion block with 6 ml 1% mepivacaine was sufficient for block success. The reasons of difference between our

study & this study are the type of drug, volume of drug, the approach of the procedure, duration of time.

In our study Mean±SD PI value at base line was 3.23±0.75, just after SCBPB was 4.12±0.96, at the time of complete sensory block was 5.47±1.12, at the time of complete motor block was 6.47±1.42, and at the end of surgery was 6.12±1.68. PI value was increased significantly at different events of time & SCBPB was adequate to perform surgery when PI was 6.47±1.42 as at that time, complete sensory & motor block was achieved.

Percentage (%) change of PI from baseline just after SCBPB was 128.5±7.4%, at the time of complete sensory block was 169.8±16.7%, at the time of complete motor block was 197.6±18.6%, and at the time of the end of surgery was 186.9±20.5%. This indicates that 186.9±20.5 % change of PI from baseline to perform surgery with adequate SCBPB, as at that time complete sensory & motor block was achieved.

Detection of block success is usually performed using traditional assessment of sensory and motor function. Traditional methods are usually time-consuming. Traditional methods need patient cooperation, so they are not applicable while the patient is under general anaesthesia. Previous studies showed other objective methods for the detection of successful block; these methods included thermographic temperature measurement, laser doppler perfusion imaging, and skin electrical resistance. The PI is characterized by being simple, rapid, and user-friendly compared with other objective methods for the evaluation of block success. Early and accurate detection of peripheral block success would enable rapid corrective action either by block supplementation or by switching to general anaesthesia; this would save the operating room time and improve patient satisfaction. Objective methods of evaluation of block success would also avoid repeated pin pricking and allow block evaluation in sedated and anaesthetized patients also.

Conclusion:

The Perfusion Index successfully demonstrates its effectiveness in ultrasound-guided Supraclavicular Brachial Plexus Block. This can be used as a parameter for effectiveness in regional blocks.

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