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Prediction of Successful Infraclavicular Brachial Plexus Block Using Perfusion Index Derived From Pulse Oximeter

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Abstract
Background: *The conventional methods for block assessment are subjective and require patient cooperation. These methods consume time and are observer-dependent. Hence, objective methods have been developed for block assessment. The primary objective was to evaluate whether the perfusion index and perfusion index ratio can be used as predictors of successful infraclavicular nerve block. The secondary objective was to determine the cut-off value for PI and any other relevant observations.*
Methodology:*After approval and permission from the institutional ethics committee no. MC/190/2007/Pt-11/July-2021/TH -26 40 patients of either sex, ASA 1 and 2, between the ages of 18-60, posted for upper limb surgeries under ultrasound-guided infraclavicular brachial plexus block were selected for the study. After the block procedure was completed, the perfusion index was recorded at every five minutes interval for thirty minutes. The PI ratio was calculated as the ratio between the PI at 10 minutes and the PI at baseline. The motor block onset time, sensory block onset time, and the surface temperature of the block limb were also recorded.*
Results:*The baseline PI was comparable between the blocked and unblocked limbs. The degree of change of PI from baseline was consistently increasing and the difference was found to be statistically significant in the blocked limb.*
Conclusion:*It was found that the PI was an effective, non-invasive, and objective predictor of peripheral nerve block. It was found to be a better method than the traditional methods of block assessment.*
Keywords: Brachial plexus nerve block, infraclavicular block, perfusion index, pulse oximeter, ultrasonography.

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I. Introduction

The technique of brachial plexus block is a popular approach for regional anesthesia in upper limb surgeries. It has evolved from the classical blind technique to the use of nerve stimulators and ultrasound guidance.(1) With the introduction of USG in the regional anesthesia practice, the imaging of peripheral nerves and guiding of the needle to the nerve site have made nerve blocking easier and safer.The conventional methods for block assessment for both motor and sensory blocks are subjective and require patient cooperation, consume time, and are observer-dependent. Hence, objective methods have been developed for block assessment.(1,2) With recent advances, various objective methods have been developed. These methods include thermographic temperature measurement, laser doppler perfusion imaging, and skin electrical resistance. These are time-

consuming and are sophisticated equipment dependent.[1]Perfusion index is one objective, non-invasive, simple, rapid, and relatively new parameter that has been used to evaluate the success of regional anesthesia in clinical practice. Perfusion index is the measurement of pulsatility, not a measurement of blood flow.[3] It is the ratio of pulsatile blood flow to non-pulsatile blood flow.The perfusion index is reduced in every vasoconstrictor stimulus or sympathetic nervous system activation as the height of the pulsatile part ofthe curve is reduced. On the other hand, any vasodilator stimulus or activation of the parasympathetic nervous system increases the perfusion index as the height of the pulsatile part of the curve is increased. [4] The perfusion index has been used to evaluate peripheral perfusion dynamics due to changes in the peripheral vascular tone and as an index for sympathetic stimulation.[2] Perfusion index has been recently studied as a predictor of various peripheral block successes such as supraclavicular brachial plexus block, axillary block, interscalene block, and sciatic nerve block.[1,5,6] Not many studies have been based on the perfusion index as a predictor of infraclavicular blocksuccess. Therefore, we aim to evaluate the performance of the perfusion index in predicting infraclavicular block success.

II. Methods And Materials

Patient selection

A total of 40 patients between the age of 18-60 years, ASA I and II,posted for elective orthopedic upper limbsurgeries under infraclavicular brachial plexus block, were selected for the study. Patients with known hypersensitivity to local anesthetic agents, infection at the site of block, known coagulopathy, patients with diabetes mellitus, pregnant or lactating mothers, patients with peripheral vascular disease and chronic analgesic therapy were excluded from the study. Written and informed consentwas taken from all patients after describing the procedure, its benefit, and itspossible adverse effects.

Sample size collection

The sample size was calculated using Medcalc software version 14 (MedCalc Software bvba, Ostend, Belgium). to detect an area under ROC of 0.7. With null hypothesis of 0.5; considering a power of 90% and a level of significance of 5%; 34 patients will be needed. Considering an attrition rate of 15%, wechose to study 40 patients.

The patients were shifted to the preoperative holding area on the day ofsurgery and connected to the monitors [electrocardiogram (ECG), noninvasive blood pressure monitoring (NIBP), peripheral oxygen saturationprobe (placed on the thumb), and surface temperature probe (connected tothe thumb). Standard monitoring was done in the form of baseline BP, HR,ECG, SpO2, and temperature. The intravenous line was accessed with an 18G cannula in the contralateral arm prior to the application of the proposed brachial plexus block. Baseline PI was recorded on the thumb of the lefthand by pulse oximeter of Meditech England Neptune plus Anaesthesiaworkstation.

After theultrasound-guided infraclavicular brachial plexus block was performed with 30 ml of 0.5% ropivacaine, the perfusion index at 0 mins, 5 mins, 10 mins, 15 mins, 20 mins, 25mins, 30 mins in both the blocked and unblocked limbs was recorded and the perfusion index ratio was calculated. The surface temperature at five minutes intervals for 30 minutes, the sensory block onset time, and the motor block onset time were recorded.The limb was evaluated for block success every 3 minutes up to 30 minutesfor sensory block and motor block. The sensory block was assessed by pinpricktest in the median, radial, ulnar, and musculocutaneous nerve distributionsusing a 3-point scale.

0 – normal sensation.
1 – loss of sensation to pinprick.
2 – loss of sensation to light touch.
The motor block will be assessed by the Modified Bromage scale.
0 – No movement in the relevant muscle group.
1 – Flicker of movement in the relevant muscle group.
2 – Ability to move relevant muscle group against gravity, inability to moveagainst resistance.
3 – Reduce power but ability to move muscle group against resistance.
4 – Full power in the relevant muscle group.

The PI ratio was calculated as the ratio between the PI at 10 mins afterinjection of local anesthetic and the baseline PI in the blocked limb.In every patient, a comparison between blocked and unblocked limbs wasperformed.A successful block was defined as[7]as the complete absenceof sensation in all the dermatomes in the operated extremity with no powerto move any of the shoulder, elbow, and wrist joints, evaluated at 30 minutesafter block administration.Block failure was defined as [7] as the absence of fullsensory block in at least

one of the dermatomes in the operated upper limbevaluated at 30 minutes after block administration. In case of block failure,the surgery was carried out under general anesthesia.
Intraoperatively, sedation with 1 mg intravenous midazolam was provided toall patients.

III. Results And Observations:

A total of 77 patients were screened for inclusion criteria for their study.40 eligible patients wereselected, among which, 2 patients were excluded from the study, one patient was not cooperative and the other because of equipment malfunction; which waswithin the attrition rate of 15% considered during the sample sizecalculation. Hence, statistical analysis was done on 38 patients.

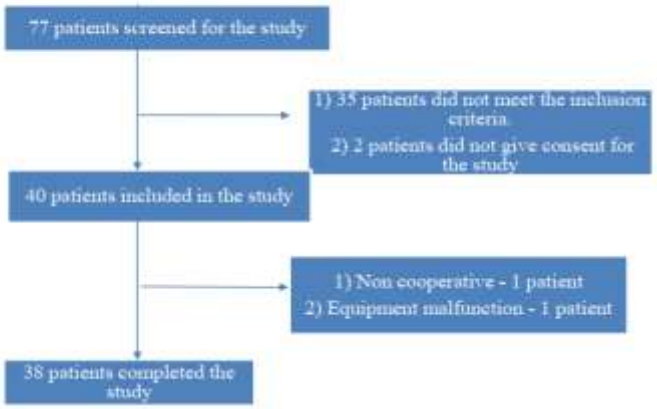

Figure1: Strobe flow chart showing recruitment of patients for the study

Demographic variables and ASA grading
The demographic details of the 38 patients are mentioned in the table below.

Table 1: Showing demographic variables and ASA physical status.

PARAMETER	DESCRIPTIVE VALUES±SD
Age(years)	35.79±11.848
Weight(kg)	61.87 ± 7.52
Sex(male/female)	26/12
Asa status (1/2)	29/9

Block characteristics
a. The onset of sensory block was found to be 11.63 ± 1.70 and the onset of motor block was found to be 15.55 ± 1.83.

Table2: Sensory and motor block onset time

	MEAN	SD
ONSET OF SENSORY BLOCK(MIN)	11.63	1.70
ONSET OF MOTOR BLOCK(MIN)	15.55	1.83

b. Block success and block failure

Table 3: Frequency of successful and failed blocks

STATUS	FREQUENCY	PERCENT
SUCCESS	36	94.73
FAILURE	2	5.27

Perfusion index
The PI values were recorded at 5 minutes intervals from 0 minutes after the block procedure was completed for 30 minutes in both limbs.

Table 4: Comparison of PI values in the blocked limb at different time intervals.

Perfusion index (n=38)	Mean ± SD	Percentage of change from baseline	P value as compared to baseline
0 MIN	2.24 ± 0.39		
5 MIN	3.17 ± 0.54	41.69%	<0.001
10 MIN	4.47 ± 1.15	99.65%	<0.001
15 MIN	5.51 ± 0.99	146.11%	<0.001
20 MIN	6.18 ± 1.03	175.94%	<0.001
25 MIN	6.76 ± 1.27	201.87%	<0.001
30 MIN	8.47 ± 1.7	278.36%	<0.001

The degree of change from baseline was consistently increasing and the difference was found to be statistically significant ($p < 0.001$) in the blocked limb. Paired t-test was used for the comparison of the baseline to different time points.

Table5: Perfusion index. Data are presented as the median (range) (IQR) and mean (SD); PI, perfusion index; PI ratio, perfusion index at 10 minutes/ perfusion index at baseline.

Perfusion index	Blocked		Unblocked		
	Mean ± SD	Median (IQR)	Mean ± SD	Median (IQR)	p value
0 min	2.24 ± 0.39	2.2 (1.9-2.53)	2.21 ± 0.39	2.2 (1.9-2.5)	0.738
5 min	3.17 ± 0.54	3.2 (2.8-3.61)	2.23 ± 0.39	2.2 (1.88-2.5)	<0.001
10 min	4.47 ± 1.15	4.2 (3.9-5.33)	2.25±0.36	2.25 (1.9-2.53)	<0.001
15 min	5.51 ± 0.99	5.2 (4.8-6.5)	2.21±0.39	2.2 (1.8-2.52)	<0.001
20 min	6.18 ± 1.03	6.1 (5.5-6.9)	2.18±0.38	2.5 (1.8-2.5)	<0.001
25 min	6.76 ± 1.27	6.7 (5.97-7.72)	2.21±0.4	2.2 (1.8-2.53)	<0.001
30 min	8.47 ± 1.7	8.35 (7.8-9.58)	2.22±0.38	2.2 (1.8-2.53)	<0.001

In the table above, Mann Whitney test is used for comparison betweenblocked and unblocked limbs. The change in PI from baseline in the blockedlimb was found to be statistically significant($p<0.001$). The PI comparisonbetween blocked and unblocked limb was found to be statisticallysignificant($p<0.001$).The baseline PI was comparable between blocked and unblocked limbs.

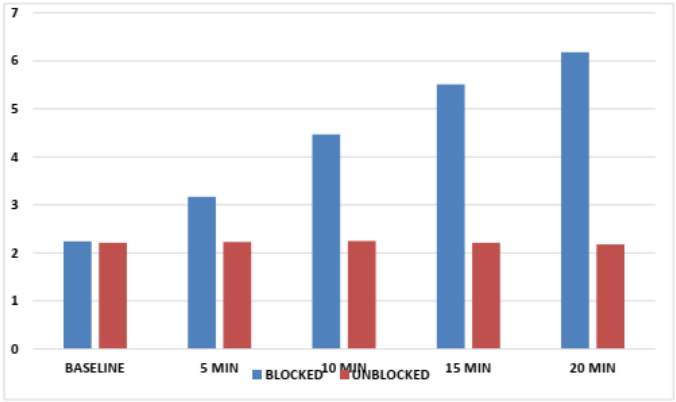

Figure 2: Perfusion index at different time intervals in blocked and unblocked limbs.

ROC curves were constructed for PI as a predictor of block success at 10min and the PI ratio, which is measured by the PI ratio at 10 minutes fromthe PI at baseline. For the PI at 10 min, the area under the ROC curve (AUC)was 1, 95% confidence interval (CI) (0.95-1), $p < 0.001$.A cut-off value of 3.35 of PI at 10 mins predicted block success with a sensitivity of 100% and specificity of 100%. For the PI ratio, the area under thecurve was found to be 1 (0.95-1), $p< 0.001$ The cut-off for the PI ratio wasfound to be 1.38 at 10 min, with sensitivity and specificity of 100%.

Table 6: Showing receiver operating curve characteristics.

	AUROC (95% CI)	Sensitivity (%)	Specificity (%)	PPV	NPV	Cut off
PI at 10 min	1 (0.95-1)	100	100	100	100	3.35
PI ratio	1 (0.95-1)	100	100	100	100	1.38

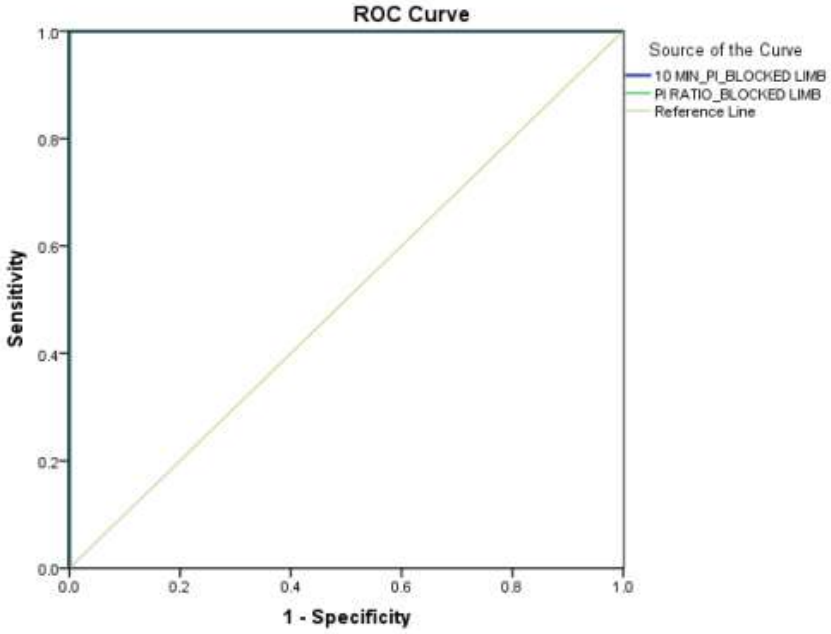

Figure 3: Receiver operating characteristics curve for PI at 10 minutes and PI ratio.

Correlation between PI and temperature of theblocked limb:

PI showed a positive correlation with the temperature at all time intervals. PIshowed a statistically insignificant correlation with temperature from 0 minute to 15 minutes; however, it showed a statistically significant correlation withtemperature from the 20th minute. ($p<0.05$)

Table 7: Pearson correlation of PI vs Temperature

PI vs TEMP	Correlation	
	r_{pb}	p value
0 MIN	.099	.554
5 MIN	.251	.129
10 MIN	.276	.093
15 MIN	.311	.057
20 MIN	.365	.024
25 MIN	.385	.017
30 MIN	.406	.011

IV. Discussion:

The efficacy ofperipheral nerve blocks are assessed by conventional methods, such assensory evaluation by pin prick and motor evaluation by the ModifiedBromage Scale. These tests are subjective and require patient'scooperation. Hence, various non-invasive, accurate and faster methods ofevaluating the efficacy of a peripheral nerve block have been developed; andperfusion index is one such non-invasive, reliable and accurate parameter ofpredicting a block success. There is peripheral vasodilatation after regionalanaesthesia due to sympathetic blockade. This vasodilatation occurs beforethe sensory and the motor block. Thus, perfusion index is an accuratemethod of evaluating a block success than the other conventional methods.[8]

After the completion of the block, theperfusion index was recorded at 5 minutes intervals for 30 minutes in boththe blocked and unblocked limbs; the baseline in both the blocked andunblocked limbs wascomparable. The blocked limb's surface temperature was also recorded at five minutes intervals for 30

minutes.The perfusion index was found to increase consistently from the baselinesignificantly. In our study, ROC analysis shows that the change in the PI at10 minutes from baseline and perfusion index ratio in the blocked limb ishighly predictive of block success, with AUC 1 (95% CI, p< 0.001),sensitivity 100%, and specificity 100%. The area under the ROC for the PI at10 minutes after the anesthetic injection is 1, with a cut-off value of 3.35,and the area under the ROC for the PI ratio is 1, with a cut-off value of 1.38.We obtained a PPV of 100% and an NPV of 100% which suggests thatthe perfusion index and perfusion index ratio can be used as predictors for theassessment of block success. The perfusion index was found to increase by100% from the baseline at the 10th minute and around 175% at the 20thminute in the blocked limb.Our study mirrored the findings obtained by Abdelnasser et al[(1)] where a cutoffvalue of 3.3 for PI and 1.39 for the PI ratio was found.Lal et al.,[(9)] also conducted a similar study on the Indian population andfound a cut-off value of 3.35 for PI, which correlates with the finding of ourstudy.

The temperature of the blocked limb was recorded every 5 minutesinterval for 30 minutes after the block procedure was completed. Thetemperature differences at different intervals were found to be significant inthe blocked limb (p<0.001). The temperature in the blocked limb increasedby 0.7-10°C.A statistically significant positive correlation was found between thetemperature at 20 minutes from the completion of the block and theperfusion index.Similar to our study, the increase in skin surface temperature was alsorecorded in the study conducted by Miniville et al.,[(10)]where he used aninfrared thermometer for temperature assessment in the blocked andunblocked limb. A rise of 10°C or more was seen in the blocked limb at 5 and10 minutes after the block.In the study conducted by Galvin et al.,[(5)] he used thermographic images tocalculate the temperature values in the blocked and unblocked limb. Theaverage mean temperature increase in the successful blocks at 15 min was4.5°C ± 2.0°C. The higher values seen in this study may be due to the difference in the method of temperature assessment.Thus, this correlates with our finding and it can be inferred that skin temperature is an important non-invasive predictor of block success.The change in perfusion index was seen as early as five minutes

after the block procedure was completed. However, the sensory block onsettime was found to be around 10 to 13 minutes and the motor block onsettime was found to be 14 to 18 minutes from the completion of the block.This may be due to the peripheral vasodilation that occurs followingregional anesthesia. This is due to the fact that sympathetic fibers areblocked at the earliest and also requires the lowest concentration of localanesthetic; followed by A delta, A beta, and C fibers.[(11)]So, the changes in perfusion index occurred earlier than the sensory and motor block onsettime. Hence, the perfusion index is a faster predictor of block success than theother conventional methods of evaluation, as inferred from our study.

Limitations of the study

a) It is a single hospital study, but for the purpose of evaluation ofparameters that we have used in our study, a multi-hospital study isconsidered to be better.

b) A low number of failed blocks and all failed blocks were consideredas one group without grading the degree of success.

c) The study population was not large enough to evaluate thedifferences, especially the cut-off values.

d) In our study, the temperature was not recorded in an unblocked armand no comparison was made.

V. Conclusion:

Thus, we can conclude that both the perfusion index and perfusion index ratioare good predictors of ultrasound-guided infraclavicular block success.

However, the PI ratio is a better predictor than PI because of a variabledistribution of baseline PI in the population. A cut-off of 3.35 for PI and1.35 for the PI ratio is an accurate predictor of block success.

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