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Predicting successful supraclavicular brachial plexus block using pulse oximeter perfusion index

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Abstract

Background. Supraclavicular nerve block is a popular approach for anaesthesia for upper limb surgeries. Conventional methods for evaluation of block success are time consuming and need patient cooperation. The aim of this study was to evaluate whether the perfusion index (PI) can be used to predict and provide a cut-off value for ultrasound-guided supraclavicular nerve block success.

Methods. The study included 77 patients undergoing elective orthopaedic procedures under ultrasound-guided supraclavicular nerve block. After local anaesthetic injection, sensory block success was assessed every 3 min by pinprick, and motor block success was assessed every 5 min by the ability to flex the elbow and the hand against resistance. The PI was recorded at baseline and at 10, 20, and 30 min after anaesthetic injection in both blocked and non-blocked limbs. The PI ratio was calculated as the PI after 10 min divided by the PI at the baseline. Receiver operating characteristic curves were constructed for the accuracy of the PI in detection of block success.

Results. The PI was higher in the blocked limb at all time points, and this was paralleled by a higher PI ratio compared with the unblocked limb. Both the PI and the PI ratio at 10 min after injection showed a sensitivity and specificity of 100% for block success at cut-off values of 3.3 and 1.4, respectively.

Conclusions. The PI is a useful tool for evaluation of successful supraclavicular nerve block. A PI ratio of >1.4 is a good predictor for block success.

Key words: nerve block; oximetry; perfusion; ultrasonography

Ultrasound-guided supraclavicular nerve block is a popular approach for anaesthesia for upper limb surgeries. The success of peripheral nerve blocks is usually evaluated by assessment of sensory and motor function; however, this method is subjective, time consuming, and depends on patient cooperation.[1] Various objective methods for evaluation of block success have been developed.[2–4] Objective methods for block assessment depend on the evaluation of the sympathetic block and consequent physiological changes, such as vasodilation and changes in blood flow[2 3] and skin temperature.[4] However, most of the objective methods are either time consuming or dependent on sophisticated equipment.

The perfusion index (PI) is a numerical value for the ratio between pulsatile and non-pulsatile blood flow measured by a special pulse oximeter.[5] Although the special probe for PI measurement is relatively more expensive compared with ordinary pulse oximeter probes, its benefits as a marker of peripheral perfusion[6] and as an index for sympathetic stimulation[7] have increased its use progressively in many institutes. Few data are available for the PI as a tool for evaluation of peripheral block success.[8] However, there is currently no cut-off value defined for the accuracy of the PI in the detection of successful block. The aim of this work was to evaluate the PI and PI ratio as

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Editor's key points

- A successful supraclavicular nerve block for limb surgery is associated with vascular dilatation.
- The perfusion index reflects the ratio between pulsatile and non-pulsatile blood flow and is a measure for the level of vascular dilatation.
- The perfusion index is a good predictor for block success and can be used as an alternative for sensory or motor function tests.

predictors of successful supraclavicular nerve block in comparison to neurological assessment, and to determine the best cut-off value for the PI in detection of block efficacy.

Methods

This prospective observational study was conducted in an orthopaedic theatre of the Cairo university hospitals after obtaining institutional ethical committee approval (number MD-3-2016). Written informed consent was obtained from all participants before enrolment in the study. The study included patients aged between 18 and 60 yr who were to undergo elective upper limb orthopaedic procedures under ultrasound-guided supraclavicular nerve block. Exclusion criteria were diabetes mellitus and peripheral vascular disease.

On arrival in the operating room, premedications included ranitidine (50 mg) and midazolam (0.03 mg kg^{-1}). Patients were monitored by three-lead ECG, automated non-invasive blood pressure monitoring, and pulse oximetry.

The supraclavicular nerve block was performed under guidance of a linear transducer (8–14 MHz; Acuson x300; Siemens Healthcare, Seoul, Korea) over the supraclavicular fossa in the coronal oblique plane immediately superior to the midclavicular point. The block was induced in the semi-sitting position, with the head of the patient turned away from the side to be blocked. A 22-gauge insulated block needle 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 under vision strictly perineural to surround all the nerve cords.

The limb was evaluated for block success every 3 min for the sensory block and every 5 min for the motor block. Sensory function was assessed using pinprick in the dermatomal areas supplied by the four main nerves (median nerve, radial nerve, ulnar nerve, and musculocutaneous nerve). Motor block was assessed by the ability to flex the elbow and the hand against gravity. The supraclavicular nerve block was considered successful with regard to neurological examination when brachial plexus dermatomes (C5–T1) were completely blocked. The gold standard for unsuccessful block was the need for general anaesthesia because of pain sensation at the site of the operation.

The PI was measured using Masimo SET pulse oximetry (Masimo Corporation, Irvine, CA, USA) applied on the index finger. The PI was recorded at baseline and at 10, 20, and 30 min after local anaesthetic injection in both the blocked limb and the contralateral unblocked limb using two separate oximeters. The PI ratio was calculated as the ratio between the PI at 10 min after injection and the baseline PI. In every patient, a comparison between the blocked and unblocked limb was performed.

Statistical analysis

Sample size was calculated using MedCalc Software version 14 (MedCalc Software bvba, Ostend, Belgium) to detect an area under the receiver operating characteristic (AUROC) curve of 0.8 with null hypothesis with AUROC curve of 0.5. We took into consideration that the rate of block failure is usually 10%. A minimal number of 70 patients (with at least seven failed blocks) was required to obtain a study power of 80% and α error of 0.05.

Statistical calculations were performed using the Statistical Package for the Social Sciences (SPSS) software version 15 for Microsoft Windows (SPSS Inc., Chicago, IL, USA). Categorical data were presented as frequency (percentage). Continuous data were presented as mean (SD) or median (quartiles) as appropriate. Data were tested for normality using the Shapiro–Wilk test. Comparison of PI between blocked and non-blocked limbs was done using analysis of variance for repeated measures with *post hoc* pairwise comparisons using the Bonferroni test. A receiver operating characteristic (ROC) curve was constructed for the ability of the PI at 10 min and the PI ratio to detect a successful block *vs* a failed block. The positive predictive value and negative predictive value were calculated for both the PI at 10 min and the PI ratio and compared with neurological examination for prediction of block success. A *P*-value <0.05 was considered significant.

Results

Ninety-six patients were assessed for eligibility, of whom 77 patients received an ultrasound-guided supraclavicular nerve block. The block was successful in 70 patients. Patient characteristic data are presented in Table 1.

The baseline PI was comparable between blocked and non-blocked limbs. A successful block was paralleled by an increased PI when compared with the unblocked limb at 10, 20, and 30 min after anaesthetic injection. The PI increased in the blocked limb at 10, 20, and 30 min compared with the baseline reading (Table 2 and Fig. 1). The PI ratio was higher in the blocked limb compared with the unblocked limb [2.4 (0.4) *vs* 1 (0.0); $P<0.001$; Table 2].

Both the PI at 10 min and the PI ratio showed a good ability to predict block success. The AUROC curve for the PI at 10 min after anaesthetic injection was 1 (0.95–1.00), with a cut-off value of >3.3. The AUROC curve for the PI ratio was 1 (0.95–1.00), with a cut-off value >1.4 (Table 3). 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

Table 1 Patient characteristic data. Data are presented as the mean (SD) or *n* (%)

Characteristic	Value
Age (yr)	34.9 (11.1)
Male [*n* (%)]	33 (47)
BMI (kg m^{-2})	23.7 (3.2)
Haemoglobin (g dl^{-1})	11.5 (1.5)
Duration of surgery (min)	78.8 (30.7)

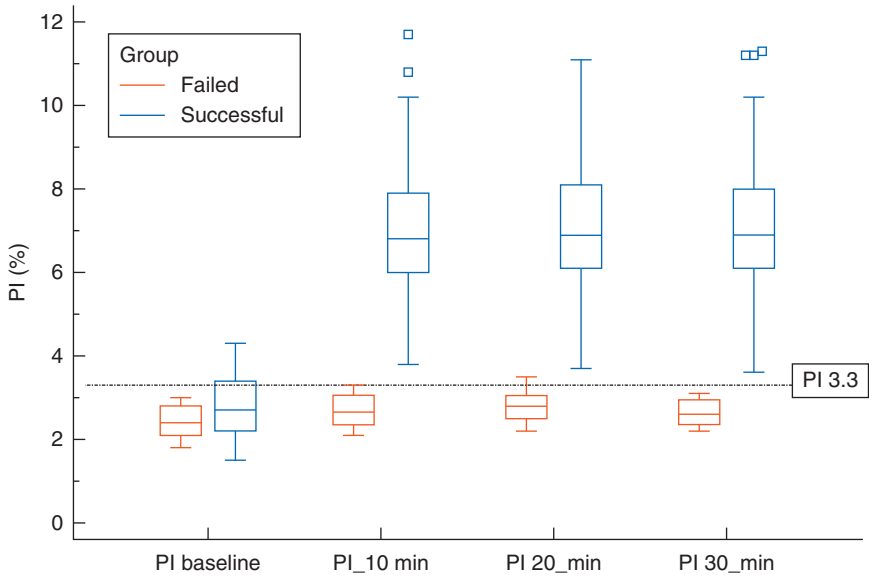

Fig 1 Perfusion index values at different time intervals in patients with successful and failed blocks. A reference line at PI 3.3 is provided. Horizontal lines are medians, boxes are quartiles, and whiskers are ranges. PI, perfusion index.

Table 2 Perfusion index. Data are presented as the median (range) (IQR) and mean (SD). IQR, interquartile range; PI, perfusion index; PI ratio, perfusion index at 10 min/perfusion index at baseline. *P<0.05 compared with the unblocked arm, †P<0.05 compared with baseline

Perfusion index	Blocked arm (*n*=70)	Unblocked arm (*n*=70)	P-value
Baseline			0.379
Median (range) (IQR)	2.7 (1.5–4.3) (2.2–3.4)	2.7 (1.5–4.5) (2.2–3.4)	
Mean (SD)	2.8 (0.8)	2.8 (0.8)	
10 min			<0.001
Median (range) (IQR)	6.8 (3.8–11.7) (6–7.9)	2.7 (1.4–4.6) (2.2–3.5)	
Mean (SD)	6.9 (1.7)*†	2.8 (0.8)	
20 min			<0.001
Median (range) (IQR)	6.9 (3.7–11.1) (6.1–8.1)	2.7 (1.6–4.4) (2.2–3.4)	
Mean (SD)	7 (1.7)*†	2.8 (0.8)	
30 min			<0.001
Median (range) (IQR)	6.9 (3.6–11.3) (6–8)	2.6 (1.4–4.5) (2.2–3.4)	
Mean (SD)	7.1 (1.8)*†	2.8 (0.8)	
PI ratio			<0.001
Median (range) (IQR)	2.5 (1.7–3.5) (2.3–2.7)	1 (0.9–1.1) (1–1)	
Mean (SD)	2.5 (0.4)*	1 (0.1)	

Table 3 Receiver operating characteristics for the ability of the perfusion index to detect block success. AUROC, area under the receiver operating characteristic curve; CI, confidence interval; NPV, negative predictive value; PI, perfusion index; PI ratio, perfusion index at 10 min/perfusion index at baseline; PPV, positive predictive value

Parameter	AUROC (95% CI)	Sensitivity (%)	Specificity (%)	PPV (%)	NPV (%)	Cut-off value
PI at 10 min	1.0 (0.95–1.0)	100	100	100	100	>3.3
PI ratio	1.0 (0.95–1.0)	100	100	100	100	>1.4

specificity of 100% were calculated for neurological examination for detection of successful block by the PI.

Discussion

A successful brachial plexus block is associated with profound vasodilation.[3] This study shows that the PI and the PI ratio are predictive for a successful supraclavicular nerve block. The PI represents the ratio between the pulsatile and non-pulsatile components of peripheral blood flow. A relative increase in pulsatile flow in states of vasodilation leads to an increase in the PI. The PI can therefore be considered as an objective measure for peripheral perfusion that can predict peripheral block success.

The PI was previously investigated for evaluation of different conditions of vasodilation, such as induction of anaesthesia,[9] epidural block,[10] stellate ganglion block,[11] and successful thoracic sympathectomy.[12] The PI was also investigated as a marker of sympathetic stimulation. Our group previously reported that a low PI predicted the need for vasopressor therapy in severe sepsis.[13] More recently, we recently evaluated the use of the PI as a tool for pain assessment in critically ill patients.[7] The role of the PI in the prediction of peripheral block success was previously reported for infraclavicular brachial plexus block,[8] axillary brachial plexus block,[14] interscalene brachial plexus block,[15] and sciatic nerve block.[14] To the best of our knowledge, our study is the first to report the use of the PI in the assessment of the successfulness of a supraclavicular nerve block. We also introduced the PI ratio for the precise estimation of a cut-off value to facilitate the clinical application of the PI for block assessment.

We evaluated the PI ratio (the ratio between 10-minute PI and baseline PI) to determine the rate of increase in PI with successful block; this is attributable to high skewness in baseline PI. The high variability in baseline PI was previously reported by Lima and colleagues,[16] who evaluated PI as a marker of peripheral perfusion. Using the changes in PI instead of absolute PI value was also reported by our group in pain assessment in critically ill patients.[7]

Detection of block success is usually performed using traditional assessment of sensory and motor function.[1] Traditional methods are usually time consuming; moreover, the need for patient cooperation makes the traditional methods not applicable under general anaesthesia. Previous studies showed other objective methods for detection of successful block; these methods included thermographic temperature measurement,[4] laser Doppler perfusion imaging,[3] and skin electrical resistance.[2] The PI is characterized by being simple, rapid, and user friendly compared with other objective methods for 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 block success would also avoid excessive patient pinpricking and allow block evaluation in sedated and anaesthetized patients.

To generalize the impact of our findings in future clinical practice, a clear cut-off value for the PI and PI ratio should be estimated to confirm block success. We reported a PI of 3.3 and PI ratio of 1.39 after 10 min as two signs of block success. Galvin and colleagues[14] reported an increase in PI by 1.55 as a predictor of block success; this finding is near to our cut-off value for PI ratio, which is 1.39. 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), technique (ultrasound *vs* nerve stimulator), and drug (bupivacaine and lidocaine *vs* mepivacaine) would be a clue to reach a definitive cut-off value. More studies are warranted for precise estimation of the cut-off value in different nerve sites and with different local anaesthetic drugs, volumes, and concentrations. We assume that using the PI ratio would be more accurate than using the absolute value of the PI at 10 min; this is because there is a high variability in PI values. This high variability is well known for baseline PI values among volunteers[16 17] and critically ill patients.[7]

Our study has some limitations. We reported the values at relatively wide intervals (10 min). We designed our measures according to the available data that reported the average time for PI to reach a significant value. Galvin and colleagues[14] reported the average time to be 12 min in sciatic block and 10 min in axillary block. Kus and colleagues[8] reported a similar finding for infraclavicular block. Yamazaki and colleagues[11] reported a shorter interval (5 min) for the PI to reach a significant increase after stellate ganglion block; however, the nature of the stellate ganglion could explain this difference. Another limitation is the low number of failed blocks, which makes the statistics shaky if more blocks had failed; however, we took this point into consideration during calculation of the sample size. More research, including more failed blocks, would confirm our findings, especially the cut-off values. Another limitation is that we considered all failed blocks as one group without grading the degree of success (according to the number of anaesthetized segments). Thus, we recommend future studies that show a correlation between the PI values and the degree of block success (number of segments or number of nerves blocked).

In conclusion, the PI is a useful tool for evaluation of successful supraclavicular nerve block. A PI ratio of >1.4 is an accurate predictor for block success.

Authors' contributions

Conception of the idea: A.A., B.A., A.E., A.R.
Study design: B.A., A.E., A.H., A.R.
Acquisition of data: A.A., B.A.
Data analysis and interpretation: A.H.
Drafting the article: A.A., A.E., A.H.
Revising the manuscript: B.A., A.E., A.R.
Research group leader and supervision of the work: A.R.
All authors approved the manuscript and agreed to be accountable for all aspects of the work.

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Declaration of interest

None declared.

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References

1. Curatolo M, Petersen-Felix S, Arendt-Nielsen L. Sensory assessment of regional analgesia in humans: a review of methods and applications. *Anesthesiology* 2000; **93**: 1517–30
2. Smith GB, Wilson GR, Curry CH, *et al*. Predicting successful brachial plexus block using changes in skin electrical resistance. *Br J Anaesth* 1988; **60**: 703–8

3. Sørensen J, Bengtsson M, Malmqvist EL-Å, Nilsson G, Sjöberg F. Laser Doppler perfusion imager (LDPI) - for the assessment of skin blood flow changes following sympathetic blocks. *Acta Anaesthesiol Scand* 1996; **40**: 1145–8
4. Galvin EM, Niehof S, Medina HJ, *et al*. Thermographic temperature measurement compared with pinprick and cold sensation in predicting the effectiveness of regional blocks. *Anesth Analg* 2006; **102**: 598–604
5. Goldman JM, Petterson MT, Kopotic RJ, Barker SJ. Masimo signal extraction pulse oximetry. *J Clin Monit Comput* 2000; **16**: 475–83
6. Hasanin A, Mukhtar A, Nassar H. Perfusion indices revisited. *J Intensive Care* 2017; **5**: 24
7. Hasanin A, Mohamed SA, El-Adawy A. Evaluation of perfusion index as a tool for pain assessment in critically ill patients. *J Clin Monit Comput* 2016. [Epub ahead of print] Doi: 10.1007/s10877-016-9936-3
8. Kus A, Gurkan Y, Gormus SK, Solak M, Toker K. Usefulness of perfusion index to detect the effect of brachial plexus block. *J Clin Monit Comput* 2013; **27**: 325–8
9. Park SG, Lee OH, Park Y-H, *et al*. The changes of non-invasive hemoglobin and perfusion index of Pulse CO-Oximetry during induction of general anesthesia. *Korean J Anesthesiol* 2015; **68**: 352–7
10. Ginosar Y, Weiniger CF, Meroz Y, *et al*. Pulse oximeter perfusion index as an early indicator of sympathectomy after epidural anesthesia. *Acta Anaesthesiol Scand* 2009; **53**: 1018–26
11. Yamazaki H, Nishiyama J, Suzuki T. Use of perfusion index from pulse oximetry to determine efficacy of stellate ganglion block. *Local Reg Anesth* 2012; **5**: 9–14
12. Klodell CT, Lobato EB, Willert JL, Gravenstein N. Oximetry-derived perfusion index for intraoperative identification of successful thoracic sympathectomy. *Ann Thorac Surg* 2005; **80**: 467–70
13. Rasmy I, Mohamed H, Nabil N, *et al*. Evaluation of perfusion index as a predictor of vasopressor requirement in patients with severe sepsis. *Shock* 2015; **44**: 554–9
14. Galvin EM, Niehof S, Verbrugge SJ, *et al*. Peripheral flow index is a reliable and early indicator of regional block success. *Anesth Analg* 2006; **103**: 239–43
15. Sebastiani A, Philippi L, Boehme S, *et al*. Perfusion index and plethysmographic variability index in patients with interscalene nerve catheters. *Can J Anaesth* 2012; **59**: 1095–101
16. Lima AP, Beelen P, Bakker J. Use of a peripheral perfusion index derived from the pulse oximetry signal as a noninvasive indicator of perfusion. *Crit Care Med* 2002; **30**: 1210–3
17. Bergek C, Zdolsek JH, Hahn RG. Accuracy of noninvasive haemoglobin measurement by pulse oximetry depends on the type of infusion fluid. *Eur J Anaesthesiol* 2012; **29**: 586–92

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