Perfusion Index after Supraclavicular Brachial Plexus Block as an Early Predictor of Successful Block

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Objective: Supraclavicular brachial plexus block is a highly popular upper extremity anesthetic technique. Theoretically, after local anesthetic agent is injected, temporary vasodilatation, sensory loss and motor weakness ensue. The assessment of successful block relies on subjective data of sensory block and patient co-operation. The present study hypothesized that perfusion index (PI) is an early predictor and provide a cut-off value for the successful block.

Materials and Methods: Sixty-two patients undergoing upper extremity operation under ultrasound-guided supraclavicular brachial plexus block were included. PI values were assessed on the operated limb at baseline, 0, 1, 3, 5, and 10 minutes after block. The patients were divided into three groups. Upon incision, patients that reported pain but tolerated the operation after anesthetic supplement were in the supplement group, patients that reported persistent pain after anesthetic supplement were in the failed group, and patients that did not required any supplement were in the complete group. The three groups were monitored with PI values.

Results: The supraclavicular brachial plexus block of fifty-nine patients (95.16%) were successfully blocked, which 42 patients (67.74%) had complete block and 17 patients (27.42%) needed supplemental treatment. Three patients (4.84%) had failed block and were converted to general anesthesia. The PI value was continuously rising from baseline in successfully blocked patients. PI value at three minutes after local anesthetic injection showed block success at cut-off value of 3.6, respectively.

Conclusion: Successful block could be determined early by the increase of PI value from baseline. A PI value of more than 3.6 at 3-minute after block is a good early predictor of successful block.

Keywords: Perfusion index; Ultrasound-guided regional anesthesia; Brachial plexus block; Supraclavicular block; Regional anesthesia; Peripheral anesthesia

Supraclavicular brachial plexus block is a highly popular regional anesthesia technique for upper limb surgery. The success of block is determined by loss of sensation and motor weakness on the blocked limb. However, the loss of sensation is subjective and requires patient's co-operation. Hence, this loss of sensation may not be accurate in situations where patients are anxious, agitated, or unable to communicate due to language barrier. Some patients misinterpret the pain sensation, which can lead the anesthesiologist to make wrong decision for further management. Lidocaine is a local anesthetic agent with three to five minutes onset. Theoretically after local anesthetic agent is injected, temporary vasodilatation, sensory loss, and motor weakness ensue[1]. Regional vasodilatation occurs due to sympathetic blockage resulting in increased blood flow to the limb[2,3]. Therefore, the detection of sympathetic blockage from regional vasodilatation should be an early predictor of successful block in early onset time.

Perfusion index (PI) is the ratio of the pulsatile to non-pulsatile blood flow in peripheral tissue. It is an objective value measured continuously and non-invasively by pulse oximetry digit probe. PI indicates the degree of tissue perfusion. High PI correlates with high tissue blood flow, thus indicates peripheral vasodilatation[4]. The authors assumed that PI should

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be useful in detecting vasodilatation following brachial plexus block. The aim of the present study was to evaluate the relationship between PI value and the success of supraclavicular brachial plexus block. The hypothesis of the present study was that, after local anesthetic agent was injected, the sympathetic nervous system would be firstly blocked, resulting in vasodilatation, followed by increased blood supply and PI.

The primary objective of the present study was to determine PI value as the early predictor of successful supraclavicular brachial plexus block and to provide a cut-off value for the successful block.

Materials and Methods

The present study was approved by Institutional Ethical Committee, approval no. SWUEC/E – 134/2558 on 23 July 2015. The prospective observational study was performed. Between August 2015 and June 2016, sixty-two patients with the American Society of Anesthesiologists (ASA) physical status I-III, age 18 to 70, undergoing upper limb surgery were enrolled after informed consent was obtained. Exclusion criteria included coagulopathy, preexisting severe peripheral vascular disease, history of allergic reaction to local anesthetic drug, psychiatric problems, inability to communicate, and patient's refusal to brachial plexus block. The present study was commenced after the ethics committee gave its approval and after obtaining written informed consent. All procedures done in the present study followed the Ethical Guidelines of the Declaration of Helsinki.

No premedication was given. All patients were transferred to the induction area where the block was performed. They were monitored by 3-lead EKG, non-invasive blood pressure and pulse oximetry on the non-operated arm. Baseline vital signs were recorded and at every five minutes thereafter. While in the supine position, all patients were asked to turn their head to the contralateral side with the ipsilateral arm straight along the body. The pulse oximetry with PI sensor (Masimo Radical 7; Masimo Corp., Irvine, CA, USA) was placed on the middle or index finger of the hand to be blocked and the value was recorded as PI_{pre}.

Ultrasound-guided supraclavicular approach brachial plexus block was performed by staff anesthesiologists or anesthesiology resident under supervision. The in-plane, at lateral to median, ultrasound-guided supraclavicular brachial plexus block was done with 22-gauge needle. Skin infiltration
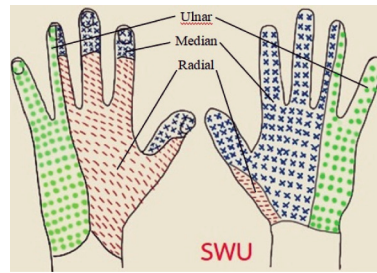

Figure 1. Hand sensory dermatome.

with 1% lidocaine was used. After the plexus was visualized by ultrasound, 20 mL of local anesthetic (mixture of 15 mL of 2% lidocaine with epinephrine 1:200,000+5 mL of 0.5% bupivacaine) was injected and the spreading of local anesthetic agent was confirmed. At the completion of injection, PI was recorded as PI_0 and at 1, 3, 5 and 10 minutes after the block, PI and pinprick sensation evaluation were recorded. Motor block was evaluated by the ability to flex/extend the elbow and finger spread against resistance at five and ten minutes. Sensation was assessed in the dermatome of radial nerve, median nerve, and ulnar nerve (Figure 1). After 10 minutes, the patient was transferred to the operating room followed by skin preparation and drapes. Before the operation started, the surgeon was asked to evaluate for pain sensation at the surgical site by surgical forceps. If pain was reported, local anesthetic was injected at the site by the surgeon or systemic fentanyl was supplemented at the discretion of the anesthesiologist for the supplement group. If pain persisted, general anesthesia was performed for the failed group. For complete block, the complete group surgery proceeded as usual without additional treatment. Complete and supplement block were considered successful block.

Sample size was calculated based on the previous study[5-7] assuming 95% confidence interval and the power of study of 95% and α of 0.05, at least 59 patients were required. Given that additional 5% drop-out, 62 patients were included. The statistical analysis was performed using the SPSS Statistics, version 15 (SPSS Inc., Chicago, IL, USA). Microsoft word and Excel were used to generate graphs and tables. Categorical data were presented as frequency (percentage). Continuous data were presented as mean (standard deviation) or median (quartiles) as appropriate. Data were tested for normality using the Shapiro-Wilk test. Comparison of PI among complete group, supplement group, and failed group was done using two-way analysis of variance

Table 1. Demographic data (n=62)

Characteristics	
Sex; n (%)	
Male	36 (58)
Female	26 (42)
Age (year); mean±SD	38.87±15.62
ASA status; n (%)	
ASA I	37 (59.7)
ASA II	19 (30.6)
ASA III	6 (9.7)
Emergency	12 (19.3)
Side; n (%)	
Left	38 (61.3)
Right	24 (38.7)
Duration of surgery (minute); mean±SD	125±76.17

ASA=American Society of Anesthesiologists; SD=standard deviation

Figure 2. Mean of PI values from baseline (pre) at each time period up to 10 minutes (n=62).

* $p < 0.05$ compared with the baseline (Pre).

Figure 3. Mean percentage of increase of PI values from baseline (pre) at each time period up to 10 minutes (n=62).

(ANOVA) 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 3-minute to detect a successful block versus a failed block by using MedCalc Software version 20.009 (MedCalc Software bvba, Ostend, Belgium). The positive predictive value and negative predictive value were calculated for the PI at 3-minute and compared with neurological examination for prediction of block success. A p-value of less than 0.05 was considered statistically significant.

Results

The demographic data including gender, age, ASA physical status, emergency condition, and duration of surgery are shown in Table 1. Among 62 patients scheduled for upper limb surgery under ultrasound-guided supraclavicular brachial plexus block, the success rate of the block was 95.16% (59 cases) in which 42 patients had complete block and 17 patients needed local infiltration or intravenous fentanyl supplement. Failed block occurred in three patients (4.84%) who were proceeded to general anesthesia. The baseline PI values ranged from 0.4 to 7.1 in 42 patients whose block was completed, 0.51 to 12.8 in 17 patients whose block needed supplement, and 0.96 to 4.8 in three patients whose block failed. This was not statistically significant (p=0.107). The PI value at each time period among the three groups is demonstrated in Figure 2. Using two-way ANOVA, there was no significant interaction effect of the duration by group for PI, Wilks'lambda, F(10,
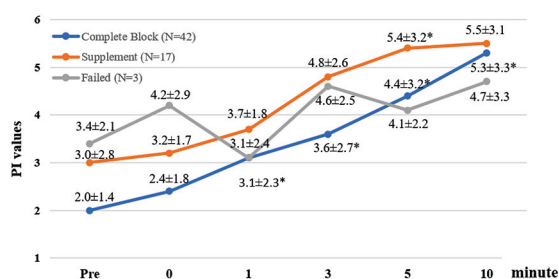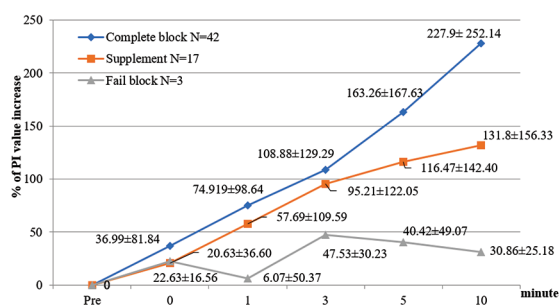
110)=1.53, p=0.14. There was no statistical difference (p>0.05) among the three groups. Percentage of changes in PI values from baseline at each time period to 10 minutes among the three groups increased. The pattern of change was continuously increasing over time in complete group up to 227.90% (p<0.05) and supplement groups up to 131.8% (p<0.05), but not in the failed group (p>0.05), which was never more than 50% as demonstrated in Figure 3. The PI at 3-minute showed a good ability to predict block success. The ROC curve for the PI at 3-minute after anesthetic injection was 0.66 (0.53 to 0.78), with a cut-off value of 3.6 (Figure 4).

In successful block, which refers to supplement and complete group (n=59), mean PI at each time period was continuously increasing from 2.32 to 5.38 up to 10 minutes as demonstrated in Figure 5. These changes from baseline were statistically significant at each time period except at 0 minute. Mean percentage of PI change from baseline was continuously increasing 32.28% at 0 minute, 104.95% at three minutes, 149.78% at five minutes and 200.21% at ten minutes. These changes from baseline were statistically significant in all time periods as shown in Figure 6. Most patients felt no pinprick sensation on evaluated site at 0 to 1 minute after block.
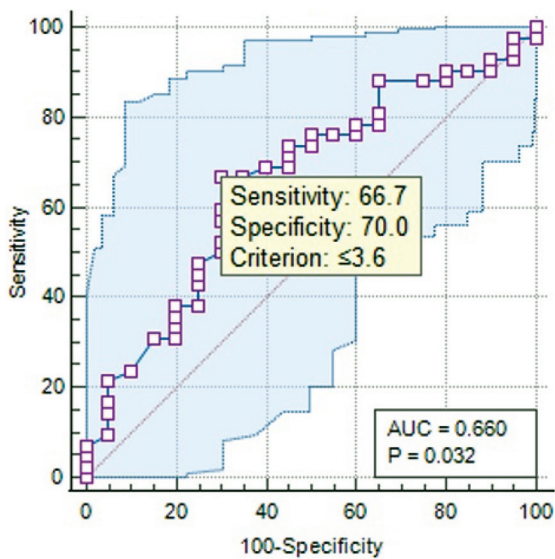
Parameter	PI at 3-minute
AUROC (95% CI)	0.66 (0.53 to 0.78)
Sensitivity (%)	66.7
Specificity (%)	70.0
PPV (%)	84.4
NPV (%)	48.1
Cut-off value	>3.6

Figure 4. 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; PPV=positive predictive value
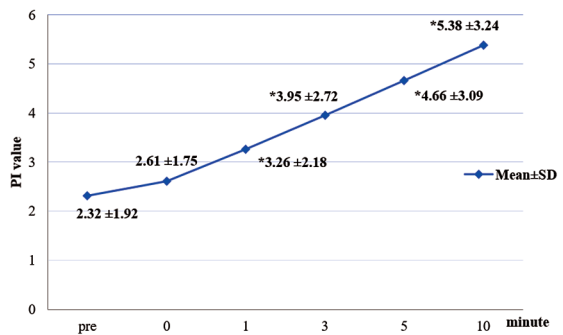

Figure 5. Mean of PI values at each time period up to 10 minutes in successful block group (n=59).

PI_Pre=PI baseline before block; PI_0, 1, 3, 5, 10=PI at 0, 1, 3, 5, 10 minute after block

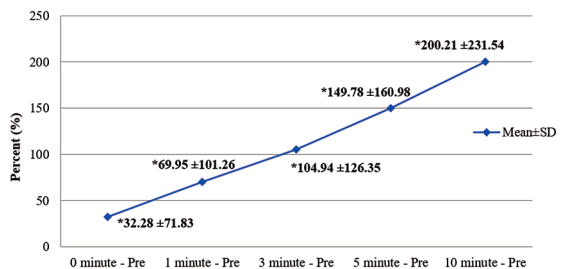* Statistical significance at p<0.05 between PI each time period and PI-pre

Figure 6. Mean percentage increase of PI value from baseline in successful block group (n=59).

* Statistical significance at p<0.05 between percentage of change of PI each time period and PI-pre

Discussion

Supraclavicular brachial plexus block is a highly popular regional anesthesia technique for upper extremity surgery. The success of block is determined by loss of sensation and motor weakness on the blocked limb. However, the patient subjectively informs the loss of sensation, and it requires patient's co-operation. The primary objective of the present study is to investigate PI as the objective indicator for early predictor of successful supraclavicular brachial plexus block. The PI is expressed as the ratio of the pulsatile component of light absorption (an analogy 'AC' signal) to the non-pulsatile component of light absorption ('DC' signal) reaching the pulse oximetry sensor and this value is independent of patient oxygen saturation. In other words, with a constant amount of light (DC) absorbed by non-pulsatile blood, a superimposed light absorption during pulsatile arterial inflow generates a proportion of two light absorption patterns[8]. The PI can be expressed by the following formula: PI = (AC/DC) × 100 [%] [6].

In the present study the success rate of the block is 95.16%, which is similar to other studies[9-14]. PI has been used in studies to assess the success of regional block in patients unable to communicate or in the practice of veterinarian. Gatson et al[15] reported in animal experiments that the PI of the limb that underwent surgery and sciatic nerve blockage was significantly higher than the contralateral pelvic limb at 10 minutes and 15 minutes after block. They concluded that partial or total failure of anesthetic blockade were indicated by failure of PI to rise within 15 minutes after the block. In the present study, the authors excluded patients with the inability to communicate. However, the present study had similar results as the Gatson et al[15] result. After supraclavicular brachial plexus block was done, if PI value did not increase for more than 50% at 10 minutes, the block was unsuccessful.

Several studies showed effectiveness of PI at predicting successful regional and peripheral nerve block after 10 minutes. Valley et al[2] studied

patients receiving epidural block with 3 mL test dose and monitored for cutaneous perfusion in the foot and the reflex vasoconstrictive response to deep inspiration (IGVR). It showed that the PI was increased to 192±38% from baseline and concluded that PI and IGVR changes were sensitive measures of sympathetic blockade and may predict successful epidural catheter placement. Ginosar et al[16] also reported in patients receiving epidural catheter placement. The study compared the changing of PI and mean arterial blood pressure. At 20-minute, PI at toe was increased by 326% compared to a 10% decrease of mean arterial blood pressure (MAP) and a 3% increase of toe temperature. They concluded that PI was an earlier, clearer, and more sensitive indicator of sympathectomy than either skin temperature or MAP. Galvin et al[3] also reported the efficacy of PI in predicting successful axillary nerve block at 10 minutes and sciatic nerve block at 12 minutes. The same result was replicated in a study by Kus et al[17] in which patients received infraclavicular block. PI was continuously increased from baseline. The largest change occurred at 30-minute, 155±144%, and the change was statistically significant at 10-minute after block, 120±119%. Abdelnasser et al[18] reported comparative PI ratio between blocked and unblocked limb in patients with supraclavicular brachial plexus block. They concluded that, 10 minutes after supraclavicular brachial plexus block, PI and the PI ratio showed a sensitivity and specificity of 100% for block success at cut-off values of 3.3 and 1.4. The present study explained in the same way that, PI increased from baseline more than 100% in 3 minutes and was continuously rising to 10 minutes to 200.21%. However, three minutes after block, PI showed a low sensitivity and specificity at 66.7% and 70.0%, respectively.

From these previous studies, PI has been shown to be a good predictor of successful regional and peripheral nerve block. The continuously increasing PI was an indicator of successful block, with a significant increase seen at 10 minutes and the peak increase seen at 30-minute[3,17,18]. In our study, PI was significantly increased from baseline by 200.21% at 10-minute. The time period was enough to decide whether the block was fully effective. As of Gatson et al[15], if PI value did not increase for more than 50% ten minutes after supracalvicular brachial plexus block, the block was likely to be unsuccessful.

Several studies reported that PI could predict the success of block faster than 10 minutes. Sebastiani et al[4] reported PI value comparison between blocked and unblocked arm in patients undergoing interscalene block and catheter insertion. The result showed that the PI significantly increased within five minutes and gradually increased until 15 minutes. Sahin et al[19] reported patients receiving stellate ganglion blockage for treatment of Raynaud's phenomenon had a 62.7% increase of PI from baseline to the first session in 5 minutes. The patients had significantly decrease in VAS pain scores after treatment.

In the present study, the increasing percentages of PI value from baseline were statistically significant at 0, 1, 3, 5 and 10 minutes. Compared to Sahin et al[19] who reported a PI increase of 62.7% five minutes after Stellate ganglion block, the present study showed a much larger (149.78%) increase. Moreover, the authors reported a significant increased PI value from baseline by 104.95% at three minutes, 69.95% at one minute, and 32.28% at zero minute. The difference in time period could be explained by the present study sample selection, which only selected patients without vascular disease, while Sahin et al studied patients with Raynaud's disease, who might slowly respond to local anesthetic agent. Compare to Buono et al[20] who reported that after three minutes, the PI was at least doubled but only 16% of them had complete block, while the present study showed a much larger 67.74% completed block and 95.16% successful block. The obtained data supported the authors' hypothesis that the PI can be used as an indicator for early prediction of successful supraclavicular brachial plexus block. An increase in PI value can be seen at zero minute after injection of a local anesthetic agent. However, clinical assessment of PI value at three minutes might be a more proper time to judge the success of a peripheral nerve block.

In summary, the authors found that PI is a non-invasive, clinically useful, early predictor of successful supraclavicular brachial plexus block shown just after only three minutes. Our result demonstrated continuous increase of PI value from zero to ten minutes.

The limitations of the present study included 1) no randomization of the sample. Selection bias might occur due to criteria set up by the researchers to allocate patients to groups and 2) the actual time period from the block to incision was not recorded. As known by anesthesiologists, ultrasound-guided nerve block can reach the onset up to 30 minutes. If such time period was shorter than 30 minutes, there was a chance that the failed group might become the supplement, or the supplement might become the complete group.

Conclusion

In conclusion, PI is a good early predictor of successful supraclavicular brachial plexus block. PI value increase of more than 100% within the first three minutes after supraclavicular brachial plexus block, indicating a successful block. Higher increase of PI value up to 200% at 10 minutes can predict a complete block. Less than 50% increase from baseline indicates a failed block. The ROC curve for the PI at 3-minute after anesthetic injection was 0.66 (0.53 to 0.78), with a cut-off value of 3.6.

What is already known on this topic?

Supraclavicular brachial plexus block is a highly popular regional anesthesia technique for upper limb surgery. The success of block is determined by loss of sensation and motor weakness on the blocked limb. Effectiveness of PI at predicting successful regional and peripheral nerve block at 10 minute or longer is well known.

What this study adds?

PI is a good early predictor of successful supraclavicular brachial plexus block. PI value that increases by more than 100% within the first three minutes after supraclavicular brachial plexus block indicates a successful block.

Conflicts of interest

The authors declare no conflict of interest.

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