Online version at http://www.minervamedica.it

Minerva Anestesiologica 2019 July;85(7):746-55
DOI: 10.23736/S0375-9393.18.13046-X

ORIGINAL ARTICLE

Perfusion Index and ultrasonography in the evaluation of infraclavicular block

Mehmet M. BEREKET [1], Bengü G. AYDIN [1] *, Gamze KÜÇÜKOSMAN [1], Özcan PİŞKİN [1], Rahşan D. OKYAY [1], Ferruh N. AYOĞLU [2], Hilal AYOĞLU [1]

[1]Department of Anesthesiology and Reanimation, Faculty of Medicine, Bülent Ecevit University, Zonguldak, Turkey; [2]Department of Public Health, Faculty of Medicine, Bülent Ecevit University, Zonguldak, Turkey

*Corresponding author: Bengü G. Aydın, Department of Anesthesiology and Reanimation, Faculty of Medicine, Bülent Ecevit University, Zonguldak, Turkey. E-mail: bengukoksal@gmail.com

ABSTRACT

BACKGROUND: It has been reported that noninvasive, objective tests are needed for determining the success of peripheral nerve blocks because conventional methods necessitate the cooperation of the patient. It is also known that the brachial plexus block causes vasodilatation and an increase in blood flow due to its sympathectomy effect. Our study aimed to determine whether Perfusion Index (PI) and measured regional hemodynamic changes using ultrasound were reliable parameters in evaluating the early success of an infraclavicular block.
METHODS: Forty ASA I-III patients who were administered a successful infraclavicular block were included in this study. In addition to the baseline hemodynamic measurements, PI and regional hemodynamic parameters, such as brachial artery diameter (BAD), brachial arterial area (BAA), blood flow (BF), end-diastolic velocity (EDV), Resistance Index (RI), peak systolic velocity (PSV), and time average velocity (TAV) were measured. After completing the block procedure, all values were rerecorded at the 10th, 20th, and 30th minute. Patients with a successful block during the first 10 minutes were assigned to Group A, while patients with a successful block after the 10th minute were assigned to Group B.
RESULTS: Statistically significant differences were observed for all regional hemodynamic variables and PI after 10 minutes. When the regional hemodynamic data and PI were compared between the groups, differences were identified for PI, BF, PSV, EDV, and TAV. Within the measured parameters, EDV was the parameter showing the greatest proportional change.
CONCLUSIONS: Changes in EDV, especially RI and PI, provide more effective and objective results for the assessment of early regional block success.

(*Cite this article as:* Bereket MM, Aydın BG, Küçükosman G, Pişkin Ö, Okyay RD, Ayoğlu FN, *et al*. Perfusion Index and ultrasonography in the evaluation of infraclavicular block. Minerva Anestesiol 2019;85:746-55. DOI: 10.23736/S0375-9393.18.13046-X)

KEY WORDS: Autonomic nerve block; Doppler ultrasonography; Perfusion.

Conventional methods such as detection of sensory block *via* cold stimulation or pinprick test are generally used when determining the success of peripheral nerve blocks. These tests are subjective and necessitate the cooperation of the patient.[1, 2] It has therefore been reported that noninvasive, objective tests are needed for an accurate determination of success.[3]

Many regional hemodynamic changes have been reported in the ipsilateral upper extremity following a sensory block. Sympathetic blockage related to plexus blocks and the resulting vasodilatation lead to an increased blood flow within the extremity, which could be used in the evaluation of block success. In some studies, it has been shown that regional hemodynamic parameters, such as brachial artery diameter (BAD, mm), brachial arterial area (BAA, mm^2), blood flow (BF, mL/min), end-diastolic velocity (EDV, cm/s) and Resistance Index (RI), which can be measured using spectral Doppler ultrasound, were significantly changed following the block.[4] The Perfusion Index (PI) has been used to evaluate peripheral perfusion dynamics as a result of changes in the peripheral vascular tone.[5] Ipsilateral PI has been demonstrated to increase subsequent to the block and can be used as a method to evaluate the success of blocks.[6] However, thus far, we have been unable to find a comprehensive study comparing brachial artery measurements with ultrasound and PI parameters to evaluate block success.

The aim of our study was to compare the regional hemodynamic data obtained *via* ultrasonography and PI data observed prior to and after the block that appear as a result of the changes observed in extremity blood flow in patients undergoing infraclavicular block, and to investigate their efficacy in evaluating the early success of the block.

Materials and methods

This study was conducted at the Department of Anesthesiology and Reanimation, Faculty of Medicine, Bülent Ecevit University between July 15th, 2016 and July 15th, 2017, following the approval of the Clinical Research Ethical Committee (meeting No.: 2016-81-29/06) and after obtaining written informed consent from the patients.

The study included a total of 40 patients between 18 and 65 years of age with an ASA status of I-III, who underwent an infraclavicular block due to elective, unilateral carpal, or cubital operations, which was evaluated as successful. Those with a neurological deficit, ipsilateral major vascular trauma, mental retardation, alcohol or drug abuse, allergy to local anesthetic agent (LAA) including amide groups, morbid obesity, coagulopathy, chronic analgesic therapy, α and/or β blocker intake, diabetes mellitus, those who were pregnant, and those with contraindications to infraclavicular block were excluded from the study.

The demographic characteristics (age, height, weight, gender) and ASA risk groups of the patients were recorded.

The patients were taken into rooms at a temperature of 23-24 °C. Prior to the blockage, electrocardiographic data (ECG), heart rate (HR), respiratory rate (RR), noninvasive blood pressure (from the contralateral arm) (BP), and peripheral oxygen saturation (SpO_2) were monitored. Vascular access was established from the contralateral arm using a 20-gauge intracath, and a crystalloid infusion at 10 mL/kg/h was begun. The patients were administered 0.01 mg/kg of intravenous (IV) midazolam (Zolamid 5 mg/5 mL, Defarma, Turkey) and 1 µg/kg of fentanyl (Talinat 0.5 mg/10 mL, Vem Ilaç, Çerkezköy, Turkey). All patients underwent blockage and received 2-4 L/min of oxygen through a face mask throughout the operation.

In addition to the basic hemodynamic measurements, a pulse oximetry sensor was placed on the second finger of the ipsilateral upper extremity (RZ-25 adult, adhesive sensors Masimo SET® Radical™ pulse oximeters, Masimo Corp., Irvine, CA, USA) to obtain PI measurements. This was connected to a Rad-7™ Pulse CO-oximetre instrument. A 10- to 18-MHz linear probe (using an Esaote ultrasound [US] device) was used to take the patients' Doppler US measurements.

The basal hemodynamic, US, and PI data were recorded just prior to the procedure. Doppler US measurements were obtained by sagittal monitoring of the brachial artery from a 2–4 cm proximal aspect of the ipsilateral antecubital fossa. The B mode US image was optimized, and the Doppler US mode was switched on. Sample volume measurements were set to include the whole of the brachial artery lumen. The Doppler angle between the blood flow and Doppler line was set to 30-60 °C. The image was frozen when cardiac traces were obtained in the form of spectral waves. To minimize measurement mistakes, five consecutive cardiac cycles were evaluated. The borders of the cardiac cycles were drawn. Peak systolic velocity (PSV, cm/s), EDV, time average velocity (TAV, cm/s), and RI values were recorded. In general, the BAD demonstrates a 10% difference between systolic and diastolic beats.[7] Thus, the end-diastole of the ECG trace of the initial cardiac cycle was marked using the US device's trackball in B mode US. End-diastolic BAD was measured as the vertical distance between two lumens of the vessel and was recorded. The BAA was measured automatically by the US device, and the flow rate was measured using this TAV area (FR, mL/dk) and recorded. To standardization the measurements performed after the procedure, the initial site of the brachial artery Doppler US measurements was marked using a skin marker pen. Baseline sensory examination of the patients was performed using the pinprick test and recorded.

Following the baseline data recording, the infraclavicular block procedure was begun. The patients were placed in the supine position with their heads facing the contralateral side. The injection site was cleaned using povidone iodine. Prior to the block, US gel was spread over the linear probe, and it was covered with a plastic cover. The site of the procedure was covered with sterile gel, and the longitudinal axis (in-plane) image was planned to be obtained using US.

The probe was placed 1 cm to the anterior aspect of the coracoid process to obtain the sectional image of the axillary artery passing below the pectoralis minor muscle in the sagittal plan.

For the blocking procedure, 22-gauge, 80-mm echogenic needles (Stimuplex Ultra, B. Braun, Melsungen, Germany) with electro-neurostimulation ports were used. When the axillary artery was visualized *via* US, 2 mL of lidocaine (Jetmonal 2%, 20 mg/mL, Adeka, Istanbul, Turkey) was injected to the planned injection site *via* cutaneous-subcutaneous infiltration. The stimulation needle to be used for the blockage was connected to the nerve stimulator concomitantly (Stimuplex HNS 11, B. Braun). The anode (positive pole) of the nerve stimulator was connected to the ECG electrode on the shoulder of the block side.

The stimulation needle was inserted through the skin and placed in the 6-8 o'clock direction of the axillary artery using the "in-plane" method under the guidance of the US probe. The concomitant stimulator was turned "on," and in case of motor movement at 0.5 mA, a local anesthetic agent was injected as a single dose following a negative aspiration test (the test was repeated after each 5 mL injection of LAA. In case of a nonresponse with a sufficient current in the stimulator during the complete positioning of the needle, in case of a lack of an accurate visualized distribution of the LA solution, and in case of resistance or pain observed during injection, the needle was redirected with minimal movements. As LAA, 10 mL of 2% lidocaine (Jetmonal 2%, 20 mg/mL, Adeka) and 20 mL of 0.5% bupivacaine (Buvasin 0.5%, 20 mL, Vem Ilaç) were used. Following the complete injection of the anesthetic agent, the U-shaped distribution of the solution around the axillary artery was visualized. The chronometer was set as soon as the needle exited the skin.

All blocks were performed by the same anesthesiologist. All measurements and examination findings were performed by another anesthesiologist and were recorded.

Following the completion of the blockage (exit of the needle from the skin was accepted as minute 0), SpO_2, mean arterial pressure (MAP), KAH and PI, TAV, BAD, BAA, AH, PSV, EDV, and RI were recorded at the 10^{th}, 20^{th}, and 30^{th} minute.

The duration of sensory loss was evaluated using the pinprick test, and the quality of the anesthesia and blockage were evaluated using the Hollmen scale[8] (Quality of anesthesia: 0 = normal transmission using the pinprick test; 1 = needle sensed less compared to the contralateral extremity; 2 = feeling the needle as a blunt object; 3 = loss of tactile sense; Quality of motor block: 0 = normal muscular function; 1 = reduced muscular function compared to preblockage; 2 = significantly reduced muscular function; 3 = complete motor block).

Quality of anesthesia and quality of motor block were recorded concomitantly (0, 10, 20, 30 minutes). In the pinprick test, the presence of pain in the related dermatomes was investigated using 27-G blunt dental needles. The quality of the motor block was investigated by evaluating the movements in the shoulder, elbow, wrist, and fingers of the blocked extremity.

Patients with a score of at least two from each quality of the Hollmen scale (quality of anesthesia and quality of motor block), who did not require additional anesthesia during the operation, were said to have a successful block. The data of the patients with a successful block within the first 10 minutes were assigned to Group A, and those with a successful block later than the first 10 minutes were assigned to Group B.

Statistical analysis

The findings were evaluated using the SPSS for Windows v. 19.0 program package. We examined the normality distribution of numerical variables using the Shapiro-Wilk test. Descriptive statistics were presented by means and standard deviations or by medians and interquartile ranges for numerical variables. We presented categorical variables using frequencies and percentages. Repeated means were compared by ANOVA or Friedman test prior to *post-hoc* comparisons. The Friedman test was also performed to explore the difference between repeated medians. Two independent means were compared using a Student's *t*-test. The relationship between two categorical variables was investigated using a χ^2 test. The ROC curve and Youden Index method were used to understand the optimal cutoff points of independent variables. A P value <0.05 was chosen as a significance level.

Results

A total of 40 patients who underwent successful infraclavicular block for hand, wrist, ankle, arm, and elbow operations were included in the study. Procedure-related or LA injection-related complications were not observed.

Among the participants, 11 (27.5%) were female, and 29 (72.5%) were male. The mean age was 36.4 years, the mean Body Mass Index (BMI) 25.33 kg/m^2. According to the Holmenn Scale, a complete block was observed in 11 patients (27.5%) at the 10th minute, in 37 patients (92.5%) at the 20th minute, and in all patients at the 30th minute. There was no significant difference in demographic characteristics between the groups (P>0.05) (Table I).

It was observed in our measurements that early diastolic flow, which typically was initially negative, was elevated to positive values at the 10th minute following the block (Figure 1).

When the parameters related to success were examined, it was seen that the greatest percentage change was in EDV, BF, PI, and TAV, respectively, and the percent change in 10th minute values was statistically significant when compared to measured values at other time intervals (P≤0.001) (Table II).

The baseline HR, MAP, and SpO_2 values were statistically similar to those measured at 10, 20, and 30 minutes after blockage. A significant difference was observed between the baseline of the regional hemodynamic measurements and PI and those at 10, 20, and 30 minutes (Table III).

The systemic hemodynamic data were similar between the groups at the baseline (P>0.05). Regarding the useful parameters in early successful blocks, a significant difference was observed between all parameters except for the BAD and BAA at the baseline and at the 10th minute between the groups (P<0.05). Only PI and PSV were different between the groups with regard to the initial regional hemodynamic parameters (P<0.05) (Table IV).

A ROC analysis was performed for the parameters that were found to significantly change in the first 10 minutes. Table V shows the cutoff value of these parameters.

Discussion

In our study, it was observed that regional hemodynamic data measured *via* PI and spectral Doppler US were effective in evaluating the success of the block. In particular, EDV, RI, and PI changes were observed to provide more ef-

Table I.—*Comparison of demographic data between the groups.*

Variables	All patients (N.=40)	Group A (N.=11)	Group B (N.=29)	P value
Mean age, years	36.4±13.13	38.9±14.6	35.5±12.7	0.464
Sex				0.137
Female	11 (27.5%)	5 (45.5%)	6 (20.7%)	
Male	29 (72.5%)	6 (54.5%)	23 (79.3%)	
BMI. kg/m^2	25.33±4.18	26.5±4.66	24.9±4.0	0.27

Data are presented as mean±SD or as number of patients (percentage).

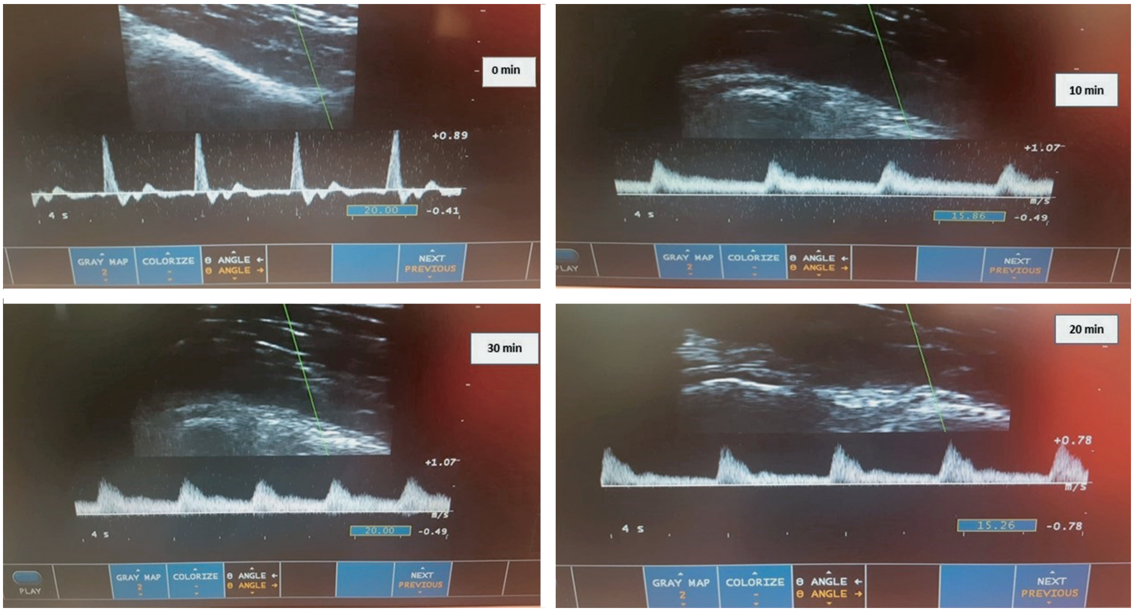

Figure 1.—Change in the PWD spectral waveform from a triphasic to a monophasic waveform.

Table II.—*Comparison of percent changes of parameters measured in time intervals.*

Parameters	0-10	10-20	20-30	P value
ΔTAV	108 (95.1%)	25.8 (45.4%)	3.51 (17.2%)	<0.001* x, y
ΔBAD	8.71 (17.6%)	5.72 (14.2%)	6.32 (9.30%)	0.461
ΔBAA	16.5 (38.4%)	11.1 (32.4%)	13.5 (16.1%)	0.509
ΔBF	148 (123%)	21.3 (50.0%)	13.0 (21.8%)	<0.001* x, y
ΔPSV	25.6 (36.5%)	13.7 (27.4%)	-2.05 (15.6%)	0.001* y, z
ΔEDV	435 (881%)	47.2 (74.3%)	8.76 (18.6%)	<0.001* x, y
ΔPI	135 (199%)	27.3 (46.4%)	7.47 (23.3%)	<0.001* x, y
ΔRI	-17.4 (8.80%)	-4.45 (12.1%)	-2.84 (5.97%)	<0.001* x, y

PI: Perfusion Index; TAV: time average velocity; BAD: brachial artery diameter; BAA: brachial artery area; BF: blood flow; PSV: peak systolic velocity; EDV: end-diastolic velocity; RI: Resistance Index: x: 0-10 *vs.* 10-20; y: 0-10 *vs.* 20-30; z: 10-20 *vs.* 20-30.

Table III.—*Comparison of the regional hemodynamic characteristics and Perfusion Index of patients*

Parameters	0 minutes	10 minutes	20 minutes	30 minutes
PI	2.78±1.67	7.12±2.62*	9.31±3.04*	10.57±3.24*
TAV, cm/s	10.03±3.25	20.40±14.29*	24.73±15.24*	25.80±15.60*
BAD, mm	3.86±0.57	4.21±0.53*	4.40±0.52*	4.69±0.56*
BAA, mm²	12.10±3.63	14.11±3.49*	15.40±3.63*	17.44±4.14*
BF, mL/min	73.20±61.46	170.37±124.14*	224.95±144.58*	265.25±171.14*
PSV, cm/s	36.60±27.53	50.32±33.65*	54.66±33.21*	55.54±33.99*
EDV, cm/s	2.66±3.80	11.85±10.01*	16.49±11.35*	18.22±12.07*
RI	0.93±0.06	0.77±0.86*	0.70±0.08*	0.68±0.08*

PI: Perfusion index; TAV: time average velocity; BAD: brachial artery diameter; BAA: brachial artery area; BF: blood flow; PSV: peak systolic velocity; EDV: end-diastolic velocity; RI: Resistance Index.
*Statistically significant difference compared to baseline value (P≤0.001).

fective and objective results in the evaluation of regional blocks.

The success of peripheral nerve blocks is generally assessed using cold stimulation or the pinprick test to find the sensory block level. Such tests are subjective and necessitate patient

TABLE IV.—*Comparison of the systemic and regional hemodynamic parameters between Group A (N.=11) and Group B (N.=29).*

Parameters	Group	0 minutes	10 minutes	20 minutes	30 minutes	P_1 value
HR	Group A	71.7±10.6	70.5±12.4	70.9±12.6	71.4±12.7	0.214
	Group B	77.8±15.8	75.8±14.5	75.9±15.0	75.5±14.8	0.264
	P_2 value	0.262	0.296	0.413	0.387	
MAP	Group A	88.8±18.7	90.4±15.2	89.7±18.8	93.6±18.2	0.070
	Group B	95.1±14.2	90.6±10.1	91.8±11.4	92.2±12.7	0.032*[a]
	P_2 value	0.208	>0.999	0.628	0.820	
SpO_2	Group A	97.6±0.94	97.2±0.99	97.6±1.13	97.3±0.91	0.433
	Group B	97.7±1.50	97.3±1.78	97.1±1.68	97.4±1.62	0.009*[b]
	P_2 value	0.424	0.412	0.599	0.400	
TAV	Group A	14.6±12.5	33.0±18.4	33.6±19.0	34.1±18.8	<0.001*[a, b, c]
	Group B	8.29±6.01	15.6±8.82	21.4±12.3	22.4±13.2	<0.001*[a, b, c, d, e]
	P_2 value	0.087	0.003*	0.051	0.076	
BAD	Group A	3.81±0.49	4.13±0.52	4.25±0.44	4.55±0.42	<0.001*[b, c, e]
	Group B	3.89±0.61	4.24±0.55	4.46±0.55	4.75±0.61	<0.001*[a, b, c, e, f]
	P_2 value	0.402	0.659	0.224	0.280	
BAA	Group A	11.5±3.17	13.6±3.30	14.3±2.96	16.3±2.89	<0.001*[c, e]
	Group B	12.3±3.83	14.3±3.60	15.9±3.79	17.9±4.50	<0.001*[a, b, c, e, f]
	P_2 value	0.405	0.650	0.209	0.282	
AH	Group A	97.3±72.7	271±163	295±177	338±201	<0.001*[a, b, c, e, f]
	Group B	64.1±55.3	132±80.4	198±123	238±153	<0.001*[a, b, c, d, e, f]
	P_2 value	0.177	0.007*	0.163	0.108	
PSV	Group A	56.8±34.8	75.9±42.1	74.3±40.9	73.0±40.6	0.017*[a, b]
	Group B	33.1±21.5	40.6±24.3	47.2±27.0	48.9±29.2	<0.001*[a, b, c, d, e]
	P_2 value	0.044*	0.008*	0.076	0.102	
EDV	Group A	3.75±5.82	21.4±13.8	23.4±15.1	25.1±14.9	<0.001*[a, b, c]
	Group B	2.25±2.72	8.22±4.68	13.9±8.52	15.6±9.92	<0.001*[a, b, c, d, e]
	P_2 value	0.347	0.001*	0.049*	0.056	
PI	Group A	3.83±1.92	9.11±2.45	10.9±2.70	11.3±3.02	<0.001*[b, c, e]
	Group B	2.39±1.41	6.36±2.30	8.73±3.00	10.3±3.34	<0.001*[a, b, c, d, e, f]
	P_2 value	0.010*	0.008*	0.021*	0.302	
RI	Group A	0.94±0.06	0.73±0.06	0.70±0.06	0.66±0.07	<0.001*[b, c, e]
	Group B	0.93±0.07	0.79±0.10	0.71±0.09	0.69±0.09	<0.001*[a, b, c, e]
	P_2 value	0.915	0.007*	0.671	0.296	

HR: heart rate; MAP: mean arterial pressure; SpO_2: peripheral oxygen saturation; PI: Perfusion Index; TAV: time average velocity; BAD: brachial artery diameter; BAA: brachial artery area; BF: blood flow; PSV: peak systolic velocity; EDV: end-diastolic velocity; RI: Resistance Index; P_1 value: within-group comparison; P_2 value: between-group comparison.
*Statistically significant difference; [a] 0-10; [b] 0-20; [c] 0-30; [d] 10-20; [e] 10-30; [f] 20-30.

TABLE V.—*Cutoff value of perfusion index and regional hemodynamic parameters and in the first 10 minutes.*

Parameters	AUC	95% CI	P value	Cut-off	Sensitivity	Specificity
EDV10	0.846	0.719-0.974	0.001	≥7.15	100%	55.2%
TAV10	0.806	0.653-0.959	0.003	≥24.4	63.6%	86.2%
BF10	0.779	0.616-0.952	0.007	≥112.5	90.9%	58.6%
RI10	0.779	0.639-0.919	0.007	≤0.795	100%	58.6%
PI10	0.776	0.617-0.935	0.008	≥9.2	54.5%	96.6%
PSV10	0.774	0.601-0.948	0.008	≥106.3	45.5%	100%

cooperation.[1, 2] Regional anesthesia can be provided under general anesthesia or deep sedation in some patients, which may mask complications or the failure of the block.[9] Therefore, noninvasive, objective, independent-observer tests are needed.[3]

Brachial plexus blockage leads to vasodilatation in the ipsilateral upper extremity and results in increased blood flow.[10] In the light of this information, in our study, we investigated the relationship between regional hemodynamic changes after the infraclavicular block and the success of the block. The PI, TAV, BAD, BAA, BF, PSV, EDV, and RI variables were compared to evaluate the success of the block. We observed that the PI and spectral wave-measured PSV, EDV, TAV, BF, BAD, and BAA values were increased, whereas RI was decreased.

In their study, Li *et al.*[4] reported that there was no significant difference in systemic hemodynamic changes following an axillary block. In our study, we have obtained the same results. However, there are conflicting outcomes in the literature on the subject. We believe that these conflicting results may have arisen from many factors, such as premedications, the initial pain status of the patients, and the anxiety formed because of the procedure.

The spectral wave form is triphasic. The triphasic wave comprises a rapid forward flow during systole and a subsequent early diastolic short retro-flow (protodiastolic flow) and a forward flow for a variable period during diastole. This type of circulation with high peripheral vascular resistance is typical in the extremities.[11, 12] In our study, it was observed that the disappearance of the retro-flow during early diastole and the spectral wave observed as a switch from a triphasic wave to a monophasic wave with an increased diastolic flow were the earliest changes at the 10th minute in regional hemodynamic changes following a block.

Li *et al.*[4] showed that the most significant difference was observed in the EDV with a 3.7-fold increase following an axillary brachial plexus block. In the same study, this increase was reported at the 5th minute. In another study investigating the regional hemodynamic changes in the radial and ulnar arteries of patients undergoing primary palmar hyperhidrosis due to a thoracic sympathetic block, EDV was reported to be significantly increased.[13] In our study, EDV was observed to be the parameter with the most significant change following the block at the 10th minute (3.45 times). The cutoff value of EDV was found ≥7.15 for early success.

PI is a parameter that reflects the strength of tissue perfusion by calculating the relationship between pulsatile (arterial blood) and nonpulsatile (venous blood or tissue blood) light in the pulse oximeter.[5, 14, 15] The output volume, skin temperature, and vasomotor tonus are the main factors that affect the PI, and the blood flow within the monitored area affects PI measurements.[16] In the study evaluating the effect of infraclavicular block on regional perfusion, an infraclavicular block was shown to increase the brachial artery BF and PI, and PI significantly increased at 5 min post-blockade in the blocked limb, from 4±3 to 9±5 (2.25 times).[17] In the study of Kuş *et al.*[6] investigating the efficacy of PI in the assessment of infraclavicular block success, PI was shown to increase by 1.94 times at 10 minutes after the block. In the succesful group, 10-, 20-, 30-minute percent change of the PI was statistically higher when compared with the initial value ($P<0.001$). In our study, the increase in PI was 2.56 times at 10 minutes and also percent changes of PI measured in the time interval of 0-10th min were statistically higher than the time interval of 10-20 minutes ($P<0.001$).

Abdulnasser *et al.*[18] showed that PI at 10 minutes was a good measurement to predict supraclavicular block success with a cutoff value >3.3. In our study, the mean PI value measured in patients with a successful block after the 10th minute was determined to be 6.4±2.3 with a cutoff value >9.2. We believe this difference in cutoff values may be because the two studies were performed using different nerve blocks.

Iskandar *et al.*[10] showed that brachial artery BF after 30 min. following an interscalene block increased from 32 (18-46) mL/min to 88 (59-98) mL/min (2.75 times, $P<0.01$). A similar increase was observed by Ebert *et al.*[19] in their study following an axillary block (1.9 times). This increased BF in the ipsilateral side was said to shorten the period of improvement, especially in patients undergoing a venous fistula operation due to terminal stage renal failure, in addition to those undergoing microsurgery.[20] Shemesh *et al.*[21, 22] reported that a brachial plexus block provided venous and arterial vasodilatation and increased the success rate in AV fistula operations. In our study, the mean values of the brachial artery BF volume were found to be increased by 2.32, 3.07, and 3.62 times at the 10, 20, and 30 minutes, respectively, similar to the literature.

Previous studies have demonstrated a significant increase in BAD and BAA following a brachial plexus blockage starting at the 10th minute.[4, 19] In our study, BAD and BAA were found to be significantly increased by the 10th minute, but BAD and BAA were not effective in revealing the early success of the block (P>0.05).

Normally, there is a 10% difference between the systolic and diastolic brachial artery diameter.[23] We took the BAD measurements at the end of the diastoles. Mistakes, especially in the vessel diameter, would lead to a second-degree exponential mistake when calculating the vessel area, and a third-degree exponential mistake when calculating the flow volume.[23] Furthermore, an observer-related difference may be seen in the measurements. In their study, Li *et al.*[4] investigated regional hemodynamic changes following axillary blockage, and 1520% of the changes in BF were observed in observer-related measurements. Therefore, all measurements were performed by the same observer in our study, and the first site of measurement was marked to ensure the same measurement of each site. BF measurement, on the other hand, is not only related to the diameter but changes proportional to the flow rate and, thus, we believe it is a rather objective parameter compared to the BAD and BAA.

Li *et al.*[4] showed that PSV was significantly increased at the 10th minute (1.36 times) but demonstrated no significant increase at the 5th minute in contrast to other parameters. In our study, PSV was observed to increase link in previous studies, and a 1.37-fold increase was observed at the 10th minute. These findings make us expand the use of PSV as an early indicator of block success.

Studies have reported significantly increased TAV starting at the 10th minute.[4, 7] In our study, TAV was the most increased parameter after EDV, PI, BF, and PSV. It increased by 1.03, 1.46, and 1.57 times at 10, 20, and 30 minutes, respectively.

As discussed previously, all parameters evaluated are susceptible to measurement and/or observer mistakes, except for the PI. However, parameters that have a rational value, such as RI, may provide more reliable data. The RI is calculated using the formula (PSV-EDV)/PSV.[24] Fei *et al.*[13] showed that the RI of the radial artery (RA) and ulnar artery (UA) of the patients after surgery were 0.85±0.05 and 0.97±0.07, respectively, while the RI of the RA and UA were 0.57±0.04 and 0.64±0.09, respectively, thus they had significantly decreased after surgery. The difference was statistically significant (P<0.01). In our study, similar decreases in RI were observed. During the literature search, many methods were used to evaluate the motor block, such as the Bromage Scale, the Modified Bromage scale, the Lovett rating scale, and the Holmenn scale. Loss of cold sensation, loss of vibration sense, and pinprick tests were also used to evaluate the sensory block.[25, 26] In their study, Galvin *et al.*[27] reported the loss of cold sense as a more sensitive test than the pinprick test in the evaluation of sensory block following an axillary block. Lee *et al.*[28] designed their durations of axillary block and sensory and motor blocks according to the Hollmen scale. In our study, both motor and sensory blocks were evaluated using the Hollmen Scale. To parallel previous studies, blocks in patients with a score of at least 2 in both motor and sensory blocks were accepted as successful.

Limitations of the study

The main limitations of the present study are the lack of an unsuccessful nerve block group and the fact that the initial value of PI was different between the groups, so more reliable values can be attained by performing studies with a larger group of patients.

Conclusions

Regional hemodynamic variables and PI showed a significant change in a successful infraclavicular block after the 10th minute. The highest change was observed in EDV using a spectral Doppler ultrasound during the evaluation of the block's success. However, we think that RI will be a more objective measurement of the success because it ([PSV–EDV]/PSV) is a rational value. If ultrasound cannot be used to evaluate block success, we think the perfusion index technology is easily applicable even though it is new.

As subjective methods could be insufficient in evaluating block success, and there is the need for effective time usage in operating rooms, we believe that RI and PI would provide more effective and objective outcomes in the evaluation of regional blocks because they are least affected by practitioner and measurement mistakes.

What is known

- Traditional methods to evaluate the success of blocks requires patient cooperation.
- After successful peripheral nerve blockade, changes in the regional hemodynamic parameters and Perfusion Index can be seen.

What is new

- Hemodynamic parameters such as end-diastolic velocity, Resistance Index, and Perfusion Index monitoring may provide a quick evaluation for block success.
- Resistance Index and Perfusion Index appear to be more objective parameters for evaluating early block success.

References

1. Albrecht E, Mermoud J, Fournier N, Kern C, Kirkham KR. A systematic review of ultrasound-guided methods for brachial plexus blockade. Anaesthesia 2016;71:213–27.

2. Sandhu NS, Capan LM. Ultrasound-guided infraclavicular brachial plexus block. Br J Anaesth 2002;89:254–9.

3. Galvin EM, Niehof S, Verbrugge SJ, Maissan I, Jahn A, Klein J, *et al.* Peripheral flow index is a reliable and early indicator of regional block success. Anesth Analg 2006;103:239–43.

4. Li J, Karmakar MK, Li X, Kwok WH, Ngan Kee WD. Regional hemodynamic changes after an axillary brachial plexus block: a pulsed-wave Doppler ultrasound study. Reg Anesth Pain Med 2012;37:111–8.

5. Ozaki M, Seller DI, Lopex BA. Pulse Oximeter-based flow index co-relates well with fingertip volume Plethysmography. Anesthesiology 1993;79:A542.

6. 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.

7. Li T, Ye XH, Nan Y, Shi T, Ye QG, Ma JF, *et al.* [Comparison of ultrasound and nerve stimulation techniques for brachial plexus block for regional hemodynamic changes of upper extremity]. Zhonghua Yi Xue Za Zhi 2013;93:187–90. Chinese.

8. Capogna G, Celleno D, Laudano D, Giunta F. Alkalinization of local anesthetics. Which block, which local anesthetic? Reg Anesth 1995;20:369–77.

9. Yanal H, Gürkan Y, Kuş A, Balaban O, Solak M, Toker K. Awake hand surgery under ultrasound-guided infraclavicular block is possible for cooperative children. Agri 2016;28:190–3.

10. Iskandar H, Wakim N, Benard A, Manaud B, Ruel-Raymond J, Cochard G, *et al.* The effects of interscalene brachial plexus block on humeral arterial blood flow: a Doppler ultrasound study. Anesth Analg 2005;101:279–81.

11. Thrush A, Hartshorne T. Peripheral Vascular Ultrasound: How, Why and When. Edinburgh, UK: Elsevier Churchill Livingstone; 2005. p. 63–74.

12. Chavhan GB, Parra DA, Mann A, Navarro OM. Normal Doppler spectral waveforms of major pediatric vessels: specific patterns. Radiographics 2008;28:691–706.

13. Fei Y, Xu MM, Huang B, Xie KY, Ni HD, Zhang L, *et al.* [Assessment of the radial and ulnar arteries hemodynamic changes by ultrasound in patients with primary palmar hyperhidrosis after thoracic sympathetic block]. Zhonghua Yi Xue Za Zhi 2017;97:1729–33. Chinese.

14. Hager H, Church S, Mandadi G, Pully D, Kurz A. The Perfusion Index as Measured by a Pulse Oximeter Indicates Pain Stimuli in Anesthetized Volunteers. Anesthesiology 2004;101:514.

15. Toyama S, Kakumoto M, Morioka M, Matsuoka K, Omatsu H, Tagaito Y, *et al.* Perfusion index derived from a pulse oximeter can predict the incidence of hypotension during spinal anaesthesia for Caesarean delivery. Br J Anaesth 2013;111:235–41.

16. Hales JR, Stephens FR, Fawcett AA, Daniel K, Sheahan J, Westerman RA, *et al.* Observations on a new non-invasive monitor of skin blood flow. Clin Exp Pharmacol Physiol 1989;16:403–15.

17. Nieuwveld D, Mojica V, Herrera AE, Pomés J, Prats A, Sala-Blanch X. Medial approach of ultrasound-guided costoclavicular plexus block and its effects on regional perfussion. Rev Esp Anestesiol Reanim 2017;64:198–205.

18. Abdelnasser A, Abdelhamid B, Elsonbaty A, Hasanin A, Rady A. Predicting successful supraclavicular brachial plexus block using pulse oximeter perfusion index. Br J Anaesth 2017;119:276–80.

19. Ebert B, Braunschweig R, Reill P. [Quantification of variations in arm perfusion after plexus anesthesia with color doppler sonography]. Anaesthesist 1995;44:859–62. German.

20. Sahin L, Gul R, Mizrak A, Deniz H, Sahin M, Koruk S, *et al.* Ultrasound-guided infraclavicular brachial plexus block enhances postoperative blood flow in arteriovenous fistulas. J Vasc Surg 2011;54:749–53.

21. Shemesh D, Zigelman C, Olsha O, Alberton J, Shapira J, Abramowitz H. Primary forearm arteriovenous fistula for hemodialysis access—an integrated approach to improve outcomes. Cardiovasc Surg 2003;11:35–41.

22. Shemesh D, Raikhinstein Y, Goldin I, Olsha O. General, regional or local anesthesia for successful radial cephalic arteriovenous fistula. J Vasc Access 2017;18(Suppl. 1):24–8.

23. Parker BA, Ridout SJ, Proctor DN. Age and flow-mediated dilation: a comparison of dilatory responsiveness in the brachial and popliteal arteries. Am J Physiol Heart Circ Physiol 2006;291:H3043–9.

24. Seçil M. Temel Ultrasonografi ve Doppler. Izmir, Turkey: Meta Basım Ve Matbaacılık; 2008. p. 1–31.

25. Piangatelli C, De Angelis C, Pecora L, Recanatini F, Cerchiara P, Testasecca D. Levobupivacaine and ropivacaine in the infraclavicular brachial plexus block. Minerva Anestesiol 2006;72:217–21.

26. Pürcü Ö, Yavaşcaoğlu B, Kaya FN. Pregabalinin Aksiller

Blok Sonrası Analjeziye Etkisi. Turkish Journal of Anesthesia and Reanimation 2013;41:1.

27. Galvin EM, Niehof S, Medina HJ, Zijlstra FJ, van Bommel J, Klein J, *et al.* Thermographic temperature measurement compared with pinprick and cold sensation in predicting the effectiveness of regional blocks. Anesth Analg 2006;102:598–604.

28. Lee R, Kim YM, Choi EM, Choi YR, Chung MH. Effect of warmed ropivacaine solution on onset and duration of axillary block. Korean J Anesthesiol 2012;62:52–6.

Conflicts of interest.—The authors certify that there is no conflict of interest with any financial organization regarding the material discussed in the manuscript.

Article first published online: January 4, 2019. - Manuscript accepted: December 17, 2018. - Manuscript revised: December 5, 2018. - Manuscript received: May 24, 2018.