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ORIGINAL ARTICLE

Early and late blood flow changes in the brachial artery following brachial plexus block

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ABSTRACT

BACKGROUND: A nerve block causes various hemodynamic changes in the vessel system. The primary objective of the present study is to examine the volume flow values in the brachial artery in the early and late period following an infraclavicular brachial plexus block. The secondary objective is to evaluate arterial diameter, forearm temperature and other Doppler ultrasound measurements in the late period.

METHODS: An infraclavicular brachial plexus block was performed in ASA class I-II patients aged 18-65 years who were to undergo upper extremity surgery. Hemodynamic measurements and the measurement of the Doppler ultrasound parameters at five minutes before and five, 15, 30 minutes, 24, 48 hours after the block.

RESULTS: Volume flow was increased at the 30th min after nerve block. A 47.17% decrease in the collected volume flow data was noted between the 30th min and 24th hour, and this change was found to be statistically significant. It is also worth highlighting the decrease in volume flow at 24 hours and 48 hours, which became closer to the volume flow value at time 0, but was still relatively higher than the value at time 0.

CONCLUSIONS: The increase in volume flow following a change in the flow morphology after an infraclavicular nerve block persists for at least 24 hours. This may be the explanation for clinical advantage in all types of surgery and in particular after fractures, graft and reimplantation surgery.

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Key words: Brachial plexus block; Blood circulation; Hemodynamics.

Peripheral nerve blocks are commonly used in clinical practice to provide anesthesia and analgesia for surgeries involving the extremities. A nerve block causes various changes in the vessel system such as dilation of the arteries and veins,[1-3] changes in blood flow morphology, fluctuations in the systolic and diastolic flow rates.[2] These changes are likely to be a result of sympathetic block in the relevant extremity.

Although early changes following a nerve block have been previously revealed in limited number of studies,[3-8] in the current literature there is no study evaluating the late hemodynamic changes seen following a nerve block. Moreover, we have no information whether these changes in the vessel system persist or fade out after the effects of nerve block have regressed.

The primary objective of the present study is to examine the early and late volume flow values of the brachial artery following infraclavicular brachial plexus (IBP) block. The secondary objective is to evaluate arterial diameter, forearm temperature and other Doppler ultrasound measurements in the late period.

Materials and methods

The study was approved by the Ethics Committee of Clinical Research of Mugla Sıtkı Kocman University and the study was registered to ANZCTR clinical trial registry with the protocol number ACTRN12619000360112. The study was designed as a prospective, observational study. The patients between 18-65 years old with ASA I-II physical status and scheduled for upper extremity surgery under IBP block were screened. All patients were informed about the study protocol during preoperative anesthesia assessment and the patients who were agreed to participate in the study were included. A detailed written informed consent was obtained both for the block procedure and participation to the study. The exclusion criteria were history of allergy to local anesthetics, known connective tissue disorders, neuromuscular diseases, skin infection over the injection site, coagulopathy, arteriovenous fistula of the arm, psychiatric disorders, cardiac dysfunction, diabetes mellitus, autonomic neuropathy and vascular diseases.

Skin temperature measurements

One hour prior to their surgeries, the patients were taken to the preoperative "block room" which is at 24 °C room temperature. Following a standard monitoring with non-invasive blood pressure measurement, ECG and pulse oximeter, all patients rested for 15 min in the room and then they received IV midazolam 0.02 mg/kg as premedication of block procedure. The skin temperature of patients was measured over dorsum of the hand by infrared thermometer (Nimomed HNK-IR-01) 5 min before the IBP block. After the block performance, the measurements were repeated five more times: at the 5th min, 15th min and 30th min in the "block room" and 24th and 48th hour in the Radiology Clinic. All measurements were done at 24 °C room temperature.

Doppler ultrasound evaluation

Patients lied in supine position with both arms adducted. A linear ultrasound probe was located to the distal one third of the arm, 2 to 4 cm proximal to the antecubital fossa. The brachial artery was visualized on the sagittal plane and USG measurements were performed in the midline of the arterial lumen. After the optimal PWD spectral waveform was detected volume flow, diameter, peak systolic velocity (V_{max}, cm/s), end-diastolic velocity (EDV, cm/s), mean velocity (V_{mean}, cm/s), time-averaged mean velocity (TAVM, cm/s), ratio of V_{max} and EDV (S/D), Resistance Index (RI), Pulsatility Index (PI) were measured. All measurements were performed by the same investigators in tandem at the 5th min, 15th min and 30th min and at the 24th and 48th hour after the block. The first four measurements were performed in the block room of the operating theatre and the last two measurements were performed in the Radiology Clinic.

Moreover, in order to ensure the reliability and accuracy of the measurements (volume flow, EDV and diameter) which was initially recorded by the anesthesiologist, same measurements were repeated by the independent radiologist for the consistency of the ratings. For this procedure, a total of six samples were chosen randomly.

IBP block procedure and evaluation of sensory-motor block

The infraclavicular brachial plexus block was performed by the lateral sagittal infraclavicular block (LSIB) technique described by Klaastad *et al.*[9] Following the administration of bupivacaine 0.5% 30 mL, the spread of local anesthetic solution was visualized around the axillary artery in a "U" shaped manner between the three and 11 o'clock positions. The maximum bupivacaine dosage did not exceed 175 mg according to recommendation of Turkish Society of Anesthesia and Reanimation.[10]

The sensory block was defined as the "loss of cold sensation", evaluated according to the Verbal Rating Score (100 = normal sensation, 0 = no sensation) by placing a ready-made frozen ice mold on the forearm dermatome area of the median, radial, ulnar nerves.

The motor block was tested for each nerve on a three-point scale (0 = normal movement and power, 1 = motor weakness or paresis, and 2 = paralysis.). The time of the successful block was defined as the presence of complete sensory block.

Sample size

The sample size was calculated with power analysis based on the data obtained from a pilot study conducted initially with eight patients in total. Based on the proposed hypothesis considering the standard deviation of 245.4 from the pilot study, which expect a 50% decrease in Volume Flow between time points four to five, the required sample size was estimated with an assumption of a type I error of 0.01 and a type II error of 0.10, which brings a power of 0.90 (1 - β). Accordingly, a sample size of 16 participants was deemed necessary, although 18 participants were recruited for the study to ensure validity in the event of dropouts.

Statistical analysis

The shapes of distribution of the measured variables were demonstrated using the Shapiro-Wilk method. Student's *t*-test was used to compare gender differences on the outcome parameters, and results are presented as mean and standard deviation. The randomly selected measurements were rated by two independent experts — an anesthesiologist and a radiologist - with reliability tests utilized to evaluate the level of inter-observer agreement between the ratings of the outcomes. An intra-class correlation coefficient (ICC) was deemed appropriate, and was calculated with a two-way random-effects model with an absolute agreement. Agreement coefficients were reported with 95% confidence intervals, with an ICC value >0.90 indicating a very good agreement between the raters on the measurement. The measurements were performed at six time points, being at time point 0, referring to the baseline measurement, to time point six, referring to the measurement at 48 hours. As the primary expectation was that a time-wise variation would be observed, especially between time point four (30 min) and time point five (24 hours), the authors decided to make repeated measures analysis of variance. Taking steps further with repeated measures, *post-hoc* analyses were performed using a Bonferroni correction for pairwise comparisons, since the within-subject variation in the overall model does not entail the specific distinction between certain time to time. Moreover, gender is considered as a between subject factor, and interaction effect is calculated. A Greenhouse-Geisser correction was considered for the interpretation of the within-level and interaction effect results, since the assumption of sphericity had been violated. In addition, time-wise lines were plotted for each parameter on the same graph to allow the visualization of the similarities and differences in the variations between variables. Statistical analyses were performed using the SPSS v. 25 (SPSS Incorporated, Chicago, IL, USA) software. A P value <0.05 was considered statistically significant for all tests results in the manuscript.

Results

A total of 40 patients were screened for eligibility and 18 of them completed the study (Figure 1). The mean age of the patients was 34.31±5.59 years (range 25-44 years). The demographic features are shown in Table I. The measurements which was initially recorded by two investigators. In terms of the reliability coefficients, the inter-rater agreement scores (ICC) revealed a very good rating agreement for the randomly

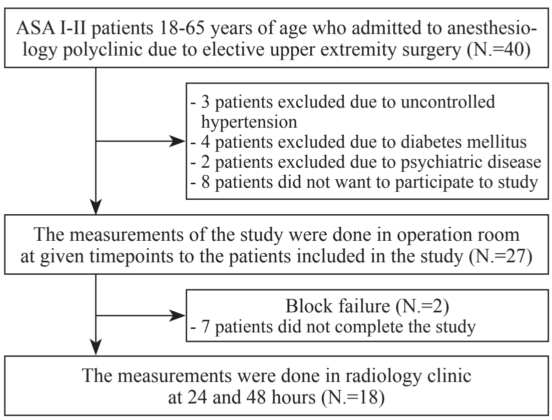

Figure 1.—Operation chart.

TABLE I.—*Demographics of the patients.*

Variable	Group	Mean±SD
Age	Male	36.6±5.1
	Female	32.6±6.0
Weight	Male	83.6±5.1
	Female	71.3±1.0
Height	Male	177.1±6.9
	Female	167.4±2.7

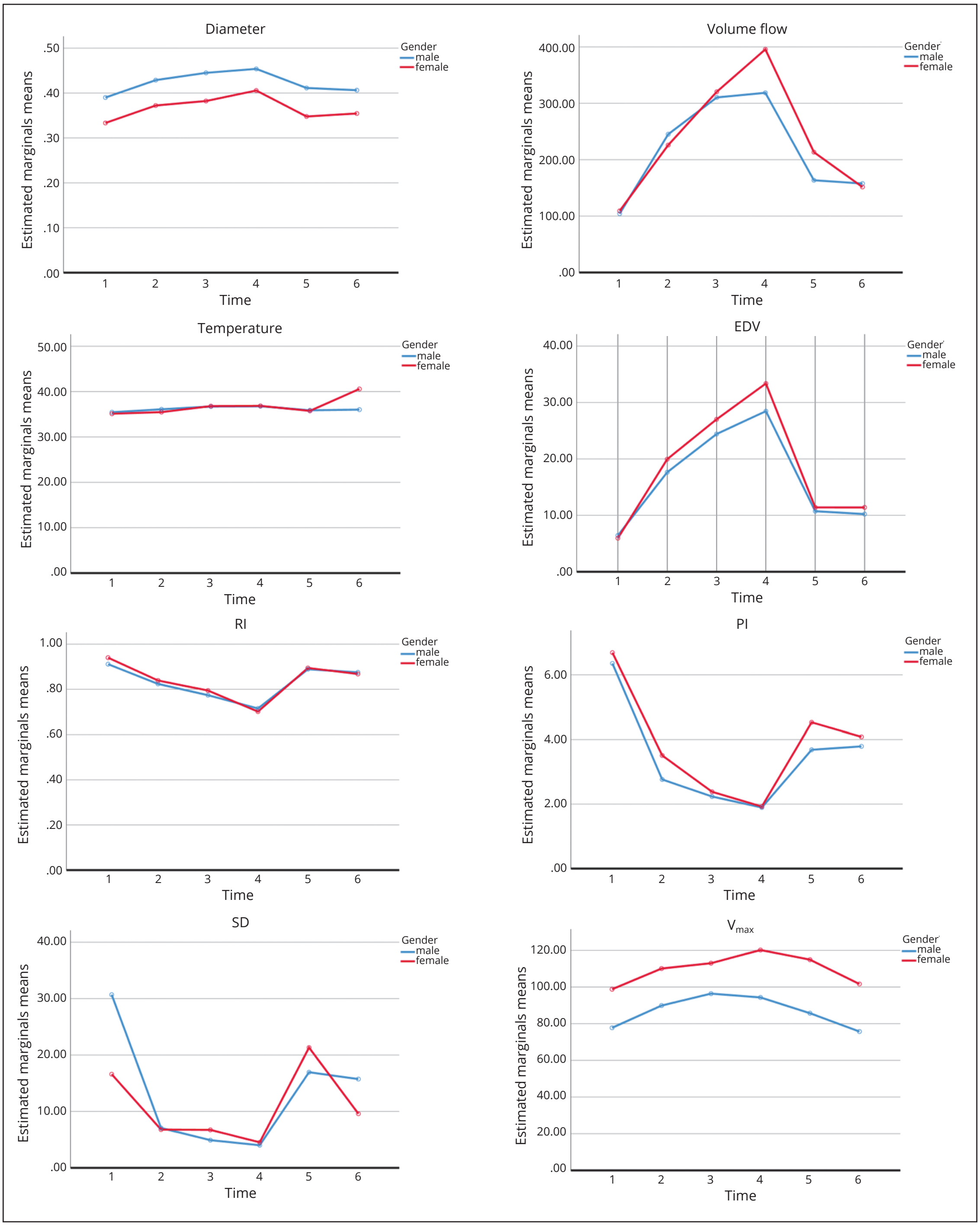

Figure 2.—Time wise dispersion of the measured variables by gender.

chosen variables of volume flow, EDV and diameter between observer one (anesthesiologist) and observer two (radiologist). The ICC values ranged between 0.836 and 0.965 overall, being 0.965 for the volume flow, 0.956 for the EDV and 0.836 for the diameter observations between

TABLE II.—*The changes of variables by time.*

Variable	-5 min	P value -5 *vs.* 5 min	5 min	P value 5 *vs.* 15 min	15 min
Diameter	0.36±0.06	0.000	0.40±0.06	0.783	0.41±0.08
Volume flow	114.72±75.92	0.001	235.67±156.49	0.009	317.11±197.16
Temperature	35.34±0.43	0.008	35.89±0.62	0.006	36.74±0.50
EDV	5.93±4.70	0.000	18.98±8.59	0.643	26.60±17.10
RI	0.93±0.08	0.003	0.83±0.07	0.317	0.78±0.09
PI	6.78±2.84	0.000	3.11±1.32	0.107	2.28±0.71
SD	25.76±25.81	0.189	6.82±2.20	1.000	5.73±3.79
V_{max}	90.15±27.25	1.000	100.92±23.30	1.000	106.52±23.18

P values presented here are obtained with pairwise comparison table from the RM-ANOVA test.

the raters. As a result, the readings in overall indicated a high level of agreement.

The mean difference in the base diameter was calculated as 0.055 (0.002-0.11), for the 24th hour diameter as 0.058 (0.003-0.115) and for the 48th hour diameter as 0.048 (0.002-0.093), as shown in Table II below. The Student's *t*-test results revealed that the most of measurements with their time wise ratings did not vary significantly (with P values ranging between 0.091 and 0.982) between males and females. However, a gender wise difference was observed for the base diameter, the 24th hour diameter and the 48th hour diameter (P=0.043, P=0.040, and P=0.041, respectively).

According to the repeated measures analysis, the mean scores of the following variables differed significantly between time points, including diameter over the time (P<0.001), volume flow over the time (P<0.001), EDV over the time (P<0.001), RI over the time (P<0.001), PI over the time (P<0.001) and SD over time (P<0.05). On the other hand, the dorsal hand skin temperature (P=0.139) and V_{max} (P=0.122) values did not differ significantly between the time points. Moreover, according to the interaction term, the time-wise change did not vary significantly between gender for diameter time (P=0.840; for volume flow P=0.537; for EDV P=0.001; for RI P=0.889; for PI P=0.874; for SD P=0.515; for temperature P=0.179; for V_{max} P=0.842. The effect of gender within the time-wise variation for each variation has been shown in Figure 2.

Table II and III details the complexity of the changes in parameters over time. The primary objective of the present study was to observe a 50% decrease in volume flow between 30 min and 24 hours, and the *post-hoc* test results showed that the mean volume flow was 359.412±52.628 at 30 min and 189.882±23.406 at 24 hours, and a difference of 169.529 (-0.194, 339.253) with a P value of 0.05 showing borderline significance. A 50% decrease was initially expected to be observes in the volume flow between the time points detailed above. Close to our expectations, a 47.17% decrease in the collected volume flow data was noted between the 30th min and 24th hour, and this change was found to be statistically significant. It is also worth highlighting the decrease in Volume Flow at 24 hours and 48 hours, which became closer to the volume flow value at time 0, but was still relatively higher than the value at time 0. The pairwise comparisons between the specific time points for volume flow variable is shown in Figure 3.

Discussion

Brachial plexus block is a commonly used method of anesthesia in upper extremity surgery. Hadziç *et al.* compared brachial plexus block and

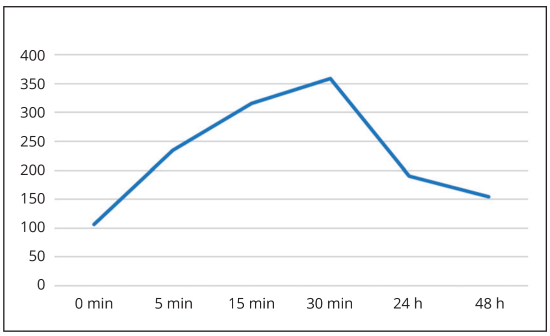

Figure 3.—Temporal changes in volume flow.

P value 15 *vs.* 30 min	30 min	P value 30 min *vs.* 24 h	24 hours	P value 24 *vs.*48 h	48 hours
0.068	0.43±0.07	0.000	0.38±0.06	1.000	0.38±0.05
0.637	359.41±216.99	0.050	188.56±93.79	1.000	150.94±71.37
1.000	36.8±0.54	0.004	35.83±0.34	1.000	37.54±5.34
0.652	31.06±16.52	0.006	10.96±6.00	1.000	10.45±6.84
0.278	0.71±0.13	0.002	0.89±0.06	1.000	0.88±0.09
0.339	1.91±0.72	0.013	4.12±1.96	1.000	4.00±1.86
1.000	4.29±2.67	1.000	18.87±30.16	0.387	12.24±14.09
1.000	108.01±45.34	1.000	101.43±28.22	1.000	88.42±24.22

TABLE III.—*Pairwise comparison for the repeated with Bonferroni adjustment measures (time to time).*

Time	To compare	Diameter	Volume flow	Temp	EDV	RI	V_{max}	PI	SD
1	2	0.040*	0.001*	0.008*	0.000*	0.003*	NS	0.000*	NS
	3	0.000*	0.000*	0.000*	0.003*	0.001*	NS	0.000*	NS
	4	0.000*	0.000*	0.000*	0.000*	0.000*	NS	0.000*	0.078
	5	NS	0.011*	0.027*	0.029*	NS	NS	NS	NS
	6	NS	NS	NS	NS	NS	NS	0.078	NS
2	1	0.000*	0.001*	0.008*	0.000*	0.003*	NS	0.000*	NS
	3	NS	0.009*	0.006*	NS	NS	NS	NS	NS
	4	0.000*	0.009*	0.011*	0.001*	0.000*	NS	0.002*	0.010*
	5	NS	NS	NS	0.058	NS	NS	NS	NS
	6	NS	NS	NS	NS	NS	NS	NS	NS
3	1	0.000*	0.000*	0.000*	0.003*	0.001*	NS	NS	NS
	2	NS	0.009*	0.006*	NS	NS	NS	NS	NS
	4	0.068	NS	NS	NS	NS	NS	NS	NS
	5	0.020*	NS	0.001*	NS	0.029*	NS	0.061	NS
	6	NS	0.031*	NS	NS	NS	NS	NS	NS
4	1	0.000*	0.000*	0.000*	0.000*	0.000*	NS	0.000*	0.078
	2	0.000*	0.009*	0.011*	0.001*	0.000*	NS	0.002*	0.010*
	3	0.068	NS	NS	NS	NS	NS	NS	NS
	5	0.000*	0.050*	0.004*	0.006*	0.002*	NS	0.013*	NS
	6	0.002*	0.011*	Ns	0.004*	0.002*	NS	0.006*	NS
5	1	NS	0.011*	0.027*	0.029*	Ns	NS	NS	NS
	2	NS	NS	Ns	0.058	Ns	NS	NS	NS
	3	0.020*	NS	0.001*	Ns	0.029*	NS	0.061	NS
	4	0.000*	0.050*	0.004*	0.006*	0.002*	NS	0.013*	NS
	6	NS	NS	NS	NS	Ns	NS	NS	NS
6	1	NS	NS	NS	NS	Ns	NS	0.078	NS
	2	NS	NS	NS	NS	Ns	NS	NS	NS
	3	NS	0.031*	NS	NS	Ns	NS	NS	NS
	4	0.002*	0.011*	NS	0.004*	0.002*	NS	0.006*	NS
	5	NS	NS	NS	NS	NS	NS	NS	NS

The data are P values obtained with ANOVA.
NS: not statistically significant P values (P>0.05).
*P values ranging between 0.05 and 0.10.

general anesthesia prior to ambulatory hand surgery and reported a higher anesthesia score with a brachial plexus block that reduced the requirement for additional analgesics, and resulted in an earlier discharge and a superior side-effect profile.[11]

Doppler ultrasound is the basic imaging method adopted to evaluate changes in arteries. Each vessel has a specific spectral waveform, depending on its anatomical position and the organ supplied by that particular vessel. The spectral waveforms produced by vascular resistance may indicate physiological and pathological conditions.[12] Exercise, changes in pressure and spatial location can all alter arterial spectral waveforms.[13] Triphasic, biphasic and monophasic waveforms constitute the three basic waveforms on a Doppler ultrasound of the peripheral arteries.[14] Triphasic waveforms are formed in the event of a strong antegrade systolic flow in the early diastole, followed by short reversal of flow, and an antegrade flow during the late diastole. Monophasic flow involves only antegrade flow during systole.[14]

Brachial plexus blocks cause vasodilation and increased blood flow.[3, 7, 8] There are limited number of studies in literature evaluating the regional hemodynamic changes following brachial plexus block.[3-8] Our literature search returned no study evaluating the late-period effects of regional hemodynamic changes following nerve blocks, and whether such changes persist after the effects of block have worn off. The main difference of the current study is that we investigated the return time of arterial morphology and flow alterations. In the present study, the first change following an infraclavicular block was the conversion of the flow morphology from a triphasic to monophasic pattern. All patients had triphasic blood flow pattern (Figure 4) at the beginning (5 min before block performance) and monophasic pattern (Figure 5) at five, 15, 30 min after the block. However, this stable blood flow pattern individually changed at the 24th and 48th hour (Figure 4, 5, 6). The number of patients which show the flow patterns at 24 and 48 hours were triphasic (4, 8), biphasic (8, 10), and monophasic (2, 4), respectively. Volume flow, V_{max}, EDV and diameter all gradually increased at 5th, 15th and 30th min while RI, PI and S/D gradually decreased (Table II, III).

Li *et al.*[2] evaluated the changes occurring in the brachial artery in the first 30 minutes after an axillary nerve block by using a pulse-waved Doppler USG, and the authors reported the conversion of the flow morphology from a triphasic to monophasic pattern. In the present study, we evaluated the changes of flow morphology at the 24th and 48th hour. At the 48th hour, the flow morphology of eight patients were triphasic, eight patients had biphasic and two patients had monophasic pattern. These results support that further

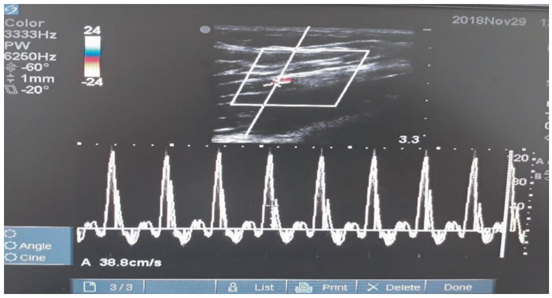

Figure 4.—Triphasic pattern of brachial artery.

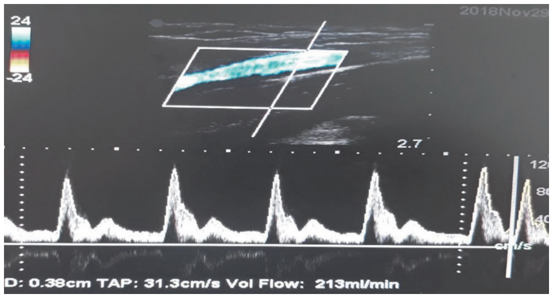

Figure 5.—Monophasic pattern of brachial artery.

Figure 6.—The biphasic flow pattern of brachial artery.

studies are needed to investigate the morphology of flow in following times.

We detected a rapid increase in the volume flow at the 5th min that persisted into the 15th and 30th min. There was then a remarkable decrease at 24 hours when compared to the values at 30th min, although the values were still significantly higher than that at 0 min. Although elevated levels persisted at the 48th hour, the difference was not statistically significant. The timings of increases and decreases in the volume flow were unaffected by the duration of the sensory and motor blocks. The blockade of the stellate gan-

Table IV.—*Sensory and motor block onset and duration of the block.*

Variable	Mean±SD	Min-max	Median (LQ/UQ)
Time of sensory block onset, min	6.56±2.81	3/14	5.5 (5/7.5)
Time of motor block onset, min	9.83±4.30	5/22	8 (7/10.5)
End time of sensory block, h	22.33±11.90	4/48	19 (16/26.25)
End time of motor block, h	15.89±5.12	8/25	14 (12/20.25)

LQ: lower quartile, UQ: upper quartile.

glion, which is a sympathetic ganglion, is known to cause an increase in blood flow[15] that has been attributed to the relaxation of the muscles in the vessel walls in relation to the sympathetic nerve block. The brachial plexus supplies sensory, motor and sympathetic nerves,[16] and it is highly possible that an increase in volume flow in patients undergoing a brachial plexus block is the result of a sympathetic nerve blockade. That said, there have been insufficient studies to date evaluating the level of increase in volume flow and its duration. One possible reason for the increased volume flow relates to the blockade of sympathetic fibers, although it may also be attributable to other factors, such as the mechanical irritation of the artery during an infraclavicular block. The authors were unable to identify any direct relationship between the mean cessation times of sensory and motor block and the time of change in volume flow (Table IV).

Significant increases were noted in diameter, EDV and temperature at the 5th, 15th and 30th min when compared to the values at five minutes prior to the block, along with decreases in the RI and PI values (Table II). In none of the measurements were significant differences noted between the values at five minutes prior to the block and at the 48th hour after the block (Table II). The changes in diameter were not unrelated to gender.

Limitations of the study

One of the limitations of the present study is that the late measurements were at 24 and 48 hours. With more late period measurements before 24 hours and after 48 hours, vessel changes after nerve blockage could be better demonstrated. Studies to be carried out assessing vessel diameter and flow measurements may provide more accurate data if the time at which volume flow returned to its baseline values could be measured. Another limitation considered by the authors relates to the possible interference of outside factors in the temperature measurements.

Conclusions

In conclusion, the increase in volume flow following a change in the flow morphology due to an infraclavicular nerve block persists for at least 24 hours. This may be the explanation for clinical advantage in all types of surgery and in particular after fractures, graft and reimplantation surgery.

What is known

- A nerve block causes various changes in the vessel system which are likely to be a result of sympathetic block such as dilation of the arteries and veins, changes in blood flow morphology, fluctuations in the systolic and diastolic flow rates.
- The brachial plexus supplies sensory, motor and sympathetic nerves, and it is highly possible that an increase in volume flow in patients undergoing a brachial plexus block is the result of a sympathetic nerve blockade.

What is new

- The first change following an infraclavicular block is the conversion of the flow morphology in brachial artery from a triphasic to monophasic pattern. The flow morphology does not fully recover within the first 48 hours after the block.
- The timings of increases and decreases in the volume flow were unaffected by the duration of the sensory and motor blocks.

• One possible reason for the increased volume flow relates to the blockade of sympathetic fibers, but it may also be attributable to other factors, such as the mechanical irritation of the artery during an infraclavicular block.

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