Evaluation of tissue oxygenation and block quality using Near Infrared Spectroscopy (NIRS) in patients undergoing ultrasound-guided infraclavicular block at different arm angles

A prospective observational study

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Evaluation of tissue oxygenation and block quality using Near Infrared Spectroscopy (NIRS) in patients undergoing ultrasound-guided infraclavicular block at different arm angles. A prospective observational study

BACKGROUND: *The preference for peripheral nerve block methods is increasing with every passing day. Our aim in this study is to evaluate tissue oxygenation using a near-infrared spectroscopy (NIRS), as a non-invasive device that detects tissue oxygen saturation (St02), in patients subjected to infraclavicular blockage at different angles.*
METHOD: *Included in the study were 34 patients aged between 18 and 65 in the ASA I-II group who were scheduled to undergo hand, forearm or arm surgery. An infraclavicular block was applied with the shoulder abducted at 0°, 45° and 90° under USG guidance while the elbow was in extension. The $St0_2$ values of the patients were measured with NIRS in both arms every five minutes.*
RESULTS: *A p value of <0.05 was considered statistically significant. Tissue oxygenation in the arm subjected to blockade increased significantly over time (p<0.001), while tissue oxygenation in the untreated arm did not change over time. The duration of the sensory blockade differed significantly only for values between 0 and 90 (p = 0.046). The block application time was lower at a 90° angle (p <0.001), and the satisfaction level decreased as the number of needle entries increased (p<0.001). Patient satisfaction increased as the angle increased (p=0.002).*
CONCLUSION: *It was demonstrated that tissue oxygenation increased with NIRS in the extremity subjected to blockade in patients who underwent a USG-guided infraclavicular block at different angles; however, different angles were not observed to affect tissue oxygenation.*

KEY WORDS: Near-infrared spectroscopy, Tissue oxygen saturation, Ultrasound, Infraclavicular block.

Introduction

With peripheral nerve block methods during surgery, the patient has continuous spontaneous breathing, is conscious, airway reflexes are maintained, hemodynamics are minimally affected and the analgesic effect continues into the postoperative period. As a result, nerve block methods are being developed and are gaining more popularity with each passing day. Ultrasonography (USG)-guided nerve blockades of the upper extremity have made the technique relatively easy, and have gradually decreased complications [1,2]. A USG-guided infraclavicular nerve block can be applied at different angles of the arm, and can affect the visualization of the plexus cords and pectoralis muscles by changing the depth from the skin to the plexus. Different angles can also affect duration, the chances of success, and the easy nature or difficulty of the nerve block. For the success of an upper extre-

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mity peripheral nerve blockade, there should be an increase in arterial vasodilatation which arises as a result of the blockade of sympathetic nerve fibers, increases in skin temperature and blood flow along the blocked arm. Tests such as the pin-prick test, cold application or the Bromage scale are currently being used to measure the success of nerve blocks, and these tests are considered subjective assessments, in that they require the patient's oral confirmation. Objective methods based on such sympathetic blockades as peripheral flow index, resistance index, perfusion index (PI), thermographic temperature measurement, skin temperature, finger photoplethysmography and noninvasive blood hemoglobin and variability index have been tested [3-6].

A near-infrared spectroscopy (NIRS) is a non-invasive device that detects tissue oxygen saturation (StO2) from the differences in oxygen consumption and oxygen delivery in tissue. In the event of a sympathetic blockade caused by an infra clavicular block, the increase in blood flow is reported to affect the tissue oxygen saturation caused by vasodilatation in the vessels [7]. Our aim in this study is to measure the efficacy and adequacy of peripheral nerve blocks by evaluating tissue oxygenation using NIRS in patients subjected to infraclavicular blockages at different angles.

Method

Population

The study was approved by Harran University Medical Faculty Ethics Committee (approval number: 2017.05.11). Included in the study were 34 patients between the ages of 18 and 65 who were included in the American Society of Anesthesiologists (ASA) I-II group and who were scheduled to undergo hand, forearm or arm surgery, after obtaining ethics committee and patient approval. Patients who did not want to be included in the study, patients with contraindications for infraclavicular block, those who were not cooperative, those with infections in the area scheduled for blockade, patients with existing peripheral vascular disease, patients with an allergic reaction to local anesthetic agents, those with renal insufficiency, those with hepatic insufficiency and patients in the ASA III-IV group were excluded from the study.

Procedures

Prior the procedure, a vascular access route was created using an 18-20 G cannula, and fluid replacement was initiated with a 0.9 percent isotonic ($NaCl^{-1}$) solution of 10 ml/kg volume. The patients were subjected to preoperative routine monitoring, and electrocardiography (ECG), peripheral oxygen saturation (SpO2) and noninvasive arterial pressure (NIAP) were monitored. The basal systolic arterial pressure (SAP) and heart rate (HR) were recorded. Basal StO2 was recorded by placing the NIRS probe into the palm of both the extremity of the patients for which the blockade would be applied, and the palm of the other extremity on which no blockade would be applied. Disinfection with polyvinyl-pyrrolidone iodine was performed in the area to be treated after the administration of 0.02 mg/kg of midazolam to the patient. The patient's head was rotated to the opposite side of the area to be treated, and the arm to which the infraclavicular block was to be applied was brought to a 0°, 45° or 90° abduction position. The linear probes of a USG (Esaote MyLab 30 Gold, Lineer Prob, 10-18 MHz, Florence, Italy) were placed in the area of the blockade and local anesthesia was applied using 3cc of 2% Lidocaine to the area of the axillary artery. A total of 22 mL of local anesthetics (50% mixture of 2% Lidocaine and 0.5% Bupivacaine) were administered with a 80 mm 22 G nerve stimulation needle (Pajunk®, Geisingen, Germany) forming a crescent shape surrounding the posterior and medial parts of the axillary artery.

Clinical Evaluation

The blockades of all patients were performed by the same anesthesiologist, and was applied with the shoulder brought to abduction (0°, 45°, 90°) under USG guidance while the elbow was in extension. During the blockade, the duration of the procedure, the number of times the needle was inserted during the procedure, the duration of the total sensory block, patient satisfaction and the presence of any concomitant disease were recorded. After the completion of the block procedure, the duration of block maintenance was accepted as 30 minutes, and the SpO2, heart rate, noninvasive arterial pressure (NIAP) and tissue oxygen saturation (StO2) of both arms were recorded every five minutes. Evaluations at 0, 15 and 30 min were made using a pinprick test (0: no sensory block, 1: feeling of touch, but no pain, 2: no feeling of touch and no pain), while the motor block level was evaluated using the Bromage scale (0: no block-total arm and forearm flexion, 1: partial block-total forearm and partial arm flexion, 2: almost complete block-inability to flex the arm and decreased ability to flex the forearm, 3: total block-inability to flex both the arm and forearm).

Statistical Analyses

The data was analyzed using the SPSS for Windows version 23.0 program. Mean and standard deviation were used for the descriptive statistical analysis of continuous variables, while categorical variables were expressed as numbers and percentages. The significance of the difference between the groups in terms of categorical varia-

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bles was evaluated with a Chi-Square test, and a Mann-WhitneyU-test was used for binary group comparisons. The significance of the difference between the repeated measurements was calculated using the Freidman test. Correlations between continuous variables were calculated with a Spearman Rho correlation analysis. A p value of <0.05 was considered statistically significant.

Results

Included in the study were 34 patients aged between 18 and 65 years who underwent elective hand surgery with an infraclavicular block at different angles. The demographic data of the patients is presented in Table I.
A non-statistical decrease in HR was noted after anesthesia (Fig. 1); SpO_2 values were found to be similar before and after anesthesia (P: 0.179); SBP decreased until the 10th minute and showed an increasing tendency after the 20th minute; and the change in time was found to be statistically significant (P:0.023). DBA decreased until the 10th minute, and showed an increasing tendency after the 20th minute; the change in time was found to be statistically significant (P:0.008)
Tissue oxygenation in the arm subjected to blockade increased significantly over time (p<0.001), while tissue oxygenation in the untreated arm did not change over time. (Fig. 1) Tissue oxygenation was similar in both arms

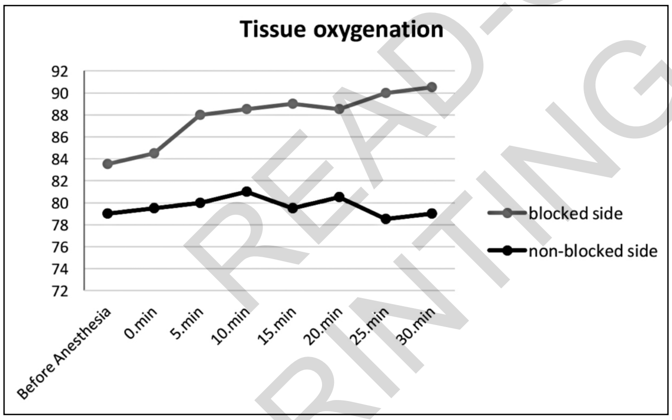

Fig. 1: Tissue oxygenation

Table I

Sex n(%)	
Male	18 (%52,9)
Female	16 (%47,1)
Age (year); median(min-max)	30,5 (18-65)
ASA score; n(%)	
ASA 1	19 (%55,9)
ASA 2	15 (%44,1)

Table II - *Tissue oxygenation*

	Blocked arm *median (min-max)*	Unblocked arm	p*
Before anesthesia	83,5 (56-93)	79 (67-92)	0,152
0.min	84,5 (67-94)	79,5 (62-93)	0,002
5. min	88 (70-98)	80 (63-95)	<0,001
10. min	88,5 (74-97)	81 (64-93)	<0,001
15. min	89 (72-97)	79,5 (61-93)	<0,001
20. min	88,5 (72-97)	80,5 (66-92)	<0,001
25. min	90 (74-97)	78,5 (68-98)	<0,001
30. min	90,5 (77-98)	79 (68-93)	<0,001
p**	<0,001	0,692	

*Wilcoxon signed rank test, **Friedmann test. Minute (min)

prior to anesthesia, and tissue oxygenation in the arms was higher in all subsequent measurements (Table II).
There was no statistically significant relationship between angle and tissue oxygenation. The duration of sensory block differed significantly only for values between 0 and 90 (p=0.046). The block application time was lower at the 90° angle (p <0.001), and acomparison between the subgroups demonstrated that the duration of the blockade was similar between 0 and 45 degrees, but shorter at a 90° angle than at the 0° and 45° angles (Tables III and IV).
Satisfaction levels decreased with the increased number of needle entries (p<0.001), and patient satisfaction increased as the angle increased (p=0.002) (Table V).
The number of needle entries was once in 80 percentof the patients, to whom block was applied at 90˚, and 27.3 percent of patients who underwent block at a 0° angle, and three-time needle entries were mostly observed at the 0° angle (Table VI).
A significant relationship was found between the pinprick test and angle at the 15th min. At the 0° and 45° angles, there was a feeling of touch but no pain in the 15th min during the Pinprick test, whereas at a 90° angle, 40 percent of the patients had no feeling of touch or pain at the 15th min.Total block was found to be achieved only at the 90° angle, according to the Bromage scale, and a significant relationship was identified between the angle and the Bromage scale (Table VII).

Discussion

NIRS is a device that detects tissue StO2 through microcirculatory perfusion, and is used in the noninvasive detection of differences in tissue StO2 resulting from changes in oxygen consumption or distribution within the tissue [7]. The NIRS signal reflects the availability of tissue microcirculation O2 through the absorption of light by hemoglobin (Hb), predominantly in small arte-

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TABLE III

	Angle			
0°	45°	90°	p	
	median (min-max)			
Block application time	12 (8-15)	10 (8-15)	6 (5-10)	<0,001
Total sensory block time	170 (160-185)	175 (160-190)	182,5 (160-190)	0,088

*Kruskall Wallis test

TABLE IV - *P values relative to angles.*

	0 & 45	0 & 90	45 & 90
Block application time	0,124	<0,001	0,001
Duration of the total sensory block	0,084	0,046	0,571

*Mann Whitney-U testi

TABLE V

	Patient satisfaction			
	Bad	Good	Very good	p
Needle entry number; n(%)				<0,001
	1	–	6 (%40)	9 (%60)
	2	2 (%16,7)	10 (%83,3)	–
	3	6 (%85,7)	1 (%14,3)	–
Angle; n(%)				**0,002**
	0^0	5 (%45,5)	5 (%45,5)	1 (%9,1)
	45^0	3 (%23,1)	9 (%69,2)	1 (%7,7)
	90^0	–	3 (%30)	7 (%70)

*Chi-square test

TABLE VI

Angle	Needle entry number			
	1	2	3	p
0°	3 (%27,3)	4 (%36,4)	4 (%36,4)	**0,010**
45°	4 (%30,8)	6 (%46,2)	3 (%23,1)	
90°	8 (%80)	2 (%20)	–	

*Chi-square test

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rioles at depths of approximately 2-6 cm in capillaries and venules. Near infrared light is not attenuated by skin, bone or other organs, but is rather absorbed by oxygenated and oxygen-free blood. NIRS devices calculate the optical density of each wavelength of the tissue based on the reflected light, and as a result, it can be applied to monitor various tissues, including brain, muscle and connective tissues [8].

NIRS is currently gaining widespread popularity as a non-invasive research tool for the measurement of oxygen status in tissue. It was first used in neurology and neurosurgery for the diagnosis of subdural and epidural hematomas, and later to measure cerebral oxygenation and blood flow in conditions requiring cardiopulmonary bypass surgery during cardiovascular operations [9-11].

This technology has become intriguing, and various studies have been conducted to evaluate whether or not it can accurately detect changes in oxygenation during ischemia and reperfusion in non-brain organs and tissues. Accordingly, based on its gradually increasing popularity, it has come to be used in the detection of changes in extremity perfusion in cases of arterial or venous damage in trauma patients, in free flap assessments due to its ability to fully perceive intraoperative and postoperative free flap perfusion, in predicting the development of multiorgan dysfunction syndrome in the classification of the severity of hemorrhagic shock, and in the detection of impaired tissue oxygen saturation in patients with regional pain syndrome type 1 [12-16].

Arterial vasodilatation from a sympathetic blockade after a peripheral nerve block results in increased blood flow

TABLE VII

	n (%)	Angle 0^0	45^0	90^0	p
Pinprick test (0.min)	0	11 (%100)	13 (%100)	10 (%100)	
Pinprick test (15.min)	1	11 (%100)	13 (%100)	6 (%60)	0,004
	2	–	–	4 (%40)	
Pinprick test (30.min)	1	6 (%54,5)	8 (%61,5)	2 (%20)	0,118
	2	5 (%45,5)	5 (%38,5)	8 (%80)	
Bromage scale (0.min)	0	11 (%100)	13 (%100)	10 (%100)	
Bromage scale (15.min)	1	11 (%100)	13 (%100)	3 (%30)	<0,001
	2	–	–	7 (%70)	
Bromage scale (30.min)	1	1 (%9,1)	1 (%7,7)	–	0,001
	2	10 (%90,9)	12 (%92,3)	4 (%40)	
	3	–	–	6 (%60)	

*Chi-square test

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velocity, which increases tissue oxygenation. As a result, several studies have been carried out to investigate block activity through the use of NIRS. Veldel et al. [17] examined the effects of NIRS on the lower extremities of 120 patients by performing a popliteal block. NIRS was measured at three different sites on the extremities subjected to blockade, and the StO2 measurement was found to be significantly higher on the plantar surface of the foot [17].

Tighe et al. [18] performed nine cervical paravertebral blockades, nine femoral nerve blockades, 10 infraclavicular nerve blockades and eight sciatic nerve blockades under USG guidance using NIRS measurements, and identified a higher baseline and increasing StO2 levels in the treated tissues.

Okano et al. [7] investigated the use of NIRS following astellate ganglion block, and concluded that the method successfully confirmed the increased blood flow from measurements performed after the stellate ganglion blockade.

Our aim in this study was to evaluate the success and effectiveness of infra clavicular blockades under USG guidance at different arm angles through the measurement of tissue oxygenation using NIRS. In previous studies conducted into infraclavicular blocksadministered at different angles, Lemus et al. [19] demonstrated in 58 patients that better visual acuity was achieved through USG when the arm subjected to an infraclavicular block at different angles was abducted, and reported further that fewer needle punctures were required and that the placement of a catheter in the region was easier. As a result of the examinations and measurements made in the infra-clavicular area by Ruiz et al. [20] on 26 patients using USG, it was found that the abduction of the arm decreased the depth of the axillary artery and the brachial plexus. In a study comparing two different infraclavicular techniques, it was reported that the vascular puncture reduced with the abduction of the arm at a 110° angle, the risk of pneumothorax was reduced and the brachial plexus became more proximal to the skin. In a study by Wang et al. [21], it was demonstrated that the brachial plexus became 1.67 cm more proximal to the skin when the arm was brought to 90^0 abduction, and that the pleura also moved 1.15 cm away from the skin. The present study is the first to show how different angles affect tissue oxygenation, as infraclavicular blocks performed at different angles under USG have not been measured previously by NIRS.

The main factor affecting blood flow in the tissue is vascular resistance, referring to the radius of the vessel. In order to increase blood flow, the pressure difference in the vessels may increase or the blood vessels may expand and decrease systemic vascular resistance [22]. SBP and DBP following anesthesia decreased until the 10th minute, and the change in time was found to be statistically significant.

In this study, tissue oxygenation was found to be similar in both arms prior to anesthesia, while tissue oxygenation was higher in the arms of subsequent measurements. Tissue oxygenation in the arm subjected to a blockade increased significantly over time (P: <0.001), while no change in tissue oxygenation was noted in the untreated arm over time. Vascular resistance in vascular structures directly affects blood flow, which is increased as a result of a sympathetic blockade due to the peripheral nerve block. It can be suggested that tissue oxygenation increased in the arm subjected to blockade with the increased blood flow.

In this study, the block application time was lower at the 90° angle (p <0.001), and a significant relationship was identified between the angle and the number of needle entries (p=0.010). The number of needle entries was once in 80 percent of patients, to whom block was applied at a 90° angle, and in 27.3 percent of patients, who underwent block at a 0° angle. On the other hand, three times more needle entries were observed mostly at the 0° angle, while none were observed at a 90° angle. Satisfaction levels decreased with increased number of needle entries (p<0.001), and patient satisfaction increased as the angle increased (p=0.002). In previous studies, it has been demonstrated that the distance between the brachial plexus and skin tissue decreased as the abduction angle of the arm subjected to blockade under USG increased, the visualization of the axillary artery and the brachial plexus became clearer, the number of needle punctures decreased, and needle penetration of the clavicle was facilitated. Consistent with literature, we demonstrated that as the abduction angle increased, the duration of blockade at 90°was lower, the number of needle penetrations was lower and patient satisfaction increased.

A pin-prick test revealed that at 0° and 45° angles, there was a feeling of touch and no pain at the 15th min, whereas at a 90° angle, 40 percent of the patients had no feeling of touch or pain at the 15th min. A total block was achieved only at a 90° angle, according to the Bromage scale. A significant relationship was identified between the angle and the Bromage scale in previous studies, and it has been reported that as the abduction angle of the arm increases, the visualization of the brachial plexus and the axillary artery became clearer with a USG-guided blockade, facilitating the administration of anesthetic agents and the insertion of a catheter around the posterior and medial cords. In our study, the significant relationship between the angle and the results of a pin-prick test and Bromage scale is suggested to have increased as the image became clearer, and the anesthetic agent was administered to the appropriate point during the blockade under USG.

Conclusion

It is demonstrated that tissue oxygenation increases with NIRS in the extremities subjected to blockade in patients who undergo USG-guided infraclavicular blocks at different angles, although different angles were not found to affect tissue oxygenation. With a 90° abduction, it was seen that the number of entries during the intervention was minimal, the duration of the procedure was shorter and patient satisfaction was higher. We suggest that NIRS measurements, which we consider to be an objective tool, may be better used in future studies with larger sample sizes in an evaluation of peripheral nerve blocks performed at different angles, rather than subjective tests such as the pin-prick test, cold application and bromage scale.

Riassunto

Il blocco anestetico dei nervi periferici acquista sempre maggiori preferenze, e con questo studio abbiamo voluto valutare l'ossigenazione dei tessuti in pazienti sottoposti a blocco infraclavicolare ad angoli diversi usando una spettroscopia nel vicino infrarosso (NIRS), come un dispositivo non invasivo che rileva la saturazione di ossigeno nei tessuti (St02).

Sono stati studiati 34 pazienti di età compresa tra 18 e 65 anni, classificati ASA I-II in programma per essere sottoposti ad un intervento chirurgico alla mano, all'avambraccio o al braccio. È stato adottato un blocco infraclavicolare con spalla abdotta a 0°, 45°, e 90° sotto guida US, con gomito in estensione. I valori di saturazione di ossigeno sono stati rilevati con apparecchio NIRS in entrambe le braccia ogni cinque minuti.

Statisticamente è stato assunto come valore significativo p <0,05.

L'ossigenazione tissutale nel braccio sottoposto a blocco è aumentata significativamente nel tempo (p <0,001), mentre l'ossigenazione del tessuto nel braccio non trattato non è cambiata nel tempo.

La durata del blocco sensoriale differiva significativamente solo per valori compresi tra 0 e 90 (p = 0,046). Il tempo di applicazione del blocco era imferiore con un angolo di 90° (p <0,001) e il livello di soddisfazione diminuiva all'aumentare del numero di agji impiegati (p <0,001). La soddisfazione del paziente risulta aumentare con l'aumentare dell'angolo (p = 0,002).

L'ossigenazione dei tessuti non sembra essere influenzata falla diversità dell'angolazione.

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