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The Effects of Axillary Nerve Block and Intravenous Regional Anesthesia on Ischemia-Reperfusion Injury Induced By Tourniquet

Aksiller Sinir Bloğu ve İntravenöz Rejyonal Anestezinin Turnike Sonucu Gelişen İskemi-Reperfüzyon Hasarına Etkileri

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ABSTRACT

Objective: *We aimed to compare the effects of axillary nerve block and IVRA (Intravenous Regional Anesthesia) techniques used in patients planned to undergo hand surgery on tourniquet induced ischemia- reperfusion injury. Ischemia due to the use of tourniquet and the subsequent reperfusion cause oxidative stress in the organism. Oxidative stress contributes to postoperative morbidity.*
Method: *The study included 65 patients who underwent hand surgery. The patients received axillary nerve block were assigned to Group A (n=33) and the patients received IVRA were assigned to Group I (n=32). Blood samples were collected at T1 before anesthesia, T2 immediately before tourniquet deflation, T3 5 min, T4 30 min and T5 4 hours after tourniquet deflation and serum TAS (total antioxidant level), TOS (total oxidant level), OSI (oxidant status index) and IMA (ischemia modified albümin) levels were studied.*
Results: *Plasma concentration of IMA and OSI were significantly higher in Group A than in Group I at T2, T3, T4 time points. Plasma TOS level was higher in Group A than in Group I at time point T3. Plasma TAS level was significantly higher in Group I than in Group A at time points of T2, T3, T4.*
Conclusion: *IVRA was more effective than axillary block in preventing ischemia- reperfusion injury induced by tourniquet used in hand surgery, but there was no difference between these two techniques in the fourth hour of reperfusion.*

Keywords: *Axillary nerve block, intravenous regional anesthesia, ischemia reperfusion, oxidative stress*

ÖZ

Amaç: *El cerrahisi planlanan hastalarda kullanılan aksiller sinir bloğu ve IVRA (İntravenöz Bölgesel Anestezi) tekniklerinin turnikenin oluşturduğu iskemi reperfüzyon hasarı üzerine etkilerini karşılaştırmayı amaçladık. Turnike kullanılması ve sonraki reperfüzyondan kaynaklanan iskemi, organizmada oksidatif strese neden olur. Oksidatif stres ise postoperatif morbiditeye katkıda bulunur.*
Yöntem: *Çalışmaya el cerrahisi uygulanan 65 hasta dahil edildi. Aksiller sinir bloğu alan hastalar Grup A (n=33), IVRA alan hastalar Grup I (n=32) olarak ifade edildi. Kan örnekleri anestezi öncesi T1'de, turnike deflasyonundan hemen önce T2, turnike deflasyonundan 5 dk sonra T3, 30 dak sonra T4 ve 4 saat sonra T5 alındı.*
Bulgular: *Plazma IMA ve OSI konsantrasyonları Grup A'da Grup I'den T2, T3, T4 zaman dilimlerinde anlamlı olarak yüksekti. Plazma TOS düzeyi Grup A'da Grup I'den T3 zaman diliminde daha yüksekti. Plazma TAS düzeyi Grup I'de Grup A'dan T2, T3, T4 zaman dilimlerinde anlamlı olarak yüksekti.*
Sonuç: *IVRA, el cerrahisinde kullanılan turnike tarafından oluşturulan iskemi reperfüzyon hasarını önlemede aksiller bloktan daha etkiliydi, ancak bu iki teknik arasında reperfüzyonun dördüncü saatinde bir fark yoktu.*

Anahtar kelimeler: *Aksiller sinir bloğu, intravenöz rejyonal anestezi, iskemi reperfüzyon, oksidatif stres*

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INTRODUCTION

Upper extremity surgery and especially hand surgery, which are increasingly gaining popularity in recent years, are an appropriate field for outpatient treatment to minimize exposure to hospital environment and reduce costs. Hand surgery can be performed under local, regional and general anesthesia. Each technique has its own advantages, as well as disadvantages. Anesthetic technique to be used should be determined depending on the patient's current condition.

The advantages such as preservation of consciousness and airway reflexes during operation and prolonged postoperative analgesia are the most common reasons for preferring regional anesthesia. Brachial plexus block for anesthesia or analgesia is a safe and commonly used technique in upper extremity surgery [1]. Intravenous Regional Anesthesia (IVRA) is widely used in extremity surgery, particularly in the upper extremity because of its reliability and ease of technique [2]. The effect of lidocaine, one of the local anesthetics that can be used in these two anesthesia techniques, provides advantages such as rapid and good tissue fixation, moderate duration of action, low toxicity and ability to provide short-term motor block [2].

Tourniquet has been used for a long time in extremity surgery [3,4]. High levels of plasma IMA due to tourniquet-induced ischemia, hypoxia and acidosis provide information on the extent of ischemia [5,6].

With reperfusion, the factor causing ischemia is eliminated and blood supply to the tissue is restored resulting in reperfusion injury which further damages the tissue [7]. One of the most important mechanisms of ischemia reperfusion injury is oxidative stress [8,9]. The total value of oxidative stress is expressed as Total Oxidative Stress (TOS). Antioxidant status is determined by total antioxidant status (TAS) by taking the total activity of all antioxidants present in plasma and body fluids into account [10,11]. The ratio of TOS level to TAS level is called Oxidative Stress Index (OSI). A high OSI value shows up in cases where oxidative stress increases [12].

Our study aims to compare the effects of different anesthesia techniques (axillary nerve block and IVRA) on ischemia reperfusion injury in patients planned to undergo hand surgery. In this study, we examined the effect of axillary block and IVRA, which are routinely used in anesthesia practice, on tourniquet-induced ischemia reperfusion injury by studying plasma oxidant (IMA, TOS, OSI) and antioxidant (TAS) levels. We thought that if there was a difference that might affect the antioxidant-oxidant balance and could reduce ischemia- reperfusion injury, use of this technique could be generalized in clinical practice.

MATERIALS AND METHODS

This study was a prospective randomized, computer-assisted double- blinded study done in a tertiary healthcare centre after obtaining institutional ethics committee approval was provided by the Medical Ethics Comittee of the Karadeniz Technical University, Trabzon, Turkey (2016-431). Between July 2016 and October 2018, we reviewed sixty-five ASA I-II patients aged 18-60 years who had undergone hand surgery. Patients with vascular, heart, metabolic, kidney and liver diseases, hemodynamic instability, metabolic and acid-base balance disorder, and with a history of steroid use, antioxidant use, allergy, alcohol-drug abuse and smoking, and patients who had cerebral stroke and myocardial infarction within the last three months, multiple trauma patients, those with connective tissue disease, acute infectious disease and patients whose anesthesia was converted from general anesthesia to regional anesthesia were not included in the study.

The patients were divided into two groups as those receiving axillary anesthesia (Group A, n=33) or IVRA (Group I, n=32). The patients received no premedication before the surgery. Heart rate (HR), noninvasive arterial blood pressure (BP), peripheral oxygen saturation (SpO_2) and end-tidal carbon dioxide pressure ($ET\ CO_2$) were observed in the operating room. A 20 G catheter was inserted into the radial artery of the arm that was not intervened and basal (T1) blood sample was taken just before the anesthesia procedure.

The patients in the axillary block group were positioned in the supine position with the arm to be

operated abducted to 90 degrees, the forearm flexed and externally rotated. The axillary region was sterilized with 10% povidone-iodine antiseptic solution and a 0.8x100 mm 21G cannula was connected to the nerve stimulator (Stimuplex ® HNS 11, B/Braun, Germany) with a sterile gauze compress by pushing physiological saline through it. The anode (+) pole of the peripheral nerve stimulator was attached to the electrocardiography electrode placed on the wrist on the block side, and the cathode (-) pole was connected to the conductive end of the needle. A total of 40 mL local anesthetic solution was prepared using two 20 mL syringes by diluting 3 mg kg^{-1} of 2% lidocaine (Aritmal 2% vial, Astrazeneca) in 0.9% NaCl. After passing through the cutaneous and subcutaneous tissue, the nerve stimulator was set to a stimulation frequency of 2 Hz and a current intensity of 1.0 mA. The needle was slowly advanced until one of the appropriate movements was seen in the muscles innervated by the examined nerves (musculocutaneous nerve; elbow flexion, radial nerve; elbow and wrist extension, median nerve; thumb and index finger opposition, ulnar nerve; thumb and little finger opposition). Next, the current of the nerve stimulator was gradually reduced and when the appropriate movements were maintained at a current intensity between 0.3-0.5 mA, the needle was kept still and aspirated by other assistant to decide that there was no vascular puncture. The prepared local anesthetic solution was injected very slowly with aspirations performed after every 5 mL of drug injection and taking the patient's pain into consideration. The procedure was completed with 2 injections, 10 mL for each nerve, by inspecting the movements of muscles innervated by radial, median, musculocutaneus and ulnar nerves one by one. After sensory and motor block were achieved, the tourniquet was applied at a pressure of 100 mmHg above the systolic pressure.

In patients who were going to receive intravenous regional anesthesia, an additional vascular access was established on the hand dorsum of the extremities to be operated using a 22G branula. A double-cuff tourniquet (VBY, Germany) was placed on the upper part of the arm. The patient's arm was elevated above the heart level for 3 minutes, and then tightly wrapped with an Esmarch's bandage from distal to proximal to completely drain the blood in the extremity. The proximal tourniquet was inflated 100 mmHg above the systolic pressure and 3 mg kg^{-1} of 2% lidocaine (Aritmal 2% vial, Astrazeneca) diluted with 0.9% NaCl, and 40 mL of local anesthetic solution was injected slowly using the IV vascular access.

The blood samples taken at T2 (immediately before tourniquet deflation), T3 (5 minutes after tourniquet deflation), T4 (30 minutes after tourniquet deflation) and T5 (4 hours after tourniquet deflation) were placed into anticoagulant tubes containing 3.8% sodium citrate. Plasma and serum were separated by centrifugation at 3000 rpm for 10 minutes. The serum and plasma samples were stored at -80°C until the biochemical analyses. After all blood samples were collected, their plasma IMA, TAS, TOS and OSI levels were measured.

The results of a reduced cobalt to albumin binding capacity (IMA level) assay were analysed using the rapid and colourmetric method described by Bar-Or et al [13]. The results were reported as absorbance units (ABSUS). TOS levels were determined using a method previously described by Erel [14] and calculated in µmol H_2O_2 equivalent L^{-1}. The TOS: TAS ratio was used as the OSI. To perform that calculation, the unit of TAS, mmol Trolox equivalent L^{-1}, was converted to µmol Trolox equivalent L^{-1} and the OSI was calculated using the formula OSI = [(TOS, µmol H_2O_2 equivalent L^{-1}) / (TAS, µmol Trolox equivalent L^{-1}) x 100]. The TOS: TAS ratio was used as OSI.

In all groups, pain levels caused by tourniquet throughout the operation and pain levels in the follow-up period after tourniquet was deflated were assessed using the 10 cm Visual Analog Scale (VAS) on a 10 cm linear scale representing 0-2 cm= no pain, 3-4 cm=mild pain, 5-6 cm=moderate pain, 7-8 cm=severe pain, 9-10 cm=unbearable pain (worst pain). The time when the first pain was felt during the follow-up period after tourniquet was deflated was determined as the first analgesic requirement time. During the operation, the distal tourniquet was first inflated at the 20th minute, then the proximal tourniquet was deflated routinely in all patients. The patients with tourniquet pain and the patients with postoperative VAS scores of >4 were given intravenous tramadol at a dose of 1 mg kg^{-1}. At the end of

the operation, sensory block recovery time after tourniquet was deflated, the amount of analgesic used in the first 4 hours of postoperative follow-ups and the first analgesic requirement time were recorded in all groups. Furthermore, hemodynamic changes and side effects such as nausea-vomiting, respiratory depression, and discharge times were recorded.

Statistical Analyses

Sample size calculations were performed in accordance with the previously published article [15] by using G*Power, version 3.1.9.2 (Heinrich Heine University, Düsseldorf, Germany). When the alpha error (0.05,) beta error (0.20) and the effect size (0.5) were determined as indicated, total number of 54 samples were required. However, after eliminating the possible data missing, the total sample size was increased (approximately 20%) and set as n=65 for groups (I+A). The normality of the continuous variables of IMA, TOS, TAS and OSI in the study was analyzed using the Shapiro-Wilk test. The descriptive statistics for normally distributed data were given as mean ± standard deviation (mean±sd), while the non-normally distributed variables were expressed as median (minimum-maximum). The categorical variables were summarized with frequency and (%) [n (%)].

The comparisons between the measurements in the IVRA and axillary anesthesia groups were tested using the independent-samples t-test or Mann Whitney U test depending on the fitness of the variables to normal distribution. The chi-square test was used to compare the anesthesia groups according to the severity of disease states, and the values were given with continuity correction. The F1-LD-F1 design, which is a non-parametric equivalent of two-way mixed ANOVA, was used to analyze the time-dependent changes in the anesthesia groups. The intragroup variations in the time-dependent measurements were analyzed using the Friedman test.

A p value of <0.05 was considered to indicate a significant difference in statistical decisions.

The IBM SPSS Statistics 21.0 (IBM Corp. Released 2012. IBM SPSS Statistics for Windows, Version 21.0. Armonk, NY: IBM Corp.) was used for the statistical analyses and calculations, and the package "nparLD" was used on RStudio v1.1.463 to analyze the time-dependent relative effects (for F1-LD-F1 analysis).

RESULTS

A total of 65 patients meeting the inclusion criteria were included in the study. Three patients in Group A were excluded because of a shorter tourniquet time less than 30 minutes, and two patients in Group I were excluded because of pain felt due to failed block. There was no difference between the groups in terms of age, gender, weight, operative time and tourniquet time. Time to first requirement of an analgesic and duration of sensory block was longer in Group A than in Group I, and the amount of analgesic consumption was higher in Group I than in Group A (p<0.001) (Table I). According to the ASA risk classification, there was no difference between the groups (Table I). Moreover, there was also no difference between the groups in terms of hemodynamic changes and side effects such as nausea-vomiting and respiratory depression.

Table I. Comparison of demographic status, block and analgesic characteristics between the two groups

Parameter	Group I (n=30)	Group A (n=30)	p
Age [year]	36.5 (19.0-61.0)	36.5 (18.0-67.0)	0.784[a]
Height [cm]	170.4±7.0	173.2±8.1	0.190[b]
Weight [kg]	75.4±9.1	76.4±8.4	0.680[b]
ASA [I/II]	22/8	24/6	0.760[c]
Tourniquet duration [min]	39.0 (30.0-65.0)	39.5 (30.0-70.0)	0.836[a]
Surgical duration [min]	44.5±6.4	43.5±7.2	0.668[b]
Duration of sensoryblock [min]	48.1±5.6	97.0±16.9	<0.001[b]
First analgesic request time [min]	11.5 (5.0-21.0)	37.5 (22.0-65.0)	<0.001[a]
Total analgesic consumption [mg]	50 (0.0-100.0)	0.0 (0.0-100.0)	<0.001[a]

Group I, IVRA; Group A, Axillary block. Descriptive statistics are given as frequency, median (min-max or mean±SD).
[a]Mann-WhitneyU-test, [b]Indepenent sample t test, [c]Chi-square test.

Table II. Within group comparison of Plasma levels of Ischemia Modified Albumin, Total Oxidant Status, Total Antioxidant Status, and Oxidant Status Indeks

	Group I (n=30)	Group A (n=30)
IMA [U ml^{-1}]		
T1	0.69 (0.52 - 0.92)	0.71 (0.26 - 1.00)
T2	0.78 (0.53 - 0.99)*	0.92 (0.54 - 1.09)*
T3	0.75 (0.64 - 1.68)*	1.19 (0.93 - 1.78)$^{*,\&}$
T4	0.80 (0.62 - 2.46)*	0.89 (0.37 - 1.26)$^{*,+}$
T5	0.73 (0.54 - 0.93)*	0.72 (0.31 - 0.92)$^{\&,+,\%}$
p	<0.001	<0.001
TOS [µmol]		
T1	6.74 (4.68 - 14.63)	8.61 (3.44 - 13.58)
T2	8.46 (4.89 - 15.42)*	10.56 (5.23 - 18.58)*
T3	12.20 (5.69 - 18.53)$^{*,\&,+}$	14.07 (8.12 - 21.07)$^{*,\&}$
T4	11.47 (5.06 - 16.81)$^{*,\&,+}$	11.58 (5.55 - 20.42)*
T5	9.54 (4.86 - 14.96)	8.78 (4.79 - 17.17)$^{\&,+,\%}$
p	<0.001	<0.001
TAS [mmol]		
T1	2.36 (1.40 - 2.94)	2.27 (1.74 - 3.12)
T2	2.02 (0.81 - 2.88)	1.28 (0.99 - 1.97)*
T3	1.62 (0.66 - 2.62)*	1.14 (0.56 - 1.88)$^{*,\&}$
T4	1.24 (0.56 - 1.46)$^{*,\&}$	1.07 (0.53 - 1.66)$^{*,\&}$
T5	1.16 (0.50 - 1.38)$^{*,\&,+}$	0.99 (0.56 - 1.66)$^{*,\&}$
p	<0.001	<0.001
OSI [µmol H_2O_2 mmol^{-1}]		
T1	2.97 (1.60 - 9.96)	3.63 (1.33 - 7.07)
T2	4.77 (1.84 - 19.08)	8.03 (3.67 - 17.91)*
T3	6.54 (2.64 - 26.97)*	11.03 (6.30 - 25.78)$^{*,\&}$
T4	9.32 (2.25 - 28.03)$^{*,\&}$	10.90 (5.02 - 22.71)$^{*,\&}$
T5	8.24 (3.43 - 29.33)$^{*,\&}$	8.73 (3.67 - 17.34)$^{*,+,\%}$
p	<0.001	<0.001

Different time points *: from the 1st point, $^{\&}$: from the 2nd point, $^{+}$: from the 3rd point, $^{\%}$: from the 4th point (p<0.05).

Group I, IVRA; Group A, Axillary block. Descriptive statistics are given as median (min-max)
T1: Before anesthesia T2: Immediately before tourniquet deflation T3: 5 min. after tourniquet deflation T4: 30 min. after tourniquet deflation T5: 4 hours after tourniquet deflation
IMA: Ischemia Modified Albumin, TOS: Total Oxidant Status, TAS: Total Antioxidant Status, OSI: Oxidant Status Indeks.

Table III. F1-LD-F1 design results of plasma levels of Ischemia Modified Albumin, Total Oxidant Status, Total Antioxidant Status, and Oxidant Status Index

	Group		Time		Group*Time Interaction	
	ATI	p	ATI	p	ATI	p
IMA [U ml^{-1}]	10.542	<0.001	43.939	<0.001	17.796	<0.001
TOS [µmol]	0.691	0.041	131.340	<0.001	8.296	<0.001
TAS [mmol]	12.725	<0.001	187.209	<0.001	13.884	<0.001
OSI [µmol H_2O_2 mmol^{-1}]	7.775	<0.001	498.367	<0.001	71.004	<0.001

ATI: ANOVA-type test statistics

The change in plasma IMA, TOS, TAS and OSI plasma levels over time was significantly different between two groups (p<0.001, Table III). When within-group differences were examined, the plasma IMA level was higher at other time points (T2, T3, T4, and T5) compared to pre-ischemic time point (T1) in both groups (p <0.001). The plasma IMA level in Group A was higher at time points T2, T3, T4 and lower at time point T5 compared to those in Group I, while there was no significant difference between the groups at time point T1 (Table II, Figure 1a, Figure 1b)

Plasma TOS level in both groups was higher at all time points compared to pre-ischemic time point (T1) (p<0.001). Plasma TOS level measured at 5 min after reperfusion (T3) was significantly higher in Group A than in Group I (Table II, Table III, Figure 2a, Figure 2b).

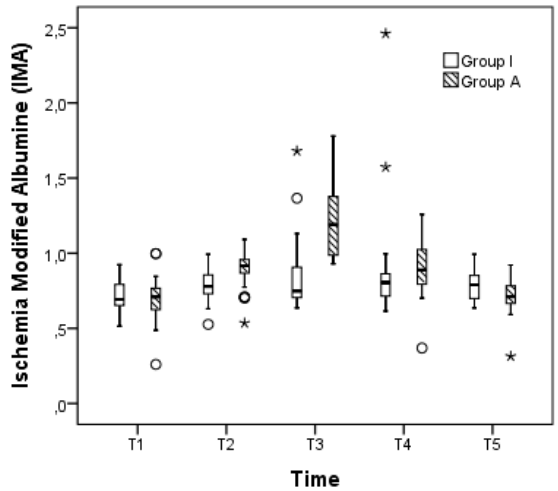

Figure 1a. Plasma levels of ischemia modified albumine versus time

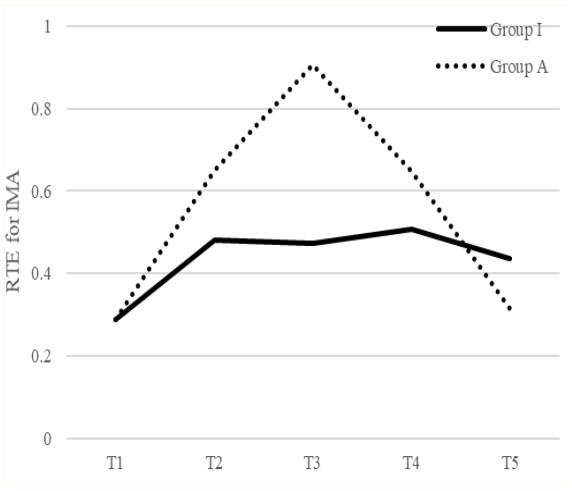

Figure 1b. Relative treatment effect for ischemia modified albumine

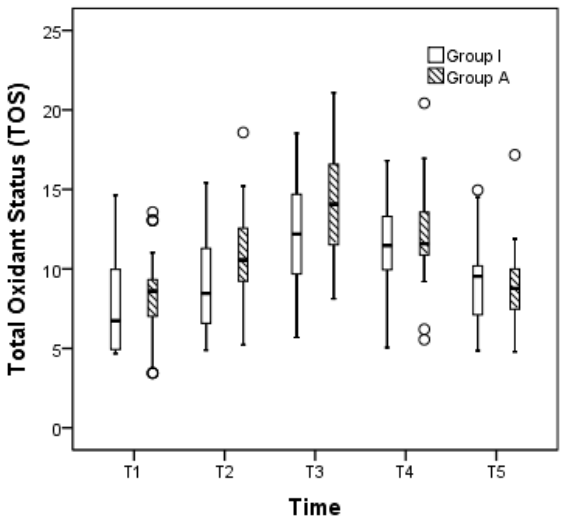

Figure 2a. Plasma levels of total oxidant status versus time

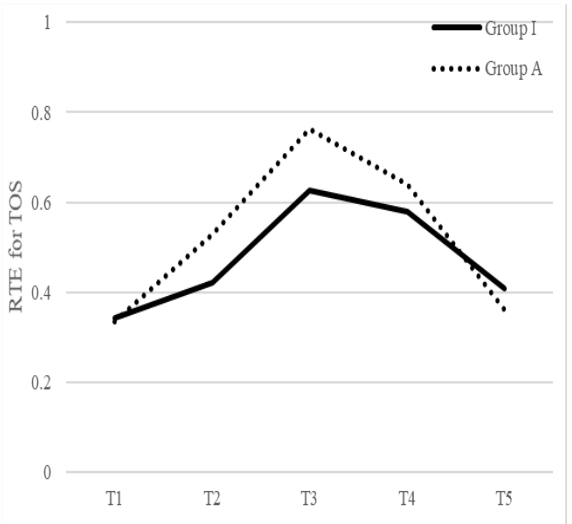

Figure 2b. Relative treatment effect for total oxidant status

TAS level gradually decreased in both groups compared to pre-ischemic time point (T1) ($p < 0.001$). Plasma TAS levels at immediately before tourniquet deflation (T2) and at 5 and 30 min of reperfusion (T3 and T4) were higher in Group I than in Group A (Table II, Table III, Figure 3a, Figure 3b)

In the time-dependent change in the values obtained from the OSI plasma measurements, it was observed that the values obtained at time points T2, T3 and T4 were significantly higher in Group A than in Group I (Table II, Table III, Figure 4a, Figure 4b).

DISCUSSION

In the present study, the effects of axillary nerve block and IVRA on ischemia-reperfusion injury induced by tourniquet were compared. Our study showed that IVRA reduced ischemia- reperfusion injury caused by the use of tourniquet in hand surgery at immediately before, and at 5 and 30 min after tourniquet deflation more than axillary block. We found that there was no significant difference between the groups in terms of preventing ischemia-reperfusion injury 4 hours after tourniquet deflation.

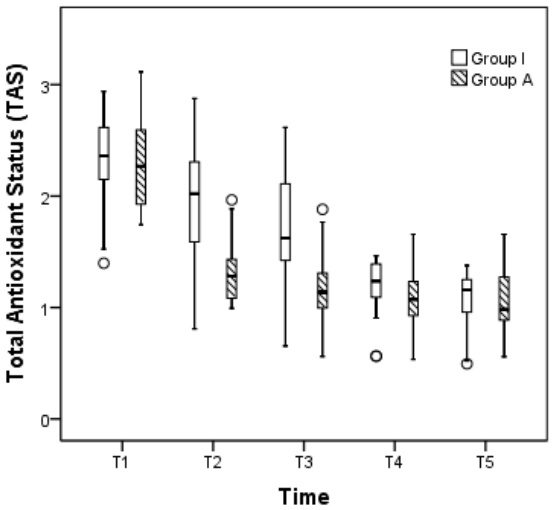

Figure 3a. Plasma levels of total antioxidant status versus time

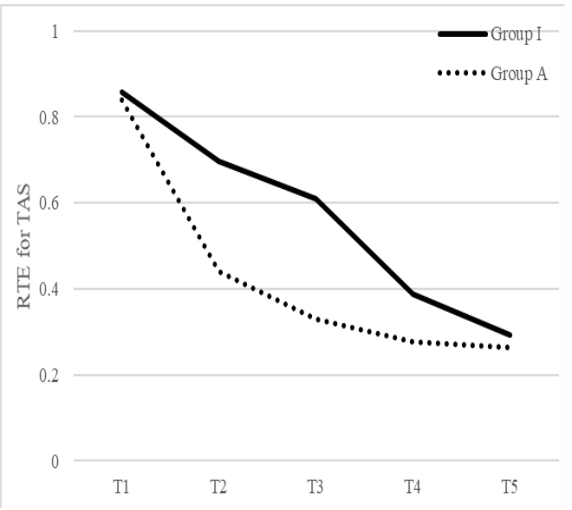

Figure 3b. Relative treatment effect for total antioxidant status

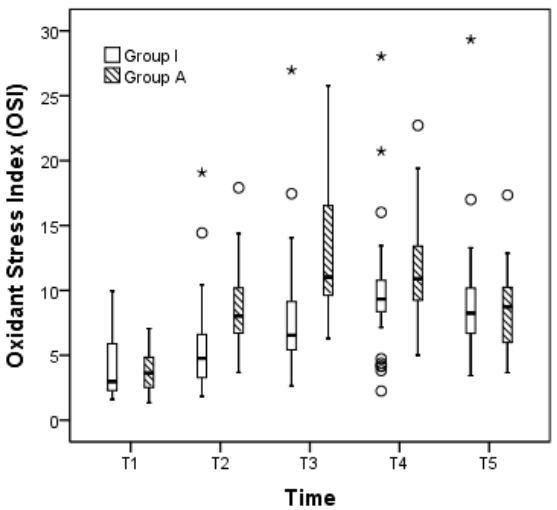

Figure 4a. Plasma levels of oxidative stress index versus time

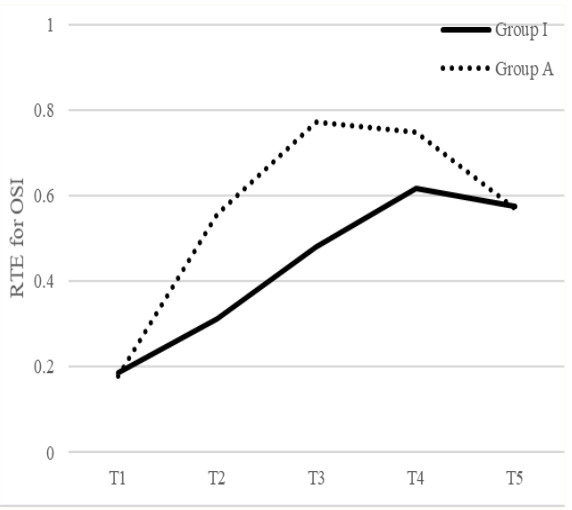

Figure 4b. Relative treatment effect for oxidative stress index

Numerous previous clinical studies investigated the effectiveness of anesthetic agents [15,16,17] and adjuvants [17,18] in preventing ischemia-reperfusion injury induced by tourniquet. However, there is a limited number of studies on the effectiveness of anesthesia techniques in preventing ischemia-reperfusion injury induced by tourniquet. Moreover, most of these studies were conducted in lower extremity surgery, unlike our study [15,16,19]. In our study, we compared the effects of two different regional anesthesia techniques on ischemia reperfusion injury induced by tourniquet.

Although there is controversy regarding the effective plasma level of lidocaine, it is a local anesthetic shown to reduce tourniquet-induced ischemia- reperfusion injury in both experimental and clinical studies [20, 21, 22]. We also preferred lidocaine considering that it could prevent ischemia- reperfusion injury induced by tourniquet.

Previous studies showed that high levels of IMA provided information about the severity of ischemia in the skeletal muscle due to use of tourniquet [16]. In our study, we also used plasma IMA value to evaluate tourniquet-induced ischemia. The IMA values

immediately before reperfusion (T2) and at the 5th and 30th minutes (T3-T4) of reperfusion were statistically significantly lower in Group I than in Group A. This result showed that lidocaine administered intravenously in Group I prevented ischemia better in the early period than lidocaine given perineurally in Group A. In addition, it was seen that a slower and less severe ischemia developed in Group I. We could explain this with the fact that lidocaine remained longer along the nerve trace and passed to the systemic circulation much later in Group A than in Group I.

Restoration of blood flow after tourniquet deflation increases the production of reactive oxygen radicals, resulting in ischemia -reperfusion injury [23]. The value of TOS, which is a marker of all these resulting oxidative stress values, gradually increased in both groups. TOS level at 5 min of reperfusion (T3) was higher in Group A than in Group I. Rapid increase in TOS level at 5 min of reperfusion (T3) in Group A compared to Group I showed that oxidative stress was higher in Group I. We are of the opinion that this difference was caused by the antioxidant effect of lidocaine by passing to systemic circulation in Group I much earlier than Group A. There was no statistically significant difference between the groups at later time points (T4, T5).

Many antioxidant enzymes function to inhibit the oxidation system. TAS allows all these antioxidant levels to be measured at once [24]. Activation of oxidant systems will result in an activation in TAS [13]. TAS had a decreasing tendency in both groups after tourniquet application. We interpreted the high value of TAS in Group I compared to Group A immediately before tourniquet release and at 5 and 30 min after tourniquet release in the manner of continuing antioxidant defense until the resulting injury in the tissues completely recovers.

We anticipated that the onset of stress response would be delayed thanks to longer sensory block created by axillary block compared to IVRA, and that the antioxidant parameters in the late period of reperfusion (T5) would be higher in Group A due to the prolonged vasodilatation created by axillary block and the antioxidant properties of lidocaine entering into the circulation in the long-term. In order to provide adequate analgesia, tramadol was administerd to the patients in Group I. Tramadol was reported to have antioxidant properties [25,26]. This may explain the insignificant difference between groups.

A high OSI value shows up in cases where oxidative stress increases [13]. In this study, OSI value was statistically significantly increased in all groups at all time points compared to the baseline value. Plasma OSI value immediately before, and at 5 min and 30 min after tourniquet release statistically significantly increased more in Group A than in Group I. This result showed that oxidative stress was higher in Group A.

There are studies reporting that antioxidant deficiency or excessive oxidative stress, and inadequate defensive mechanism result in tissue damage [27,28]. In our study, we have concluded that IVRA is more effective in maintaining the antioxidant defense compared to axillary block. In addition, we are of the opinion that oxidative stress resolves faster and terminates earlier in axillary block.

Our study showed that IVRA was more effective than axillary block in reducing upper extremity ischemia and reperfusion injury induced by tourniquet in the early period. In the late period of reperfusion, it was seen that the groups were not superior to each other in terms of ischemia- reperfusion injury. Moreover, it was found that the effective duration of analgesia was significantly longer in Group A than in Group I, and that tramadol consumption was higher in Group I than in Group A. None of our patients in Group A had tourniquet pain or required tourniquet change.

Limitations

Plasma levels of lidocaine were not measured, which limits our understanding of the effectiveness of both anesthetic techniques. Due to short duration of surgery and anesthesia, the results of this study cannot be extrapolated to the cases with prolonged operative times. Also, lack of ultrasound use during axillary block should be noted, since this may both increase the quality of the block and reduce any trauma to the skeletal muscles, which may affect the plasma levels of oxidant and antioxidant markers.

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