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Background: This study was conducted to compare low concentration-high volume intravenous regional anesthesia (IVRA) method with local anesthetic method in upper extremity surgery in terms of efficiency and adverse effects.

Material/Methods: Thirty-nine patients were divided into 2 groups; the first group received a 2% concentration of 12–15 mL lidocaine (Group 1) and the second group received a 0.5% concentration of 30–50 mL lidocaine (Group 2). Intraoperative hemodynamic data of patients (systolic blood pressure, diastolic blood pressure, mean blood pressure, heart rate, and peripheral oxygen saturation- SpO_2) was recorded before and after anesthesia at 1, 5, 10, 15, 20, and 40 minutes.

Results: The intergroup and intragroup comparisons did not reveal any significant differences in hemodynamic data. The onset time of sensorial block was shorter and the regression time of sensorial block was longer in Group 1 than Group 2. Group 1 had shorter onset time of motor block and longer regression time of motor block than Group 2. There were no significant differences between the study groups in terms of the time of tourniquet and postoperative analgesia time.

Conclusions: IVRA technique applied with 2% concentration and volume of 12–15 mL lidocaine may be suggested as a safe option.

Key words: intravenous • lidocaine • regional anesthesia

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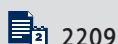
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Background

Intravenous regional anesthesia (IVRA) is a safe and effective anesthesia technique that is usually used for short-term lower and upper extremity surgery [1]. It is generally administrated as low concentration-high volume local anesthetic solution by intravenous route [2–4]. Recently, administration of high concentration-low volume local anesthetic solution has been suggested as an alternative [1].

To the best of our knowledge, there is no published study comparing the efficiency of these 2 methods. The aim of the present retrospective study was to compare the low concentration-high volume IVRA method with the local anesthetic method in upper extremity surgery in terms of efficiency and adverse effects.

Material and Methods

The present study consisted of IVRA administrations for hand, wrist, and forearm surgeries in the Hospital of Pamukkale University Medical Faculty between January 2011 and January 2012. The demographic variables, as well as type of anesthesia, surgery, and findings in the postoperative period were all recorded from the anesthesia and recovery records.

The protocol of IVRA

The 5 mL·kg^{-1} crystalloid fluid infusion was started after an 8-hour fasting period while being taken to the operating theatre with venous access to the non-surgical arm using a 20G cannula placed on the dorsal side of the hand in the upper surgical extremity. The arm was held above the level of head for 3 min. Exsanguination was completed by an Esmarch bandage from distal to proximal applied tightly. A pneumatic tourniquet is placed on the upper arm after application of binding cotton. The proximal cuff of a double-cuff tourniquet was inflated to pressure, as the systolic blood pressure of the same arm was 250 mmHg or 100 mmHg above the patient's blood pressure. The development of occlusion pressure was confirmed by the lost of radial pulse.

The exclusion criteria for IVRA were: history of allergy to lidocaine, presence of thrombophlebitis or atherosclerotic vascular diseases, Raynaud disease, arteriovenous fistulas, scleroderma, sickle cell anemia, wide burn on the surgical extremity, laceration and infection, myasthenia gravis, epilepsy or liver dysfunction, anticoagulant therapy for thromboembolic diseases, and digitalization due to decompensated heart failure. Pregnant women and patients not giving consent for the anesthesia technique were also excluded from the study. Patients were divided into 2 groups: the first group (Group 1) received

2% concentration of 12–15 mL lidocaine, and the second group (Group 2) received a 0.5% concentration of 30–50 mL lidocaine. The dose of lidocaine was adjusted to 4.5 mg·kg^{-1} or not to exceed 300 mg. Midazolam (1–3 mg) was administrated intraoperatively in case of need for additional sedation. When the Visual Analog Scale (VAS) was ≥4, fentanyl was applied.

Intraoperative hemodynamic data of patients (systolic blood pressure [SBP], diastolic blood pressure [DBP], mean blood pressure [MBP], heart rate [HR], and peripheral oxygen saturation [SpO$_2$]) were recorded before and after anesthesia at 1, 5, 10, 15, 20, and 40 minutes. Requirement for additional sedative, analgesic agents, and complications with the quality of anesthesia (perfect, best, good, and bad) were recorded. The onset time of sensorial block was determined and recorded when loss of pain sense was detected by pinprick test in the dermatomes of median, radial, and ulnar nerves every 30 seconds after the injection. The onset time of motor block was recorded when the patient became unable to move the fingers. The time of regression of sensory block was recorded when recovery of pain sense was determined by pinprick test after removing the tourniquet at the end of the operation. The time of regression of motor block was recorded when the patient could move the fingers. The time of tourniquet was the period between tourniquet application and reducing the cuff.

Analgesic for postoperative pain control was applied when VAS was ≥4. The period from releasing the tourniquet to administering the analgesic was recorded as the time of analgesic administration.

Statistical analysis

SPSS (Statistical Package for Social Sciences) 17.0 was used for statistical analysis. The normality of distribution was tested by the Kolmogorov-Smirnov Z test and the homogeneity of the variances was tested with the Levene and Welch test. The Mann-Whitney U test was used for the comparison of quantitative data, and for the comparison of parameters between groups and the Wilcoxon Sign test was used for the comparison of parameters within the same group between various time points. The chi-squared test was used for statistical analysis of qualitative data. The results are stated as mean ± standard deviation. Statistical significance was evaluated between p<0.05 and p<0.01 level in 95% confidence interval.

Results

A total of 39 patients aged between 55 and 65 years were included in the study. Demographic data for the groups are given in Table 1. There was no significant difference between the

Table 1. Demographical data (mean ±SD).

	Group 1 (n=21)	Group 2 (n=18)	p
Age (years)	61.1±13.8	59.9±15	0.652
Weight (kg)	66.6±13.9	64.9±17	0.551
Height (m)	1.6±0.1	1.59±0.1	0.552
Female/Male (n)	3/18	4/14	0.835
ASA I/II	17/4	13/5	0.782
Operation time (min)	40.5±21	38.4±16	0.559

study groups in terms of age, weight, height, sex, ASA status classification, and operation time (p>0.05) (Table 1).

The intergroup and intragroup comparisons did not reveal any significant differences in systolic, diastolic, and mean blood pressure, heart rate, and peripheral oxygen saturation data (p>0.05). All measurements were similar and within normal ranges (Table 2).

When the onset and regression time of sensorial block were compared between the study groups, the onset time of sensorial block was shorter, and the regression time of sensorial block was longer in Group 1 than Group 2 (p<0.01) (Table 3). When the study groups were compared in terms of the onset and regression time of motor block, Group 1 had shorter onset time of motor block (p<0.01) and longer regression time of motor block than Group 2 (p<0.01) (Table 3).

There were no significant differences between the study groups in terms of the time of tourniquet and postoperative analgesia time (p>0.05). All measurements were similar and within the recommended limits (Table 3). In both groups, the need for additional analgesic was 15 minutes after the tourniquet release (p>0.05).

When the groups were compared in terms of complications, tourniquet pain was similar in both groups. Insufficient block and need for opioid was noted in 2 patients in Group 2 (7.1% each), and additional local anesthesia was used in 1 patient (p<0.05). Sedation was used in 1 patient in Group 1 due to tourniquet pain; but in Group 2, it was used in 8 patients because of tourniquet pain and insufficient block (p<0.01). Local anesthetic toxicity did not develop in any patients (Table 4). Scale of anesthesia quality was higher in Group 1 than Group 2 (89% and 29%, respectively) (p<0.01).

Discussion

Adverse effects developing due to medicines in both anesthesia and medical applications except for anesthesia have caused dose and concentration reduction, and concordantly increased the application volume. Therefore, the possibility of toxicity depending on local anesthetic has made this application mode a general rule of IVRA. The applications in this direction have been categorized into 3 groups [1,3]:
a. Diluting local anesthetics with saline;
b. Reducing the dose and concentration of local anesthetic without adjuvant;
c. Reducing the dose of local anesthetic with an adjuvant.

The option "a" is a general, well-accepted application for both upper and lower extremities. In many studies [2–4], local anesthetics for IVRA have been used with this method and high volume medicine has been given to make sure that the venous volume of the upper extremity is complete. However, the findings in Group 1 suggest that this concern was not warranted. Numerous studies have attempted to reduce the high volume dose and concentration of local anesthetic, as in option "b". For this purpose, Chan et al. [5] monitored the regressions of sensorial and motor block with higher doses of ropivacaine. The option in "c" has been the most attractive field for research, which aims to reduce the dose of local anesthetic by adding an adjuvant medicine and increasing the quality of IVRA. Although adding adjuvant has been thought to increase the quality of IVRA in general, there have been studies reporting conflicting data despite usage of the same medicine [6,7].

We compared the high concentration-low volume of lidocaine with the common application as low concentration-high volume; therefore, the features of not using adjuvant were evaluated. The present data suggest that using an adjuvant medicine in the local anesthetic in high concentration is not compulsory and it can be securely applied without increasing the complications.

The important concern in applying high-concentration lidocaine is the risk of systemic toxicity. However, the dose applied in our study was below the recommended dose in the USA, which is 3 mg·kg⁻¹ for lidocaine [5,8]. Moreover, the generally accepted maximum dose of lidocaine is 4.5 mg·kg⁻¹ [9].

Table 2. Comparison of hemodynamic variables in the study groups (mean ±SD).

		Group 1 (n=21)	Group 2 (n=18)	p
SBP (mmHg)	0 min	144.9±21.7	149.1±22.2	0.517
	1 min	143.7±18.8	147.3±21.9	0.633
	5 min	142.4±18.8	148.2±20.6	0.336
	10 min	140.1±19.3	142.7±21.5	0.657
	15 min	139.6±19.5	142.8±20.1	0.268
	20 min	138.7±16.9	141.3±19.3	0.317
	40 min	140.2±17.3	143.8±22.5	0.396
DBP (mmHg)	0 min	85.9±14.0	84.7±17.4	0.548
	1 min	85.7±12.6	84.9±15.5	0.701
	5 min	83.5±11.9	84.4±15.4	0.963
	10 min	83.3±11.3	81.7±13.3	0.525
	15 min	79.6±10.6	81.8±12.1	0.486
	20 min	80.1±11.5	80.4±14.7	0.999
	40 min	81.3±12.5	86.6±15.9	0.285
MBP (mmHg)	0 min	110.2±15.2	109.8±18.5	0.699
	1 min	108.7±13.1	109.9±19.1	0.889
	5 min	105.9±12.7	109.1±15.8	0.594
	10 min	104.8±13.3	103.8±15.7	0.563
	15 min	102.7±11.3	102.8±15.2	0.772
	20 min	103.3±12.9	101.4±15.9	0.595
	40 min	102.3±14.9	99.3±20.0	0.601
HR (beat/min)	0.min	81.5±15.2	81.4±16.1	0.866
	1 min	81.6±14.9	79.4±15.3	0.665
	5 min	81.8±12.7	80.7±15.6	0.445
	10 min	77.8±12.5	77.4±13.2	0.868
	15 min	76.9±13.2	76.2±12.3	0.863
	20 min	75.2±11.2	75.0±11.4	0.988
	40 min	75.5±11.0	77.0±14.1	0.854
SpO_2 (%)	0 min	96.3±1.8	96.5±1.9	0.537
	1 min	97.0±1.8	96.4±1.9	0.281
	5 min	96.7±2.2	96.2±2.0	0.225
	10 min	97.0±1.8	96.2±1.8	0.174
	15 min	97.2±1.8	96.2±1.9	0.127
	20 min	97.2±1.6	96.2±1.9	0.114
	40 min	97.1±1.8	96.7±2.1	0.560

SBP – systolic blood pressure; DBP – diastolic blood pressure; MBP – mean blood pressure; HR – heart rate; SpO_2 – saturation of oxygen.

Niekerk et al. [10] applied 0.5–1% concentration lidocaine and 0.5% mepivacaine to groups in their research; convulsion was noted in 8 patients. The dose of lidocaine administered to the patients, who developed convulsion ranged between 300 and

Table 3. Comparison of complications in the study groups (mean ±SD).

	Group 1 (n=21)	Group 2 (n=18)	p
Sensory block onset time (min)	4.24±1.3	6.82±1.5	**0.000**
Motor block onset time (min)	9.12±1.9	13.87±2.2	**0.000**
Sensory block regression time (min)	10.98±1.9	8.85±1.6	**0.000**
Motor block regression time (min)	5.92±1.6	4.41±1.4	**0.000**
Tourniquet time (min)	41.9±9.8	45.2±16.2	0.573
Postoperative analgesia time (min)	14.19±3.1	14.57±3.3	0.656

Table 4. Comparison of complications in the study groups.

	Group 1 (n=21)		Group 2 (n=18)		p
	n	%	n	%	
Tourniquet pain	1	4.7	1	5.5	>0.05
Insufficient block	0	0.0	2	11.1	**<0.05**
Additional opioid (50 μg Fentanyl)	0	0.0	2	11.1	**<0.05**
Additional local anesthesia	0	0.0	1	5.5	**<0.05**
Sedation	1	4.7	5	27.7	**<0.05**
Local anesthetic toxicity	0	0.0	0	0.0	

500 mg. The dose of lidocaine administered according to the weight of the patient was between 5.8 and 7.5 mg·kg^{-1}. Toxic reactions were seen with doses higher than that recommended for both total dose and the dose per weight.

The recommended plasma concentration of lidocaine for analgesia is 1–5 μ·mL^{-1} [11]. In a study by Maze et al. [12], the plasma level of lidocaine was comparatively measured following different regional anesthesia applications (IVRA, axillary block, and caudal and lumbar epidural anesthesia) [12]. The dose of lidocaine was 3 mg·kg^{-1}, 6–6.8 mg·kg^{-1}, 4.7–6.5 mg·kg^{-1}, and 5.8–7.5 mg·kg^{-1} in intravenous regional anesthesia, axillary block, lumbar epidural anesthesia, and in caudal anesthesia, respectively. It was reported that plasma lidocaine concentration in IVRA (1.5±0.2 μ·mL^{-1}) was lower than axillary block (2.5±0.5 μ·mL^{-1}) and lumbar epidural anesthesia (3.1±0.7 μ·mL^{-1}). Although it was administered in a high dose of 3 mg·kg^{-1}, it was shown that lidocaine plasma concentration was close to the lower limit (1–5 μ·mL^{-1}) that provided analgesia [11,12].

The maximum dose of lidocaine was 300 mg or 4.5 mg·kg^{-1} in our study, and these are all within the limits recommended in the USA. Failure to detect systemic toxic symptoms with 2% lidocaine suggests that the dose and the concentration are clinically safe. However, further studies are warranted to determine how different concentrations of lidocaine affect the plasma level.

Reduction of the volume of local anesthetic in the literature was done for IVRA in the forearm rather than in the arm [13]. In that study, 1.5 mg·kg^{-1} prilocaine was applied in 10 mL volume. The concern to reduce the total volume in IVRA application for the arm is not new. A series of features were suggested for IVRA in 1966 [14]. Colbern [14] has recommended application of local anesthetic volumes between 6–40 mL on IVRA. Application of 6 mg could possibly provide poor analgesia because of extravasation. However, that was the only study using application of 6 mL and, therefore, the finding is yet to be confirmed.

The second small-volume application is 15 mL. This application has provided an overall successful IVRA and no complications have been reported. In addition to this application, 18 mL has been applied to 1 patient and 20 mL has been administered to 3 patients; these have been successful without causing any complications. Colbern [14] has used 0.5% of lidocaine for all patients as local anesthetic volumes in this application. The successful result achieved with 0.5% concentration and low volume is of historical importance and has led to the current application.

Plourde et al. [15] stated that vein volume was important as an angiographic, the weight of the patient correlated with vein volume, and that the vein volume could be calculated with (0.281 x weight) + 3.3 mL formula. According to this formula,

the volume of 22.97 mL local anesthetic should be administered to patients over 70 kg body weight.

It is well known that vascular elasticity decreases with increasing age. The amount of venous pressure that occurs during the injection of local anesthetic is dependent on the volume of the anesthetic agent [16,17]. Therefore, high-concentration low-volume anesthesia may be helpful to avoid exceeding tourniquet pressure, particularly in elder patients whose vascular elasticity is decreased.

Magora et al. [18] compared the 0.25% and 0.5% concentrations with bupivacaine on the application of high concentration local anesthetic. The authors suggested that increasing the concentration increases analgesia duration after deflation of the tourniquet cuff. The findings of Marsch et al. [19] further supported these findings.

In our study, although the onsets of anesthesia (sensorial and motor block) were shorter, the regression of blocks were longer, and the quality of anesthesia was better in the group where 2% lidocaine was administered, there was no significant difference between the study groups in terms of tourniquet time and of postoperative analgesia time. The main determinant was the application of nearly the same dose in both groups, which might explain the similar ratios of complications observed in the present study groups.

Conclusions

IVRA technique applied with 2% concentration and the volume of 12–15 mL lidocaine may be suggested as a safe option due to the fast onset time of sensorial and motor block, long block duration, and less need for additional analgesic and sedation, particularly in elderly patients.

Statement

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