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Effects of hydrodissection on anesthesia characteristics in ultrasound guided infraclavicular brachial plexus blockade

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Abstract

Background: The development of ultrasonography technology and its widespread application have increased peripheral nerve block applications, especially in limb surgeries, since it reduces complication rates and increases success rates in peripheral nerve block applications. However, even experienced physicians need to direct a large number of needles and injections for adequate local anesthetic spread, which can cause accidental vascular puncture and local anesthetic systemic toxicity. Such complications can be prevented by hydrodissection and a safer and successful anesthesia can be provided to patients in this study, it was aimed to investigate the effects of hydrodissection on anesthesia characteristics in the infraclavicular brachial plexus blockade.

Materials and methods: Ninety patients were included in our study after approval by the Ethics Committee. These patients were randomly divided into 2 groups (Group I: Infraclavicular brachial plexus blockade with normal method and Group II: infraclavicular brachial plexus blockade with hydrodissection). After obtaining patient consent, monitoring and vascular access were provided. Group I patients were mixed with 30 mL of local anesthetic mixture (15 mL of distilled water and 15 mL of 0.5% bupivacaine), and Group II patients were treated with 15 mL of distilled water by hydrodissection and 15 mL of 0.5% bupivacaine anesthesia resident. Block characteristics were evaluated and recorded every 5 minutes for the first 30 minutes by a blinded observer. The sensory block score was 7, the total score was 14 or above, and the block was considered successful, and the patient was ready for surgery. Postoperative block removal times, analgesia, and complications were evaluated and recorded.

Results: A significant difference was found between the sensory and motor block onset times and postoperative VAS scores between the normal and hydrodissection groups ($P < .05$). There were no significant differences in terms of block application times, postoperative block removal times, and complications between the groups.

Conclusion: In this study, it has been shown that hydrodissection in peripheral nerve blocks does not lag in terms of block success and characteristics compared to normal methods, whereas anesthetists with less experience in peripheral nerve block experience obtain safer and more successful results in practice.

Abbreviations: ASA = American society of anesthesiologists, BMI = body mass index, ICB = infraclavicular brachial plexus blockade, LA = local anesthetics, LAST = local anesthetic systemic toxicity, PI = perfusion index, PNB = peripheral nerve block, USG = ultrasonography, VAS = visual analog scale.

Keywords: hydrodissection, infraclavicular block, peripheral nerve block, regional anesthesia, ultrasonography

Design: Prospective, Randomized

All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Declaration of Helsinki (as revised in 2013) and its later amendments or comparable ethical standards.

The authors have no conflicts of interests to disclose.

The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

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1. Introduction

Anesthesia for the surgery of the elbow, forearm, wrist, hand, and fingers can be readily achieved by in jecting local anesthetics (LA) around the brachial plexus.[1] This regional anesthesia technique obviates the need for general anesthesia and helps avoid associated risks (airway injuries, postoperative nausea and vomiting, or postoperative numbness). Control of postoperative pain is also excellent with this technique because sensory block typically persists for several hours after the injection.[2] Advances in ultrasonography (USG) technology and its widespread use in practice have increased the use of peripheral nerve block (PNB) administration, especially because ultrasound-guided techniques reduce complication rates and improve success rates in extremity surgeries.[3] However, to achieve adequate dissemination of LA, even experienced physicians need to manipulate the needle several times and perform multiple injections, with potential consequences of unintentional vascular punctures and local anesthetic systemic toxicity (LAST).[4] In order to prevent such complications, it is necessary to confirm the needle location before giving LA. Hydrodissection is performed by giving liquids such as distilled water or saline before LA to see the place where the given liquid reaches in the ultrasound image. Thus, the location of the needle tip is confirmed. However, since hydrodissection dilutes LA, it may reduce the effectiveness of the block.[5]

This study aimed to investigate the postoperative effects of hydrodissection on infraclavicular brachial plexus blockade (ICB) in patients who underwent elbow, forearm, wrist, hand, and finger surgery. The primary objectives were to evaluate the time to wear off and the effectiveness of postoperative analgesia after ICB with hydrodissection. The secondary objectives were to evaluate the following parameters: the characteristics of the motor and sensory blockade (sensory and motor block onset and regression times), block success rates, the length of time to administer the nerve block, perfusion index, side effects, and complication rates.

2. Materials and methods

The University of Health Sciences Ankara Numune Health Practice and Research Center Ethics Committee approval number E-19-2676, dated 18.04.2019, was obtained for this study. A total of 90 patients, who presented to University of Health Sciences, Ankara Numune Health Practice and Research Center in the period between 19.04.2019 and 27.05.2019 to undergo scheduled surgery for the elbow, forearm, hand, wrist, and fingers, were included. Written and oral informed consent was obtained from all patients who agreed to participate in the study.

The inclusion criteria were to be scheduled to undergo ICB for surgery of the elbow, forearm, wrist, hand, or finger; to be in the age range of 18 to 65 years, have a body mass index (BMI) value in the range of 17 to 31 kg/m^2, be able to consent voluntarily, and be assigned to American Society of Anesthesiologists (ASA) physical status classification levels of 1 to 3. Patients were included in the study regardless of their gender. The exclusion criteria were as follows: a condition creating a contraindication for ICB (local infection, sepsis, allergy to LA; severe neurological, muscular, or psychiatric disease, coagulation disorders),[6] not to sign the informed consent form, or not to comply with the conditions specified therein. Patients who met the inclusion criteria were randomized to Group I (conventional ICB) or Group II (ICB with hydrodissection) by using the randomization software on the link www.random.org.[7] After admitting patients to the premedication room, demographic data such as age, sex, height, weight, BMI, ASA status, and the surgical procedure to be performed were recorded immediately by an observer blinded to the study procedures. In accordance with the standard monitoring procedures described by ASA, the patients were monitored for oxygen saturation with pulse oximetry, heart rate with a three-lead electrocardiogram, and arterial blood pressure with noninvasive methods. Perfusion index (PI) was measured by a pulse oximetry sensor (M-LNCS Adult Adhesive Sensors, Masimo SET Radical pulse oximeters; Masimo Corp, Irvine, CA ABD) attached to the second finger of the upper extremity on the side, where the procedure would be performed. The sensor was connected to a Rad-87 Pulse CO-Oximeter device. During the procedure, oxygen was administered at 2lt/min through a nasal oxygen cannula. An intravenous line was established by placing an 18 or 20 gauge intravenous catheter on the upper extremity on the opposite side of the surgical site.

ICB was performed on all patients by a resident in the third year of the anesthesiology specialization program. Nerve block needles of 10 cm (21G, Echoplex, Vygon, Ecouen, France), a portable USG device (Logiq E, General Electric, USA), and 6- to 13-MHz linear USG probes were used for all procedures. Following skin asepsis with povidone-iodine and sterile dressing, 2 mL of 2% lidocaine was routinely injected for LA infiltration to the injection site during the nerve block procedure. In the supine position, the head of the patient was turned to the opposite side of the extremity, on which the block was performed, with the forearm placed on the patient's torso at a 90-degree angle to the elbow. Adjacent to the coracoid process, the USG probe was placed in the infraclavicular fossa. In this way, a USG image section was obtained, with the subclavian artery on the short axis in the midline. Using the in-plane technique, the tip of the 21 gauge, 10 cm block needle was advanced until its tip reached the dorsal end of the artery. After confirming the placement of the needle tip in the image section, a 30 mL volume of LA mixture (15 mL 0.5% bupivacaine + 15 mL distilled water) was administered to Group I. Hydrodissection was performed by administering 15 mL of distilled water to the patients in Group II. Thus, a crescent-shaped hypoechoic area was formed in the area under the subclavian artery, as observed in the USG image. Then, 15 mL of 0.5% bupivacaine was administered to this area.

The block characteristics, including the length of time to administer the block, and sensory and motor block onset and regression times; PI, the need for additional anesthetic methods, patient and surgeon satisfaction, postoperative analgesia, and occurrence of complications were recorded for the purposes of this study. An observer, who was blinded to the administered technique, examined and recorded the block characteristics and PI every 5 minutes during the first 30 minutes after the block. After the block procedure, sensory blocks in the musculocutaneous, median, radial, and ulnar nerves were rated using the cold stimulation test on a three-point scale as follows: 0 = no block, 1 = analgesia (patient can feel touch, not cold), and 2 = anesthesia (patient does not feel anything).[8] The lateral aspect of the forearm, volar aspect of the thumb, dorsum of the hand, and volar aspect of the fifth finger were examined to evaluate the sensory blockade in the musculocutaneous, median, radial, and ulnar nerves, respectively. Motor blockade was rated on a three-point scale as follows: 0 = no block, 1 = paresis, and 2 = plegia.[8]

Motor blockade in the musculocutaneous, radial, median, and ulnar nerves were evaluated with elbow flexion, thumb abduction, thumb opposition, and thumb adduction. The highest overall sensorimotor score was 16. A sensory block score of 7 and an overall total score of 14, or scores higher than those, were considered procedural success, indicating that the patient was ready for surgery. Patients with sensory block scores of less than 7, total scores less than 14 at the end of 30 minutes, or who needed additional anesthetic methods, were not included in the study. The following parameters included the operative time, the length of time to administer the block, sensory and motor block onset and regression times, the occurrence of complications, and additional need for anesthesia.[9]

Postoperative analgesia was assessed using a numerical pain rating scale and the visual analog scale (VAS).[10] Patients who were discharged to home after day surgery were given a telephone call from the numbers they provided for further communication. The severity of pain was evaluated at the end of 24 hours as follows: 0 = no pain at all and 10 = the worst pain ever experienced. If the severity of pain was ≥4, the patient was instructed to take the analgesic prescribed by the surgeon. The onset of block administration was defined as the time point when the block needle touched the skin. The end of the block procedure was accepted as the time point at which the needle was removed after LA injection. Sensory and motor block onset times were recorded at the time points when the block scores were 7 or more according to the three-point scale described above. Patients were asked to record the time when they first started to feel the hand or arm and when they were able to move their hands or arms for the first time after discharge to home. The sensory block regression time was recorded as the time point when the patient felt the hand or arm for the first time. The motor block regression time was recorded as the time point at which the patient moved the hand or arm for the first time. The patients were contacted on the postoperative 7th day to evaluate any complications.

2.1. Statistical analysis

Data analysis was performed using IBM SPSS 25.0 statistical package programs. Descriptive statistical methods (frequency, percentage, mean, standard deviation, median, and min-max) were used to summarize the data. Qualitative data were compared using the Chi-Squared (χ^2) test. The conformity of the data to the normal distribution was evaluated using Kolmogorov-Smirnov and Shapiro–Wilk tests. The independent samples *t*-test and the paired samples *t*-test were used to compare normally distributed quantitative data between groups and to perform intra-group comparisons, respectively. Values with probability (P) values of less than α 0.05, were accepted as significant, indicating a difference between the groups, whereas values with higher probability values were considered insignificant, indicating that there were no differences between the groups.

3. Results

Ninety patients who met the inclusion criteria for elbow, forearm, wrist, hand, and finger surgery were included in the study. Patients in Group I underwent ICB, which was performed conventionally. Patients in Group II underwent ICB after hydrodissection. A total of 45 patients were included in each group. Three patients from Group I and 2 patients from Group II were excluded from the study due to block failures and the need for additional anesthetic methods (Fig. 1).

Power analysis of the study was performed using the G*Power 3.1.9.4 statistical package software. The following results were calculated: $n_1 = 42$, $n_2 = 43$, $\alpha = 0.05$, effect size d = 0.8, and power (power [1-β]) = 0.95.

There were no statistically significant differences in the distribution of sex, age, BMI, and ASA class between the groups ($P > .05$) (Table 1).

Comparisons between groups revealed no statistically significant differences in operative times and times needed to administer the blocks between the groups ($P > .05$) (Table 2).

Comparisons of the time of the onset of motor and sensorial blocks revealed statistically significant differences between the groups ($P < .05$). Patients in the hydrodissection group had higher block scores at the time of the onset of both blocks (Table 3).

The PI values were not significantly different between the groups ($P = .594$). Intragroup comparisons showed that there was a statistically significant difference ($P < .01$) between the PI values measured in minutes 0 and 30 both in the conventional group and the dissection group, with the 30th minute PI values being higher in both groups (Fig. 2).

There were no statistically significant differences in the sensory and motor block regression times between the groups ($P > .05$) (Table 4).

There was a statistically significant difference in VAS scores between the groups ($P = .018$), with higher pain scores in the conventionally treated group (Fig. 3).

There were no statistically significant differences in the frequency of complications between the groups ($P > .05$) (Table 5). Seven days later, no complications in direct association with the nerve block (nerve damage, paresthesia, etc.) were reported by any patient in any of the groups.

4. Discussion

The use of USG in PNB has increased considerably in recent years, replacing other techniques with parallel improvements in success rates.[11] The real-time visualization of nerves, vessels, needles, and other tissues, along with the observation of the spread of LA, has been reported as an advantage of USG use.[2]

It is reported in the literature that regional anesthesia with the use of USG provides faster and longer block times and better block quality compared to other methods.[12] In addition, the use of USG can further reduce the risk of accidental intravascular LA injections by providing information that cannot be obtained using neurostimulation alone. Furthermore, the use of USG provides a real-time view of the LA spread, allowing the user to detect the potential for dose accumulation, which may result from the repeated injections of doses with a risk of reaching toxic levels.[13]

In their study, Sites et al described several technical errors during ultrasound-guided block procedures, including the lack of ability to precisely trace the needle on its route to target structures, the inability to evaluate the structures using color-flow analysis, and the misidentification of relevant structures.[14] Therefore, each patient's unique anatomy should be thoroughly evaluated before the block is performed, and the spread of LA should always be monitored during the procedure. If a problem is detected during the injection, the needle should be repositioned before the injection of LA.[15]

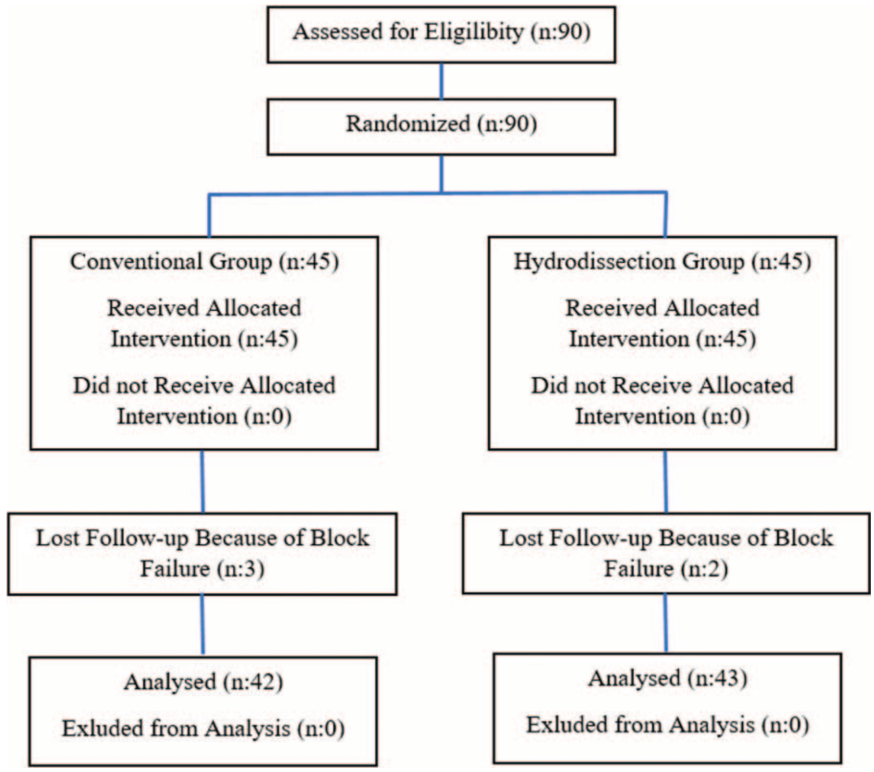

Figure 1. Flowchart of patients.

Table 1

Comparison of patient characteristics between groups.

	Conventional (n=42)	Hydrodissection (n=43)	*P*
Gender			
Men	34 (81.0%)	30 (69.8%)	.345*
Women	8 (19.0%)	13 (30.2%)	
Age (years)	39.4±16.3	38.4±13.6	.746**
BMI (kg/m^2)	25.2±3.9	26.1±3.4	.249**
ASA			
I	15 (35.7%)	17 (39.5%)	.935*
II	25 (59.5%)	24 (55.8%)	
III	2 (4.8%)	2 (4.7%)	

ASA = American society of anesthesiologists, BMI = body mass index.
* Chi-Squared Test.
** Independent Samples *t*-Test.

Table 2

Comparison of operative times and the time needed to administer the block between groups.

	Conventional (n=42)	Hydrodissection (n=43)	*P**
Operative Time (minutes)	49.5±23.1	51.6±21.0	.662
Time needed to administer the block (seconds)	144.5±63.5	130.6±35.3	.217

* Independent Samples *t*-Test.

Table 3

Comparison of nerve block onset times between groups.

Block Onset Time (minutes)	Conventional (n=42)	Hydrodissection (n=43)	*P**
Sensorial Block	22.5±5.1	28.0±2.7	.000
Motor Block	29.2±3.0	30.8±0.9	.002

* Independent Samples *t*-Test.

In their study conducted for the precise monitoring of the needle location, Garnier et al[16] defined the term hydro-localization, which helps observe the location of the tip of the needle by giving small amounts of fluid from the needle tip. Using this method, the needle can be precisely directed to the target area. However, the risks of injury to microvascular structures and inadvertent injections of LA into vascular structures always persist despite the localization of the needle tip in the target tissue even by experienced anesthesiologists using USG. During hydrodissection, high volumes of fluids are used to check whether the needle is located in the target area and whether fluids are injected into the vascular structures. Hydrodissection also allows the user to create a pocket in the target area so that the LA can safely be injected into the targeted site. Thus, complications such as LAST, vascular injury, and nerve damage are prevented by hydrodissection.[5]

When the block administration times were compared in the present study, a significant difference was not observed between the groups because a total volume of 30 mL fluid was

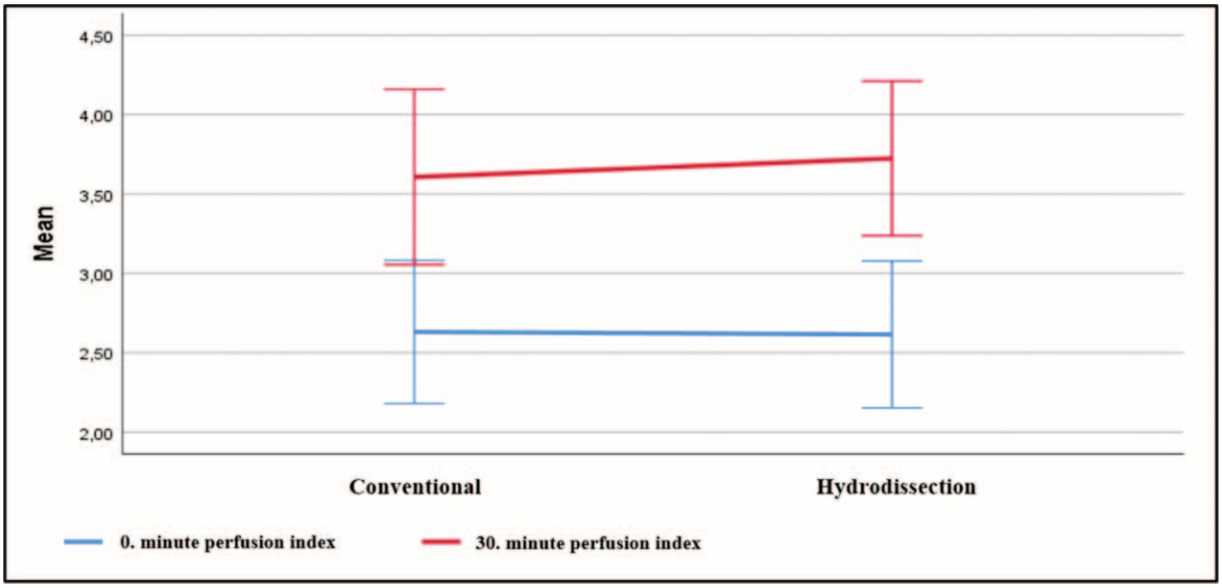

Figure 2. Intergroup and intragroup comparisons of perfusion index values.

Table 4

Comparison of block regression times between groups.

Block Regression Time (hours)	Conventional (n = 42)	Hydrodissection (n = 43)	P*
Sensorial Block	14.2 ± 4.5	15.7 ± 4.8	.123
Motor Block	10.7 ± 3.9	11.6 ± 3.8	.304

* Independent Samples *t*-Test.

administered to patients in both study groups. In Group I, the participants received a homogeneous mixture of 15 mL of LA and 15 mL of distilled water through 2 injectors. In Group II, hydrodissection was performed first by giving participants a 15 mL volume of distilled water, followed by the administration of 15 mL of LA. Two injectors per patient were used to perform the nerve block procedure in both groups. The duration of nerve block administration was similar between groups. Similar lengths of nerve block times were found in similar studies in the literature, too, because both the conventional method and the nerve block procedure with hydrodissection were performed under ultrasound guidance by anesthesiologists with low levels of PNB experience at all times.[5,17,18]

Dufour et al[5] dissected the perineural sheath with 6 mL of 5% dextrose before the median nerve block in their study, but they did not find a significant difference in the block onset and regression times or the block efficacy in comparison to the group in which they did not perform hydrodissection. When the block onset times were compared in the present study, both sensorial and motor block onset times were found to be later in patients who underwent hydrodissection in Group II, compared to those observed in Group I, despite the administration of LA with the same volume and the same concentration in each patient in either group. It may be suggested that hydrodissection with 15 mL in Group II caused this finding. Dufour et al used a lower volume and 5% dextrose instead of distilled water for hydrodissection in their study, in which they did not find a significant difference in the block onset times between groups. These findings may lead to the conclusion that the difference between the results of that study and ours regarding the block onset times may have occurred because of the use of distilled water and a high volume for hydrodissection.

The PI increased from minute 0 to minute 30. However, the increase in PI was not significantly different between the groups. In patients undergoing regional anesthesia, the nerve block primarily produces a sympathetic block, which is followed by sensory and motor blocks. Consequently, local vasodilation occurs, resulting in increased perfusion in the sympathetic block area. Thus, the occurrence of sympathetic block and the effectiveness of the block can be determined by PI.[19] In the present study, the increase in PI appeared to be an important parameter in demonstrating block efficacy. Despite the significant differences in the onset times of sensory and motor blockades between the 2 groups in this study, the lack of a significant difference in PI between the groups indicated that sympathetic block was not affected by hydrodissection.

A comparison of block regression times revealed no statistically significant differences between the 2 groups in our study. Although the block onset time was later in Group II, hydrodissection did not significantly affect block regression times. This finding may have occurred because of the use of equal concentrations of LA in both groups. However, the assessment of block regression times based on reports from patients discharged to home after day surgery may not have provided a precise measurement.

The VAS was used to evaluate the efficacy of postoperative analgesia in this study. When comparing between groups, VAS was found to be lower at the end of the 24th hour in Group II, where hydrodissection was performed. Although the same volume of LA was administered at the same concentration to each patient in either group, the direct administration of the mixture of LA and distilled water to patients in Group I may have impaired the effective spread of the LA mixture to the target area, resulting in higher VAS scores compared to Group II

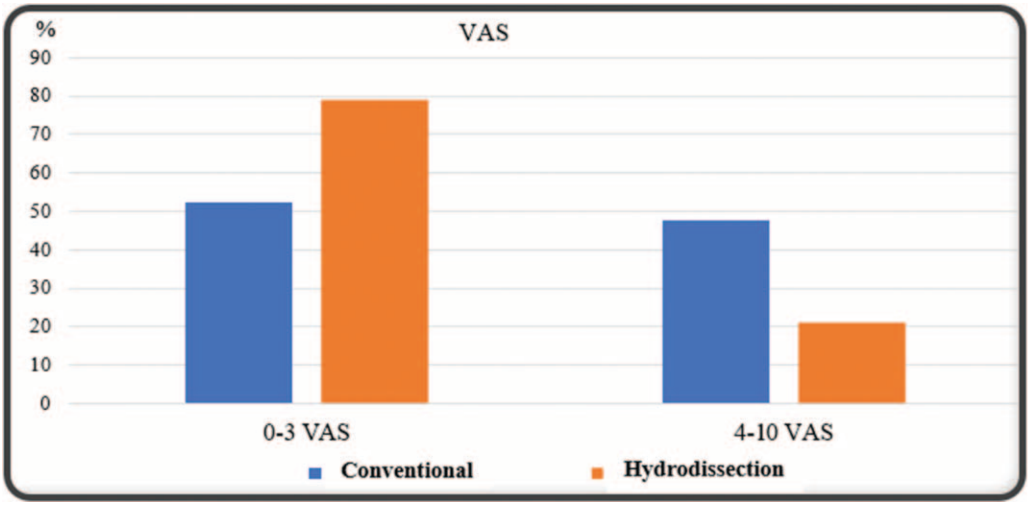

Figure 3. Comparison of VAS scores between groups. VAS = Visual analogue scale.

Table 5

Comparison of the occurrence of complications between the groups.

Complications	Normal (n=42)	Hydrodissection (n=43)	P^*
No	38 (90.5%)	43 (100.0%)	.055
Yes	4 (9.5%)	–	
Arterial puncture	4 (9.5%)	–	

* Chi-Squared Test.

patients who underwent hydrodissection. Furthermore, the three-dimensional spread of LA may not have been observed in Group I because USG produces only a two-dimensional real-time image. Moreover, the blocks were performed by a resident, who was in the third year of the specialty training and had a low level of experience in ultrasound-guided PNB. However, hydrodissection may have allowed inexperienced residents to direct the appropriate volume of LA precisely to the targeted site in patients in Group II. Bloc et al[20] showed in their study that anesthetists with a low level of experience in ultrasound-guided PNB were able to follow the needle tip advantageously and directed the precise amount of LA to the target area by administering 1 to 2 mL of 0.9% isotonic saline solution in a similar way to performing hydrodissection. Thus, the success of the PNB improved. In the hydrodissection procedure, because the pocket is created by the injection of distilled water, the fluid, which will fail to reach the target site, will be primarily distilled water. In this way, the accurate location of the needle tip will be confirmed, which will be followed by the reliable administration of LA over the created pocket, reaching the target site effectively most of the time. Because of such variations in the method of performing PNB, LA, albeit in small volumes, may have reached far beyond the target region in patients in Group I, and this may have affected the efficiency of postoperative analgesia, resulting in higher postoperative VAS scores in these patients. The study results have shown that LA administered after hydrodissection has reached the target area advantageously.

Patient and surgeon satisfaction scores rated on the Likert scale showed that there was no statistically significant difference between the 2 groups in terms of surgeon satisfaction. However, patient satisfaction scores showed that Group II patients seemed to be more satisfied with the procedure than Group I patients. This may be associated with better postoperative analgesia in patients in Group II.

The examination of complication rates showed that the small number of accidental arterial punctures in Group I did not cause a statistically significant difference in acute or chronic complication rates between the 2 groups, although no complications were observed in Group II undergoing hydrodissection. Bloc et al observed in their study that anesthetists with a low level of experience in ultrasound-guided PNB encountered fewer complications with lower rates of injuries to vessels and nerves during the efforts to direct the needle to the target area when hydrodissection was performed.[18] In the present study, ICB was performed by a resident in the third year of anesthesiology specialty training. Accidental arterial punctures occurred in 4 patients in Group I in this study, but no injuries to vessels or nerves occurred in patients undergoing hydrodissection in Group II. These findings show that hydrodissection is an important and beneficial technique for inexperienced anesthesiologists to direct the needle tip to the target tissue without complications.

Recent studies have shown that the use of USG in peripheral nerve blocks does not reduce the emergence of perioperative nerve damage in the long term, with nerve injury rates similar to those caused by other techniques. On the other hand, the ultrasound-guided nerve block technique may not completely prevent but significantly reduce LAST and unilateral diaphragmatic paralysis.[21] Hydrodissection allows the user to administer LA directly to the targeted area and to protect vascular and neural structures, which cannot be easily visualized in the USG image. Thus, potential injuries to the nerves and LAST are avoided. In the present study, no findings associated with LAST or perioperative nerve injury were reported by patients from either group during the follow-up calls performed one week later after the procedure.

In summary, in light of the information and data discussed above, hydrodissection should become the technique to be employed to avoid complications, especially by inexperienced anesthesiologists, who have just started building experiences in ultrasound-guided PNB. This study shows that hydrodissection can play a key role in the safe administration of nerve blocks within the context of residency training curriculum by providing confidence to the instructor in the administration of the block and reducing the error margin of the procedure performed by a resident. The administration of PNB with hydrodissection allows supervisors, instructors, and trainees to achieve a safe and successful procedure for both practitioners and patients.

There are some limitations in this study. The primary limitation of this study is that it was conducted in a single center. It is thought that further studies with larger samples and different experienced anesthesiologist groups are needed to compare the role of hydrodissection in reducing complications and to show its advantages and disadvantages compared to normal techniques. In addition, due to the fact that some of the patients were not inpatients, postoperative analgesia and block dissolution times could be recorded by telephone interview only after discharge, in line with the patient's statement. Accordingly, it can be thought that some data do not fully reflect the reality.

5. Conclusion

With the widespread use of USG in peripheral nerve blocks, the superiority of conventional variables, including the occurrence of nerve injury and block administration times over newly introduced techniques (anatomical marking, neurostimulation) has received attention, but none of them has been proven to be superior to the other. However, several studies have shown improvements in some variables, including LAST, and the quality and duration of the block in association with the use of USG in PNB procedures. In addition, some studies have shown that hydrodissection prevents serious complications such as LAST and perioperative nerve damage and allows safe surgery by facilitating the protection of vascular and neural structures and enabling the user to definitely confirm the location of the needle tip in the target area in ultrasound-guided PNB procedures. Furthermore, some studies have shown that hydrodissection in PSB is an ideal method for providing a safe mode of administration for beginners. This study has shown that ultrasound-guided PSB with hydrodissection, which was not previously studied in randomized controlled studies, does not fall behind conventional methods in terms of block success and characteristics; in contrast, anesthetists with low levels of experience with PNB achieve safer and more successful results in practice. Further large-scale studies, which will include anesthetist groups with different levels of experience, are needed to compare the advantages and disadvantages of hydrodissection with those of conventional techniques, including the investigation of the role of hydrodissection in reducing complications.

Author contributions

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