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Original Research Article

Effects of varying concentrations of ropivacaine on pain relief in ultrasound-guided brachial plexus block surgery in the intercostal space

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Abstract

Purpose: *To investigate the anesthetic efficacy of various concentrations of ropivacaine in ultrasound-guided brachial plexus block surgery in the inter-costoclavicular space.*
Methods: *94 patients for brachial plexus block surgery identified from March 2021 to March 2023 in Jilin Province, China were selected as the study subjects; they were divided into control group and study group, and the control group received 0.3% ropivacaine 20 ml while the study group received 20 ml of 0.4% ropivacaine. The nerve block efficiency, secondary evaluation index, VAS scores at 12 h, 24 h and 48 h after surgery and the occurrence of adverse reactions were determined.*
Results: *There was no notable difference in the success rate of nerve block between the control and study group (91.49 % vs 95.74 %, χ^2 = 0.712, p = 0.399). In comparison to control, the study group exhibited no noteworthy variance in the commencement time of the sensory block, whereas the remaining three indicators were significantly shortened (p < 0.05). The VAS scores at 12 and 24 h after surgery were markedly lower compared to the control (p < 0.05), while at 48 h, VAS scores were slightly lower (p > 0.05). There was no significant disparity in the overall incidence of adverse reactions between the two groups (4.26 vs. 6.38 %), neither were there serious complications such as tube nerve injury, local anesthetic poisoning, Horner's syndrome, pneumothorax, and postoperative sensory-motor abnormalities (p < 0.05).*
Conclusion: *Using 0.4 % ropivacaine in ultrasound-guided intercostal brachial plexus block surgery achieves a higher success rate, enhances nerve block onset and duration, and improves postoperative pain relief, all without raising the incidence of adverse reactions, when compared to the use of 0.3 % ropivacaine concentration. However, larger clinical trials are required before the application of this strategy in clinical practice.*

Keywords: *Ropivacaine, Nerve block, Analgesic effect, Ultrasound-guided, Intercostal brachial*

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INTRODUCTION

In recent years, advancements in science and technology have led to the widespread utilization of agricultural machinery. While this has boosted work efficiency, it has also resulted in a notable rise in various types of agricultural machinery injuries due to improper usage. These injuries range from machine-related fractures, broken fingers, light skin, bone, nerve, or blood vessel

damage to severe limb injuries resulting in disability. The hospital's hand surgery department treats a substantial number of such patients annually, characterized by severe injuries, wound infections, prolonged recovery periods, and poor prognoses. Previous research has demonstrated that effective postoperative pain management not only alleviates patient discomfort but also enhances their confidence in the treatment, ultimately expediting their recovery [1].

In recent years, research focus has shifted to the ultrasound-guided brachial plexus nerve block protocol, which offers significant anatomical advantages and is extensively applied in hand trauma clinical settings [2]. Ropivacaine is the preferred anesthetic for peripheral nerve blocks in contemporary clinical practice, due to its low toxicity to the central nervous system and the heart, sensory-motor separation, peripheral vasoconstriction, and prolonged duration of action [3,4]. Previous research has shown that the effectiveness of various concentrations of ropivacaine administered in ultrasound-guided brachial plexus nerve blocks varies significantly. Choosing an appropriate concentration is crucial for ensuring effective anesthesia in clinical practice while minimizing postoperative complications and enhancing overall safety [5]. In this study, controlled tests were conducted using the commonly employed clinical concentrations of 0.3 % and 0.4 % ropivacaine to assess the anesthetic efficacy and safety profile of these two concentrations.

METHODS

Study subjects

The study included patients who had forearm or hand surgery at The Affiliated Hospital of Beihua University, Jilin City, China between March 2021 and March 2023, and all of them underwent ultrasound-guided brachial plexus nerve blockade at the intercostal locking space.

Ethics approval

All procedures performed in the studies involving human participants were approved by the Ethics Committee of The Affiliated Hospital of Beihua University (approval no. 2020-13) and complied with the guidelines of the 1964 Helsinki Declaration and its later amendments for ethical research involving human subjects [6]. Written informed consent was obtained from the legally authorized representative(s) for anonymized patient information to be published in this article.

Inclusion criteria

Patients eligible for ultrasound-guided brachial plexus nerve blockade in the intercostal locking space, with a procedure expected to last for 4 hours; aged 18 or older; categorized as American Society of Anesthesiologists (ASA) class I to II; have complete clinical information; and provided voluntary informed consent.

Exclusion criteria

Women who are pregnant or nursing babies; individuals with low compliance rates; patients suffering from severe cardiovascular or coagulation issues alongside study-related trauma; patients with psychiatric disorders or long-term use of opioids and other psychoactive drugs; individuals with allergies to the study drugs; and patients lacking complete clinical data.

A 1:1 ratio for grouping enrolled patients was achieved using computerized random sequence generation. To determine the sample size for the study, a non-inferiority trial was performed with the nerve block success rate as the primary endpoint.

Previous studies found a 95 % success rate for ultrasound-guided costoclavicular interspace nerve block using 0.5 % ropivacaine. The present study recruited 94 patients, including for a potential 10 % dropout rate due to serious adverse events, missed visits, or death.

Procedures

All the subjects, after a period of fasting and abstaining from alcohol, were admitted to the operating room without prior pharmacological interventions. Upon admission, peripheral venous access was established on the non-operative upper extremity. Patients were administered oxygen via a mask and underwent standard assessments, including electro-cardiogram (ECG), pulse oxygen saturation (SPO2), non-invasive blood pressure, respiratory rate, and temperature measurements. Patients were positioned flat with the affected limb at a 90° abduction, while the head was gently inclined towards the contralateral side. The anesthesiologist connected ultrasound equipment and probe, fixing the continuous nerve block catheter tip under ultrasound guidance in the axillary artery cribriform space, where it intersected the medial, lateral, and posterior bundles of the brachial plexus nerves. The other end of the catheter was connected to an electronic pain pump. The control group

received 0.3 % ropivacaine, while the study group received 0.4 % ropivacaine, both in 20 ml doses.

Evaluation of parameters/indices

Nerve block

Assessment of nerve blocks comprised two methods as follows.

Sensory block: Within 30 minutes after the block, cold stimulation (using alcohol swabs or ice) was applied at 5-minute intervals to the innervated areas of the ipsilateral musculocutaneous nerve (forearm's radial side), median nerve (thumb's palm side), ulnar nerve (little finger's palm side), and radial nerve (hand's radial dorsum). The block's effectiveness was assessed using a 3-point scale: 0 for no block, 1 for tactile sensation without cold sensation, and 2 for no tactile sensation.

Motor block: Muscle strength in the muscles innervated by the musculocutaneous nerve (elbow flexion), median nerve (thumb-to-palm movement), ulnar nerve (thumb moving inward), and radial nerve (thumb moving outward) was examined. A 3-point scale was used for assessment: 0 for no block, 1 for weakened muscle strength, and 2 for muscle paralysis. The highest achievable block effectiveness score is 18, and a total score of 16 or more was considered a standard block effect.

Efficiency of sensory and motor blockade:

Nerve block effect grading criteria applied in this study were: *Grade I* - Ideal block range, pain-free patient, and excellent muscle relaxation, offering ideal surgical conditions. *Grade II* - Suboptimal block range, inadequate muscle relaxation, noticeable patient discomfort. *Grade III* - Suboptimal block range, significant pain, poor muscle relaxation, and patient display restlessness and moaning. Although adjunct medication improves the situation, but it still can't obtain an ideal surgical conditions and scrape through an operation.

The success rate of block procedures is calculated as the percentage of cases meeting the criteria for Class I and Class II, achieving the desired effect within 30 min of drug injection, and requiring no additional local anesthesia, sedatives, analgesics, or general anesthesia during the procedure. This success rate is determined by dividing the number of successful block cases by the total number of block cases and then multiplying by 100 to express the result in percentage.

Sub-evaluation indicators for nerve block

This includes the onset time (the time it takes for the total block score to reach 16 or higher), as well as the duration of sensory and motor blocks. Sensory duration refers to the period from the injection's conclusion to when the operated area begins to experience pain or sensations comparable to the healthy side. Motor block duration is the time between the injection's completion and when the normal movement of the hand, elbow, and wrist is regained.

Pain levels at different postoperative times

A Visual analog scale (VAS) was employed to assess patients' pain levels 12, 24 and 48 h after surgery, using a 0 to 10 scale, where higher values signify more severe pain.

Incidence of adverse reactions

The occurrence of nausea, vomiting, dizziness, sleepiness, and itching was compared between the groups.

Statistical analysis

The data were analyzed using SPSS 23.0. Count data were presented as numbers (%) and analyzed using a chi-square test, while continuous data, verified for normal distribution, were expressed as sample means and analyzed using an independent sample t-test. $P < 0.05$ indicates statistical significance.

RESULTS

Patient profile

The general profile of the study groups is shown in Table 1.

Nerve block success rate

The success rates of the nerve block in the two groups are shown in Table 2. The table reveals that four patients in the control group met the Level III criteria, compared to two patients in the study group. While the study group had a slightly higher success rate, a statistical analysis showed that the difference between the groups was not significant ($p > 0.05$).

Table 1: Comparison of general information for the two groups (n = 47)

Group	Age (years)	Gender (male/female)	Height (cm)	Weight (kg)	BMI	ASA (Ⅰ/Ⅱ)
Control	37.82 ± 7.12	25/22	164.42 ± 12.57	62.75 ± 11.70	22.99 ± 2.30	32/15
Study	38.32 ± 9.29	30/17	168.04 ± 11.93	65.64 ± 10.06	23.58 ± 2.66	36/11
t/χ^2 value	0.296	1.096	1.433	1.285	1.142	0.851
P-value	0.768	0.295	0.155	0.202	0.257	0.356

Table 2: Comparison of nerve block success rate between the two groups (n = 47)

Group	Ⅰ level	Ⅱ level	Ⅲ level	Nerve block success rate
Control	21 (44.68)	22 (46.81)	4 (8.51)	91.49 %
Study	29 (61.70)	16 (34.04)	2 (4.26)	95.74 %
χ^2 value				0.712
P-value				0.399

Table 3: Comparison of secondary assessment indicators between the two groups (mean ± SD, n = 47)

Group	Time of onset (min)		Duration (min)	
	Sensory blockade	*Motor blockade*	*Sensory blockade*	*Motor blockade*
Control	13.63 ± 3.05	13.17 ± 3.07	549.72 ± 72.19	553.91 ± 49.95
Study	12.53 ± 2.69	11.48 ± 3.01	459.94 ± 66.98	456.31 ± 64.12
t value	1.850	2.707	6.250	8.232
P-value	0.068	0.008	<0.001	<0.001

Table 4: Comparison of pain levels at different postoperative times between the two groups (n = 47)

Group	12 h postoperative	24 h postoperative	48 h postoperative
Control	3.86 ± 0.28	3.56 ± 0.35	2.16 ± 0.53
Study	2.90 ± 0.33	2.74 ± 0.33	2.05 ± 0.19
t-value	15.308	11.828	1.314
P-value	< 0.001	< 0.001	0.192

Secondary assessment indicators

The onset time and duration of sensory and motor blocks in the two groups are presented in Table 3. Upon comparison, no significant difference was observed in the onset time of sensory block between the groups. However, the study group exhibited significantly shorter onset time and duration of motor block, as well as a shorter duration of sensory block compared to the control group ($p < 0.05$).

Pain levels at different postoperative times

The VAS scores for both patient groups were assessed at 12, 24, and 48 h post-surgery. The results (Table 4) show that the study group had significantly lower VAS scores than the control group at 12 h and 24 h after surgery, with statistically significant differences ($p < 0.05$). However, there was no significant difference ($p > 0.05$) between the study group and the control group in VAS scores at 48 h post-operation.

Incidence of adverse reactions

Both groups experienced no serious complications like vascular nerve injury, local anesthetic poisoning, Horner's syndrome, pneumothorax, or postoperative sensory-motor abnormalities. The control group had one case of nausea and vomiting, and one case of hypotension, resulting in a total adverse reaction rate of 4.26 %. In the study group, two cases of nausea and vomiting, and one case of hypotension occurred, leading to a total adverse reaction rate of 6.38 %. There was no statistically significant difference in the incidence of adverse reactions between the two groups (χ^2 value = 0.211, $p = 0.646$).

DISCUSSION

An effective anesthesia plan is essential for the successful execution of surgery. Its significance goes beyond pain relief and discomfort mitigation, as it also minimizes stress responses during surgery and lowers surgical risks [7]. Nevertheless, when it comes to surgery, the choice of anesthetic agents and their concentration settings, although crucial, can potentially result in side effects that impact the patient's quality of life and postoperative recovery, despite their pain-relief benefits [8].

The brachial plexus nerve block is commonly employed in clinical settings, with minimal complications, such as nerve damage, one-sided diaphragm weakness, pneumothorax, laryngeal nerve issues, Horner's syndrome, and adverse reactions to local anesthetics [9]. Anesthesiologists typically address the side effects by making pre-surgery adjustments, like altering the anesthesia method, modifying anesthetic dosage, and providing suitable supportive treatment and other alternatives [10]. Currently, ultrasound-guided brachial plexus nerve block in the costoclavicular space is widely acknowledged for its higher success rate and lower complication rate [11,12]. Other studies indicate that the success of ultrasound-guided brachial plexus nerve block is somewhat linked to the volume and concentration of local anesthetic agents. Opting for lower concentration and smaller volumes of local anesthetic effectively lowers the chances of complications [13]. Thus, it is important to choose the right local anesthetic concentration so as to minimize complications, while maintaining the desired nerve block effect. Currently, there is no universally accepted standard for the concentration and volume of local anesthetic agents worldwide. The published articles on ropivacaine concentration and its effects vary significantly. One study suggests that using 0.5 % ropivacaine in a 20 ml injection achieved a block success rate of about 97 % within half an hour. However, another report indicates that for the same effect through a sequential method, 0.5 % ropivacaine at 20.9 ml is required [14]. In the clinic where the present study was undertaken, ropivacaine concentrations below 0.5 % are typically used for ultrasound-guided brachial plexus nerve blocks, with 0.3 and 0.4 % being the more common choices [15]. As mentioned previously, higher local anesthetic concentrations pose risks of toxicity and increased neurotoxic effects. This study aims to gather data supporting the selection of safer and more effective anesthetic concentrations for ultrasound-guided brachial plexus nerve blocks.

In the present study, the control group received 0.3 % ropivacaine, while the study group was administered 0.4 %. Comparative results revealed that, within thirty minutes of the injection, the block success rate was 91.49 % for the control group and 95.74 % for the study group. Although the increase in concentration led to a higher block success rate, the difference was not statistically significant, indicating that both 0.3 and 0.4 % ropivacaine exhibited a high nerve-blocking effect. Additionally, the study compared the onset time and duration of sensory and motor blocks in both groups in order to investigate protocol differences. The results showed that the sensory block onset time was slightly shorter in the study group compared to the control group, but the difference wasn't statistically significant. However, the study group had significantly shorter onset times for motor block, duration of sensory block, and duration of motor block. This suggests that higher ropivacaine concentration promotes faster onset and longer duration of neurological block due to ropivacaine's mechanism of action, particularly its enhanced inhibition of sodium ion conduction in bodily fluids at higher concentrations [16].

Previous research has indicated a positive correlation between the effectiveness of local anesthetics and their concentration [17]. Comparison of VAS scores between the two groups at 12, 24 and 48 h post-surgery revealed that the study group exhibited significantly lower VAS scores than the control group at 12 and 24 h post-surgery, affirming the superior analgesic effect of this concentration. However, at 48 h post-surgery, the differences between the two groups were not significant, which deviated somewhat from previous findings [18]. This variance may be attributed to sample size limitations and individual differences. To further understand the factors responsible for these discrepancies, future research may benefit from expanding the study's sample size and extending the follow-up duration. The 0.4 % ropivacaine demonstrated a superior analgesic effect, possibly due to its enhanced nerve block capabilities, including quicker onset and prolonged duration. To assess the potential for local anesthetic toxicity and liver and kidney function damage with increased concentration, adverse reactions were studied in both groups. The results revealed no significant difference in adverse reaction occurrence between the two groups, suggesting that higher drug concentration did not significantly elevate the risk of adverse reactions.

CONCLUSION

It is evident from the present study that 0.4 % concentration of ropivacaine in ultrasound-guided cribriform interspace brachial plexus nerve block is more effective than 0.3 % ropivacaine. This is reflected in shorter nerve block times, extended block duration, smoother surgical progress, improved postoperative pain relief, and safety. Differences between the present findings and those of previous studies may be attributed to the limited study times and sample size. Further research, including investigation of patient serological markers and stress response, is recommended.

DECLARATIONS

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Ethical approval

This study was approved by the Ethics Committee of The Affiliated Hospital of Beihua University (approval no. 2020-13).

Availability of data and materials

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

Conflict of Interest

No conflict of interest associated with this work.

Contribution of Authors

We declare that this work was done by the authors named in this article and all liabilities pertaining to claims relating to the content of this article will be borne by the authors. Lin Shen, Jiayu Lu and Wei He designed the study and carried them out, supervised the data collection, analyzed and interpreted the data, prepared the manuscript for publication and reviewed the draft of the manuscript. All authors read and approved the manuscript.

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