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ORIGINAL ARTICLE

Effective analgesia with ultrasound-guided interscalene brachial plexus block for postoperative pain control after arthroscopic rotator cuff repair

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Abstract
Purpose Ultrasound (US)-guided continuous interscalene brachial plexus block (CBPB) is known to provide effective pain relief for arthroscopic rotator cuff repair. This study was conducted to compare analgesic efficacy and forearm muscle tone of the basal infusion rate and bolus dose of 0.2 % ropivacaine for US-guided CBPB with intravenous patient-controlled analgesia (IV-PCA).
Methods In a prospective trial, 99 patients scheduled to undergo arthroscopic rotator cuff repair were divided into three groups. In groups A and B, an US-guided 17-gauge Tuohy needle was inserted into the interscalene brachial plexus. A loading dose of 10 ml 0.2 % ropivacaine was administered via the needle. A 19-gauge perineural catheter was then inserted through the needle and advanced to a depth of 1.5 cm beyond the needle tip between the C5 and C6 nerve trunks. After surgery, groups A and B received a continuous infusion of 0.2 % ropivacaine at 4 or 0 ml/h, a bolus of 0 or 4 ml, and a lockout time of 60 min through the catheter, respectively. Group C received IV-PCA. Pain scores and the forearm muscle tone of patients were compared using a numeric rating scale (NRS), rates of patients taking supplementary opioid analgesics, and manual muscle test (MMT) scoring.
Results The NRS scores and rate of patients taking supplementary opioid analgesics in groups A and B were lower than those in group C after surgery. Groups A and B showed similar clinical efficacy. There were no significant differences in MMT scoring among the three groups.
Conclusions The bolus dose of 0.2 % ropivacaine using US-guided CBPB would provide equivalent analgesic efficacy comparable with the basal infusion and motor weakness comparable with IV-PCA after arthroscopic rotator cuff repair.

Keywords Arthroscopic surgery · Muscle relaxation · Nerve block · Patient-controlled analgesia · Rotator cuff · Ultrasonography

Introduction

Although arthroscopic rotator cuff repair has the advantages of decreased scarring, faster recovery owing to decreased overall pain and infection, and a shorter admission period than open shoulder surgery, it often causes severe postoperative pain [1]. Appropriate pain control after arthroscopic rotator cuff repair has been reported to enhance postoperative rehabilitation, help early mobilization, and have better measures of functional recovery, including range of motion and muscle power [2].

Continuous interscalene brachial plexus block (CBPB) is known to improve postoperative analgesia, reduce postoperative requirements for opioids, and produce fewer side effects than intravenous patient-controlled analgesia (IV-PCA) after arthroscopic shoulder surgery [3, 4]. However, there is no consensus regarding the optimal basal infusion rate and bolus dose of ropivacaine for CBPB. As a result, many different basal infusion rates and

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bolus doses for CBPB have been used. Ilfeld et al. [5] reported that providing patients with 0.2 % ropivacaine CBPB at 8 ml/h produced potent analgesia after moderate to severely painful shoulder surgery, whereas higher infusion rates carried a potential risk of local anesthetic toxicity and muscle weakness caused by excessive nerve block. Therefore, minimal local anesthetic volume and concentration for CBPB are needed when it is used for postoperative analgesia after arthroscopic rotator cuff repair.

Recently, by using ultrasound (US) to visualize the nerves, nearby anatomic structures, and spread of local anesthetic, it has become possible to perform nerve block using smaller volumes of local anesthetics with a high success rate and without causing unintended nerve stimulation or paresthesia [6, 7].

This prospective study was conducted to compare basal infusion and bolus dose alone of 2 % ropivacaine for US-guided CBPB using a posterior approach technique reported by Antonakakis et al. [8] after arthroscopic rotator cuff repair. The basal infusion and bolus dose using US-guided CBPB were also compared with intravenous patient-controlled analgesia (IV-PCA). It was hypothesized that the bolus dose of 0.2 % ropivacaine using US-guided CBPB would provide analgesic efficacy comparable with the basal infusion and motor weakness comparable with IV-PCA after arthroscopic rotator cuff repair.

Materials and methods

The Institutional Review Board of the Hospital approved this study, and written informed consent was obtained from each patient. Ninety-nine inpatients of American Society of Anesthesiologists (ASA) physical status I–II undergoing arthroscopic rotator cuff repair with CBPB or IV-PCA were examined. Patients receiving chronic analgesic therapy; pregnant women; those with coagulopathy, neurological deficit, allergy to amide local anesthetics, or severe chronic lung disease; and patients with whom it was difficult to maintain cooperation were excluded.

As preanesthetic medication, 0.05 mg/kg midazolam and 0.003 mg/kg glycopyrrolate were injected intramuscularly. The patients' vital signs were measured using electrocardiography, a pulse oximeter, and a sphygmomanometer immediately after they arrived in the operating room.

All the patients were allocated randomly to one of three groups using a table of random sampling numbers. In all groups, before brachial plexus local anesthetic injection, preoperative pain score and forearm muscle tone were assessed using a numeric rating scale (NRS) and manual muscle test (MMT) scoring (Table 1) [9].

Table 1 Manual muscle test scores

Score	Description
0	No palpable or observable muscle contraction
1	Palpable or observable contraction, but no motion
2	Moves without gravity loading over the full ROM
3	Moves against gravity over the full ROM
4	Moves against gravity and moderate resistance over the full ROM
5	Moves against gravity and maximal resistance over the full ROM

ROM range of motion

In groups A ($n = 33$) and B ($n = 33$), the patients were placed in the lateral decubitus position with the operative shoulder nondependent. After skin preparation with chlorhexidine-alcohol, nerve location was assessed using a 5.0–13.0 MHz linear probe (LOGIQ e; GE Healthcare, Princeton, NJ, USA). The probe was placed on the supraclavicular fossa and the brachial plexus was identified. While maintaining the brachial plexus in the center of the image, the probe was moved in a cephalad direction until the brachial plexus could be identified between the anterior and middle scalene muscles. After 3 ml 2 % lidocaine was infiltrated into the skin, a 17-gauge Tuohy needle (Perifix; B. Braun Melsungen, Melsungen, Germany) was inserted using an in-plane approach and advanced until it was located between the C5 and C6 nerve trunks. Along the direction of the nerve trunks, the needle was turned 90°. We ensured that 2 ml 0.2 % ropivacaine was injected in increments to surround the nerve trunks, while intermittently aspirating to rule out intravascular location. A loading dose of 10 ml 0.2 % ropivacaine was administered before perineural catheter insertion. A 19-gauge perineural catheter was then inserted through the needle and advanced to a depth of 1.5 cm beyond the needle tip between the C5 and C6 nerve trunks. All catheters were secured with cutaneous adhesive suture and occlusive dressing (Tegaderm; 3 M Corporation, St. Paul, MN, USA). The success of the block was evaluated by the presence of a sensory block after 15 min. The brachial plexus block was evaluated using an alcohol swab and was considered to be successful when subjects demonstrated a decrease in perceived sensation to cold on the skin dermatomes involved in the surgical field (from C5 to C6). The block was considered to have failed if the block was not complete 30 min after injection. In group C ($n = 33$), a perineural catheter was not inserted. Instead, a loading dose of 30 mg ketorolac and 4 mg morphine sulfate was injected via the intravenous route. All these procedures were performed by a single anesthesiologist.

For the induction of anesthesia, 5 mg/kg thiopental sodium, 0.8 mg/kg rocuronium, and 0.5–1 μg/kg/min remifentanil was

administered to all groups, followed by tracheal intubation. Anesthesia was maintained using a 1.0 minimal alveolar concentration of sevoflurane with a fractional inspired oxygen concentration (FiO_2) of 0.5. Arthroscopic subacromial decompression and acromioplasty were performed in all patients. Arthroscopic cuff repair was performed with suture anchors. A single-row technique was used for small tears, and a double-row technique was used for medium- to large-sized tears. All operations were performed by a single surgeon.

In the postanesthetic care unit (PACU), 0.2 % ropivacaine was infused through the indwelling perineural catheter via an advanced ambulatory infusion system (Gemstar; Hospira, Lake Forest, IL, USA) for the first 48 h after surgery in groups A and B. Group A received a continuous infusion of 0.2 % ropivacaine at 4 ml/h plus a bolus dose of 0 ml with a lockout time of 60 min through the interscalene catheter using a portable battery-powered pump. In group B, the continuous infusion rate, bolus dose, and lockout interval were 0 ml/h, 4 ml, and 60 min, respectively. Group B also used a portable battery-powered pump. Group C received IV-PCA with 100 ml normal saline mixed with 150 mg ketorolac and 60 mg morphine sulfate (infusion rate 1 ml, bolus of 1 ml every 15 min).

Postoperative pain was assessed using the NRS when patients arrived in the recovery room, at 1 and 4 h after surgery, and then every 8 h for 48 h. If a patient requested further pain control, 25–50 mg pethidine was administered intramuscularly. Pethidine requirements were documented and registered by a blinded investigator during the first 48 h after operation. Muscle tone was evaluated using a MMT scoring system for muscle power assessing wrist flexion, wrist extension, finger abduction, and finger flexion. MMT scoring was also performed when patients arrived in the recovery room, at 1 and 4 h after surgery, and then every 8 h for 48 h. Eventual side effects, such as tingling, perioral numbness, hearing disturbance, visual disturbance, dysarthria, dizziness, nausea and vomiting episodes, and neurological deficits were monitored. All data were collected by an anesthesiologist who was not involved in the administration of the procedure and anesthesia.

Statistical analysis was performed using PASW Statistics 18.0 for Windows (SPSS, Chicago, IL, USA). Except for patient number, gender, ASA physical status, rate of patients taking supplementary analgesics, and incidence of side effects, all the measured values were denoted by their mean ± standard deviation. The chi-squared test was used to compare the three groups with respect to gender, ASA physical status, and rate of patients taking supplementary analgesics. Fisher's extraction test was used to compare the three groups with respect to the incidence of side effects. NRS and MMT scores were analyzed within the groups by using an analysis of variance (ANOVA) test with multiple comparisons. The preoperative/postoperative NRS and MMT scores were compared between the groups by using a repeated-measures ANOVA test. For post hoc comparisons, we used the Tukey test. A P value <0.05 was considered significant.

Results

Ninety-six of the patients who were enrolled completed the study. In 2 patients in group A and 1 patient in group B, the interscalene perineural catheter was accidentally pulled out 24 h after surgery. The demographic data and preoperative variables of the patients were statistically similar (Table 2).

The preoperative NRS scores were similar in all three groups. No significant difference was found in the PACU after surgery. The NRS scores of groups A and B were significantly lower than those of group C at 1, 4, 8, 16, 24, 32, and 40 h after surgery ($P < 0.05$, Fig. 1). In addition, the rate of patients taking supplementary opioid analgesics in groups A and B was significantly lower than that of group C ($P < 0.05$, Table 3).

There were no significant differences in MMT scoring among the three groups. In groups A and B, MMT scores in the PACU and 1 h after surgery were statistically lower than preoperative MMT scores ($P < 0.05$, Fig. 2).

The rates of adverse events during the study are summarized in Table 4. Paresthesia was observed in groups A and B. However, no statistical difference was observed among the three groups. Adverse events were observed mainly during the immediate postoperative period.

Table 2 Demographic data

Characteristic	Group A ($n = 31$)	Group B ($n = 32$)	Group C ($n = 33$)
ASA physical status (I/II)	19/12	22/10	14/19
Sex (M/F)	17/14	16/16	17/16
Age (years)	53.5 ± 13.3	54.3 ± 14.6	56.6 ± 18.0
Height (cm)	162.1 ± 9.1	162.5 ± 10.0	162.4 ± 10.4
Weight (kg)	63.2 ± 10.5	63.6 ± 10.2	60.6 ± 11.2

All measured values are presented as mean ± standard deviation or numbers of patients. *Group A* continuous interscalene brachial plexus block of 0.2 % ropivacaine at 4 ml/h plus bolus of 0 ml with a lockout time of 60 min. *Group B* continuous interscalene brachial plexus block of 0.2 % ropivacaine at 0 ml/h plus bolus of 4 ml with a lockout time of 60 min. *Group C* intravenous patient-controlled analgesia with 100 ml normal saline mixed with 150 mg ketorolac and 60 mg morphine sulfate (infusion rate 1 ml, bolus 1 ml every 15 min). *ASA* American Society of Anesthesiologists

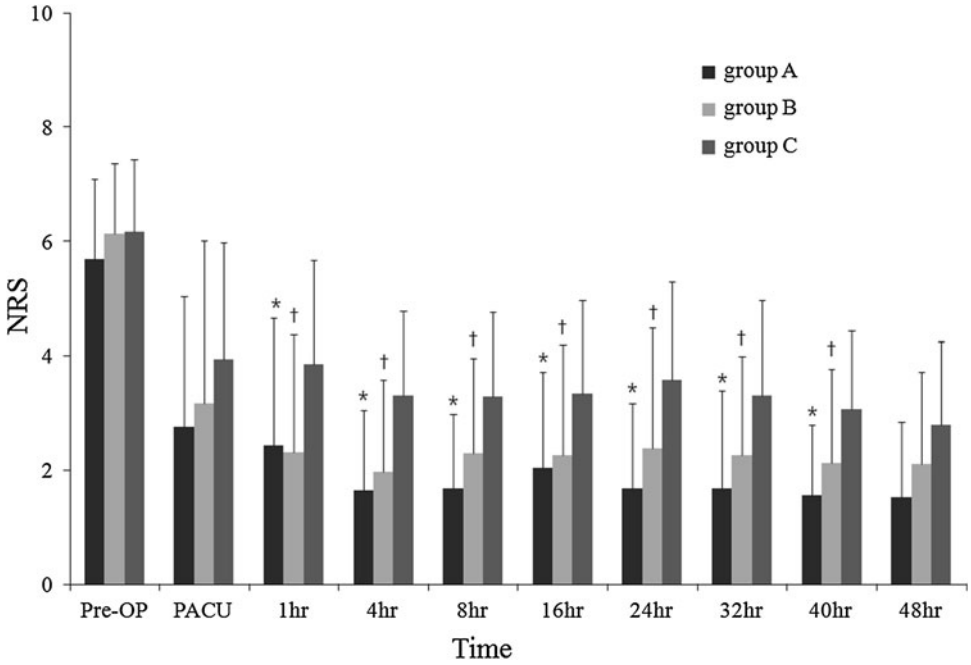

Fig. 1 Preoperative numeric rating scale (*NRS*) scores were similar in the three groups. The NRS scores of groups A and B were significantly lower than those of group C at 1, 4, 8, 16, 24, 32, and 40 h after surgery. *PACU* postanesthetic care unit, *Pre-OP* preoperation. *All variables were significantly lower in group A than in group C ($P < 0.05$). †All variables were significantly lower in group B than in group C ($P < 0.05$). *NRS* numeric rating scale

Table 3 Rate of patients taking supplementary opioid analgesics

Group A ($n = 31$)	Group B ($n = 32$)	Group C ($n = 33$)
5 (16.1)*	6 (18.8)†	14 (42.4)

Values are number of patients (%). *Group A* continuous interscalene brachial plexus block of 0.2 % ropivacaine at 4 ml/h plus bolus of 0 ml with a lockout time of 60 min. *Group B* continuous interscalene brachial plexus block of 0.2 % ropivacaine at 0 ml/h plus bolus of 4 ml with a lockout time of 60 min. *Group C* intravenous patient-controlled analgesia with 100 ml normal saline mixed with 150 mg ketorolac and 60 mg morphine sulfate (infusion rate 1 ml, bolus 1 ml every 15 min). The rates of groups A and B were significantly lower than that of group C

* $P < 0.05$ compared with group C

† $P < 0.05$ compared with group C

Discussion

This study shows that different basal infusion rates and bolus doses of CBPB provide better pain control than IV-PCA for analgesia after arthroscopic rotator cuff repair. In addition, significantly reduced additional requirements for opioid analgesics were observed in groups A and B after surgery compared to group C. Patients who received CBPB complained of motor weakness in the upper extremities in the PACU and at 1 h after surgery. However, all patients completely recovered from this motor weakness.

Arthroscopic shoulder surgery is associated with severe postoperative pain. The options available to optimize postoperative pain control after shoulder surgery include IV-PCA, intraarticular injection, suprascapular nerve block, single-shot interscalene plexus block, and CBPB. CBPB consistently provides superior analgesia with fewer side effects than either continuous subacromial infusion or single-shot interscalene plexus block [10]. Fredrickson et al. [4] reported that continuous interscalene block with basal local anesthetic infusion and patient-controlled bolus is the most effective analgesic technique after both major and minor shoulder surgeries.

CBPB with a large volume of local anesthesia has the potential risk of toxicity from accumulation of the drug [11]. However, by using US to visualize the nerves, nearby anatomical structures, and spread of local anesthetic, it is possible to perform a nerve block with small volumes of local anesthetic [6]. Singelyn et al. [12] reported that reducing the background infusion of 0.125 % bupivacaine by half (5 ml/h) is associated with the use of small-sized (2.5 ml/30 min) PCA boluses and provides excellent pain relief, causes no side effects, and results in a 36 % decrease in local anesthetic consumption. On the basis of the results of that report, our study involved a technique consisting of basal infusion and PCA bolus. In addition, we performed US-guided block. Because US guidance offers direct visualization of anatomic structures, as well as dynamic vision of needle advancement and local anesthetic spread, smaller amounts of local anesthetics can be used effectively for nerve block [13, 14].

In our study, patients who underwent CBPB complained of motor weakness in the upper extremities in the PACU and at 1 h after surgery. However, all patients completely recovered from this motor weakness. Although mild motor weakness was reported by group A and B patients, CBPB in these groups was associated with lower NRS scores than in

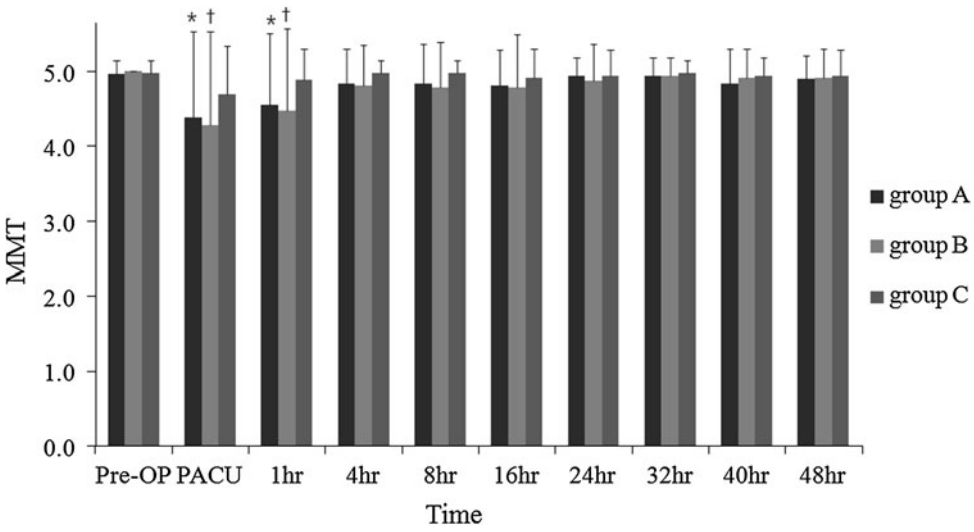

Fig. 2 There were no significant differences in manual muscle test (*MMT*) scoring among the three groups. In groups A and B, MMT scores in the PACU and at 1 h after surgery were lower than preoperative MMT scores. *MMT* manual muscle test, *PACU* postanesthetic care unit, *Pre-OP* preoperation. $^{*}P < 0.05$ compared with the Pre-OP value in group A. $^{\dagger}P < 0.05$ compared with the Pre-OP value in group B

Table 4 Adverse effects

Adverse effects	Group A ($n = 31$)	Group B ($n = 32$)	Group C ($n = 33$)
Nausea and vomiting	4 (12.9)	3 (9.4)	5 (15.2)
Dizziness	0 (0.0)	1 (3.1)	0 (0.0)
Paresthesia	6 (19.4)	4 (12.5)	0 (0.0)
Itching sensation	0 (0.0)	0 (0.0)	1 (3.0)

Values are number of patients (%). Group A, continuous interscalene brachial plexus block of 0.2 % ropivacaine at 4 ml/h plus bolus of 0 ml with a lockout time of 60 min. Group B, continuous interscalene brachial plexus block of 0.2 % ropivacaine at 0 ml/h plus bolus of 4 ml with a lockout time of 60 min. Group C, intravenous patient-controlled analgesia with 100 ml normal saline mixed with 150 mg ketorolac and 60 mg morphine sulfate (infusion rate 1 ml, bolus 1 ml every 15 min)

the IV-PCA group (group C) after surgery. Postoperative pain may originate in part from muscle spasm. Muscle traction is mandatory to facilitate reinsertion of the tendon during arthroscopic shoulder surgery and could facilitate the occurrence of postoperative muscle spasm [10]. CBPB will allow denervation of neuromuscular activation of the rotator cuff muscles. In turn, the effect of inhibition of rotator cuff muscle contraction will reduce postoperative pain.

We hypothesized that group B would obtain analgesic efficacy comparable with group A and low motor weakness comparable with group C, shown by differences in their NRS and MMT scores. We had expected that group A would show lower NRS and MMT scores than group B. Although it provides adequate pain control, continuous basal infusion of 0.2 % ropivacaine at 4 ml/h has the potential risk of muscle weakness caused by excessive local anesthetic infusion. However, there was no statistically significant difference in the NRS or MMT scores of group A. In addition, there was no significant difference in additional requirement for opioid analgesics between these two groups. Furthermore, adverse effects were not statistically different between the groups. We conclude that, when properly used by patients, the opportunity to self-administer additional boluses through an interscalene catheter guarantees low postoperative pain scores and muscle weakness.

Although the interscalene block provided better postoperative analgesia, it was not devoid of side effects. Nausea and vomiting developed in 12.9 %, 9.4 % %, and 15.2 % of patients in groups A, B, and C, respectively. We thought that CBPB would decrease the incidence of nausea and vomiting because it would reduce the usage of opioid administration. We also believed that nausea and vomiting would not be associated with central nervous system toxicity of CBPB but with general anesthesia. Paresthesia is frequently described as uncomfortable side effects by patients. In our study, 19.4 % of patients in group A and 12.5 % of patients in group B complained of paresthesia and numbness, respectively. The persistence of paresthesia for a number of hours after CBPB can cause anxiety and discomfort to patients. However, after discontinuation of the drug or removal of the catheter, sensory function was normalized in all patients. Borgeat et al. [15] reported minor neurological complications in 2.4 %, 0.3 %, and 0 % of patients who received a CBPB at 1, 3, and 6 months postoperatively, respectively.

There were some limitations in this study. First, we could not maintain blinding of the subjects and investigators were not masked to the treatment group. The infusion pump for CBPB continuously displays the reservoir volume. Second, all patients underwent surgery with general anesthesia. General anesthesia might have influenced the results because patients received similar doses of remifentanil to maintain anesthesia.

In conclusion, US-guided CBPB with 0.2 % ropivacaine at a bolus of 4 ml provided equivalent analgesic efficacy comparable with basal infusion of 4 ml/h and motor weakness comparable with IV-PCA after arthroscopic rotator cuff repair. Therefore, if properly using US-guided CBPB with 0.2 % ropivacaine at a bolus dose, postoperative pain and motor weakness caused by overuse of local anesthetics after arthroscopic rotator cuff repair will be reduced.

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