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SHOULDER

Analgesic efficacy of two interscalene blocks and one cervical epidural block in arthroscopic rotator cuff repair

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Abstract
Purpose Despite its effectiveness in other surgeries, studies on continuous epidural block in upper-extremity surgery are rare because of technical difficulties and potential complications. This study compared postoperative analgesic efficacy and safety of ultrasound-guided continuous interscalene brachial plexus block (UCISB) and fluoroscopy-guided targeted continuous cervical epidural block (FCCEB) in arthroscopic rotator cuff repair (ARCR).
Methods Seventy-five patients were randomly and equally assigned to groups FCCEB (0.2 %), UCISB75 (0.75 %), and UCISB20 (0.2 %) according to the initial ropivacaine dose (8 ml). The background infusion (0.2 % ropivacaine at 5 ml/h), bolus (3 ml of 0.2 % ropivacaine), and lockout time (20 min) were consistent. Respiratory effects [respiratory discomfort (modified Borg scale), ventilatory function, and hemidiaphragmatic excursion (ultrasound)], analgesic quality [pain severity at rest and motion attempt (VAS-R and -M), number of boluses, analgesic supplements, and sleep disturbance], neurologic effects, procedural discomfort, satisfaction, and adverse effects were evaluated preprocedurally and up to 72 h postoperatively.
Results FCCEB caused less respiratory depression and sensorimotor block, but had less analgesic efficacy than UCISBs ($P < 0.05$). FCCEB caused nausea, vomiting, and dizziness more frequently ($P < 0.05$) and had lower patient satisfaction than UCISBs ($P < 0.05$). UCISB75 can cause severe respiratory distress in patients with lung disorders. Other variables were not significantly different between the groups.
Conclusions UCISB20 may provide superior postoperative analgesia and is the most recommendable postoperative analgesic method in ARCR.
Level of evidence Randomized controlled trials, Therapeutic study, Level I.

Keywords Analgesia · Epidural · Arthroscopes · Brachial plexus · Rotator cuff

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Introduction

Patients who undergo arthroscopic shoulder surgery often report severe pain [9, 13, 25, 37, 39]. Adequate pain control is important to prevent complications and aid in rehabilitation [10, 13, 19, 25, 26].

Various regional anaesthesia techniques have been attempted for shoulder surgeries [9, 13]. Several reviews found continuous interscalene brachial plexus block (CISB) to be the most effective postoperative analgesic method [13, 14]. However, continuous cervical epidural block (CCEB) was not examined in these reports. Epidural analgesia is considered as the most effective method in thoracic, abdominal, and lower-extremity surgeries [15, 28, 33]. CCEB can provide excellent analgesia [8, 24, 27, 35, 36], but is not commonly used in upper-extremity surgery because of technical difficulties and potential complication [28, 36]. Increasing evidence shows that thoracic paravertebral block is as effective as thoracic epidural block [11, 18, 28]. Because CISB is a type of continuous

paravertebral block in the cervical region [5], CCEB and CISB might have comparable efficacy. Moreover, as ultrasound-guided CISB (UCISB) has fewer side effects than blind CISB, fluoroscopy-guided CCEB (FCCEB) would have fewer side effects than blind CCEB. The purpose of this study was to compare the postoperative analgesic effects of UCISB and FCCEB following arthroscopic rotator cuff repair (ARCR).

Materials and methods

This randomized controlled trial (RCT) was approved by the Institutional Review Board of Chung-Ang University hospital, registered with the Clinical Research Information Service (CRiS, KCT0000883), and conducted between 2012 and 2013. Written informed consent was obtained. Seventy-five patients scheduled for elective ARCR under general anaesthesia (GA), aged 20–70 years, and having American Society of Anesthesiologists physical status ≤ 3 were included. Exclusion criteria were refusal to participate, psychotic disorders, infection, coagulopathy, allergy to local anaesthetics, neuromuscular disorders, cardiopulmonary disorders, use of analgesics within 24 h before the surgery, and prior neck surgery.

Patients were randomized into one of three groups (FCCEB, UCISB75, and UCISB20) using a random table generated using PASS 11 (NCSS, Kaysville, Utah, USA). Wei's Urn model was used to prevent imbalances in treatment assignments. The randomization sequence was generated by a statistician who was not involved with the study. Group assignment was revealed to the investigator immediately prior to induction of anaesthesia in numbered sealed envelopes.

Anaesthetic technique

UCISB

The patient lay in the lateral decubitus position with the surgical side up [1]. A linear transducer (4–13 MHz; Acuson P300™ LA523 transducer, Siemens Medical Solutions, Malvern, USA) was used. The procedure was refined to reduce sequelae [1, 17]. First, after identifying C5–7 nerve roots between the anterior and middle scalene, we rotated and tilted the transducer until their diameters became smallest. This produced "real" short-axis images of the C5–7 nerve roots. Then, a 17-gauge Tuohy needle was inserted 1 cm lateral to the probe and advanced by using the short-axis in-plane technique [1, 17]. The needle was passed through the middle scalene (bevel facing upward), aiming just between the C5 and the C6 nerve roots (Fig. 1a), until a "pop" was felt [1]. The target was between the brachial plexus sheath and middle scalene fascia. We then injected 4 ml (30 mg) of 0.75 % ropivacaine in group UCISB75 and 4 ml (8 mg) of 0.2 % ropivacaine in group UCISB20 to create a space between the sheath and the fascia [17]. Next, we rotated the needle 90° caudad to ensure that the 20-gauge reinforced epidural catheter (Epina®, Ace Medical, Seoul, South Korea), threaded 3–4 cm, did not contact the nerve roots when emerging from the needle [1, 32]. Therefore, the catheter could recoil in the space instead of penetrating the anterior scalene or recoiling within the brachial plexus. The final position was confirmed sonographically (Fig. 1b) [17]. Catheter migration was checked on POD1 and 2 with ultrasound.

FCCEB

The patient lay in the prone position. After sterilization, a Tuohy needle was inserted contralaterally under fluoroscopic guidance into the T2–3 interlaminar space using the paramedian approach [31]. After loss of resistance, an epidural catheter with a guide wire was advanced cephalad under the fluoroscopic visualization [23, 36]. After the catheter tip was positioned at the ipsilateral C4 body level, 2 ml of Iohexol (Omnipaque®, GE Healthcare AS Korea, Seoul, South Korea) was injected to confirm the dorsolateral epidural spread and absence of vascular uptake. Then, 4 ml of 0.2 % ropivacaine was injected [23, 35, 36].

Routine monitors were applied, and oxygen was administered throughout procedures. Subcutaneous tunnelling, a suture, and additional fixation by a transparent dressing were performed to secure the surgical field. Finally, an additional 4 ml of ropivacaine, as assigned for each group, was injected. In total, 60 mg (8 ml) of 0.75 % ropivacaine was administered in UCISB75 and 16 mg (8 ml) of 0.2 % ropivacaine in UCISB20 and FCCEB as the initial dose, respectively [29]. Procedural success was defined by the presence of reduction in VAS, motor-sensory blocks, and images [17].

One anaesthesiologist performed all block procedures. Thirty minutes after catheterization, all patients received GA and ARCR according to standard protocol with no premedication. No opioids were administered during GA. At the beginning of ARCR, a patient-controlled analgesia (PCA) machine (Accumate® 1100, Woo Young Medical, Seoul, South Korea) was connected to the catheter. Continuous infusion of 0.2 % ropivacaine was started at a rate of 5 ml/h following a bolus infusion of 3 ml and a lockout of 20 min [21, 29, 32, 41]. All surgical procedures were performed by one surgeon.

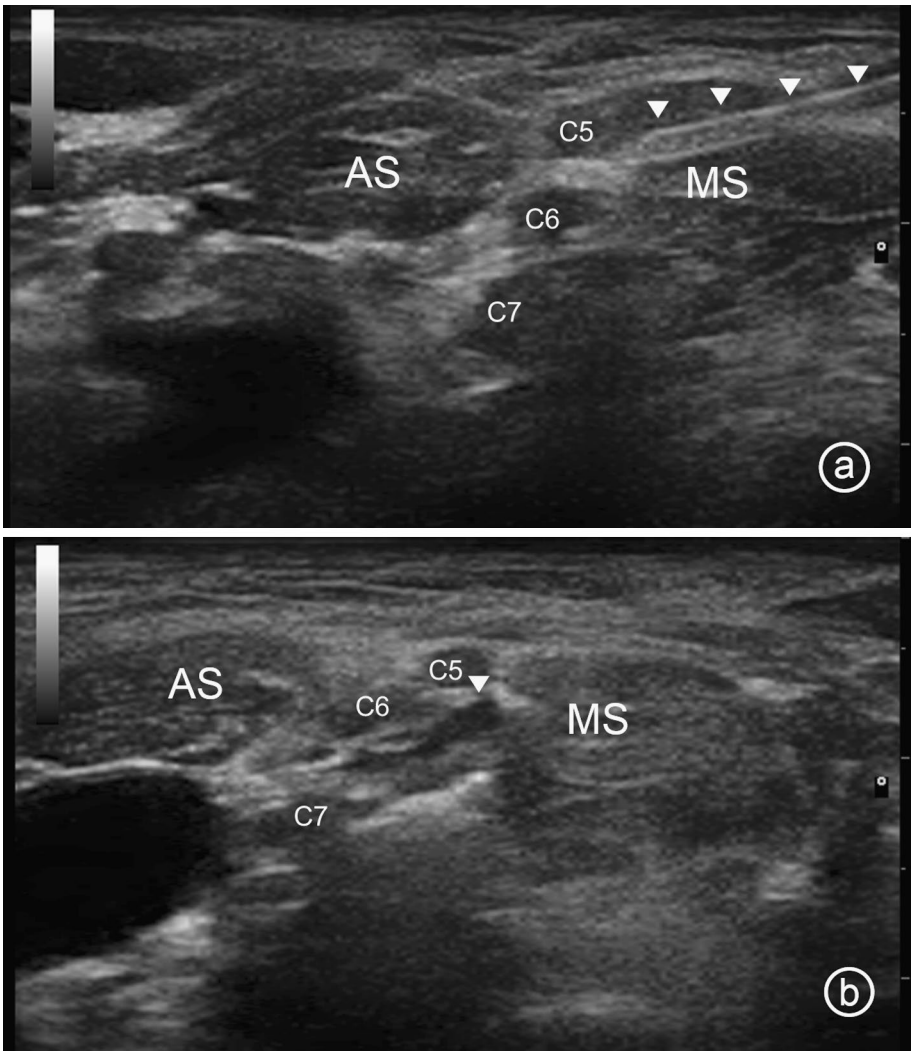

Fig. 1 Ultrasound images of interscalene brachial plexus catheterization. **a** Short-axis view showing C5–7 nerve roots in the brachial plexus. The 17-gauge Tuohy needle (*arrowheads*) was advanced by using the in-plane technique through the middle scalene with the bevel directed upward and the needle tip positioned just lateral and between the C5 and the C6 nerve roots. **b** After catheterization, flow of local anaesthetic (*arrowhead*) was visualized behind the C5–7 nerve roots. AS, anterior scalene muscle; MS, middle scalene muscle

Evaluation

Pain severity, motor-sensory block, respiratory discomfort, and complications were recorded before and after the procedure. Postprocedure pain evaluations were performed 20 min and 1, 4, 8, 12, 24, 48, and 72 h after surgery. Pulmonary function test (PFT) and hemidiaphragmatic excursion were evaluated at preprocedure, postprocedure—20 min and postoperative—24 h.

The visual analogue scale [VAS, scale from 0 (no pain) to 10 (unbearable pain)] was used to quantify perioperative pain at rest (VAS-R) and during attempted motion (shoulder shrugging, VAS-M). When the patients felt unbearable pain, they were advised to push the bolus button. If pain was still intolerable, 30 mg intravenous ketorolac was administered. The number of boluses and analgesic supplements was recorded. Sleep disturbance on the three postoperative nights was assessed by yes/no.

Sensory loss was evaluated with a pin prick and a cold sensation in the C6 dermatomes and was defined as the percentage decrease in the anaesthetized side relative to the contralateral side [6, 10, 30]. Motor weakness during resisted wrist extension was evaluated by a five-point scale [0 (no contraction)–5 (normal strength)] [6, 10, 30]. Sensorimotor functions for C5 nerve were not tested because of the proximity to the surgical site.

The PFT [forced expiratory volume in 1 s (FEV1), forced vital capacity (FVC), and peak expiratory flow rate (PEFR)] was performed with a spirometer (Spirobank® USB, Medical International Research, Rome, Italy). Predicted values were calculated with Winspiro Express software (Medical International Research, Roma, Italy) by referring to the in-built normative value of the Hong Kong Thoracic Society. Hemidiaphragmatic excursion was evaluated by M-mode ultrasound using a convex transducer (2–5 MHz; Acuson P300™ CA 431, Siemens Medical Solutions, Malvern, USA). Patients were examined in the supine position and scanned, using the liver (right) and spleen (left) as acoustic windows [7, 29, 30]. The extent of excursion was recorded in centimetres during quiet

breathing, voluntary sniffing, and deep breathing [7, 29]. Each test was performed thrice, and the values were averaged [7]. The modified Borg scale [from 0 (no breathlessness) to 10 (maximum breathlessness)] was used to rate respiratory discomfort.

Procedural discomfort was assessed using the VAS [scored from 0 (no discomfort) to 10 (unbearable discomfort)] immediately after the block procedure. Satisfaction with the analgesic method was also assessed by a VAS [from 0 (not satisfied) to 10 (most satisfied)] at the end of PCA [20]. Adverse effects, (e.g. nausea/vomiting, dizziness, urinary retention, and Horner's syndrome) were also noted.

Statistical analysis

The primary endpoint was the VAS-R. To estimate the sample size needed to achieve statistical significance of results, a pilot study was conducted for measuring VAS-R at each time point in ten patients. In chronological order, average VAS-R was 3.5, 1.2, 5.5, 4.2, 3.3, 2.7, 1.9, 0.9, and 0.5. The standard deviation ranged from 0.5 to 1.2, and autocorrelation between adjacent measurements on the same individual was 0.6. For power calculations, we assumed that the first-order autocorrelation adequately represented the autocorrelation pattern. To detect a 10 % difference in UCISB20 and a 20 % difference in UCISB75, 22 patients per group were needed ($\alpha = 0.05$, power of 80 %). Three patients were added to each group to increase the power and in anticipation of potential subject dropout.

An intention to treat strategy was used—that is, all participants were included in the analysis irrespective of whether they had completed the study. All subjects had baseline observations. However, some patients had missing data on the outcome variables after postoperative 1 h, which were completed using a last-observation-carried-forward (LOCF) analysis.

The Shapiro–Wilk test was used to test for normality of continuous variables. Age, height, weight, body mass index, duration of anaesthesia, PFT results, and perioperative pain passed the normality test. As operative time, procedural discomfort, satisfaction, hemidiaphragmatic excursion, sleep disturbance, number of boluses and analgesic supplements, and motor-sensory blocks did not pass the normality test, we additionally checked the Q–Q plot, which did not show marked deviation from linearity. Therefore, we considered that all variables had normal distribution.

Analysis of variance (ANOVA) followed by Tukey's *B* test was used to compare patient-related factors (age, height, weight, body mass index, operative time, duration of anaesthesia, procedural discomfort, and satisfaction). Intergroup comparisons over time (perioperative pain, sleep disturbance, number of boluses and analgesic supplements, motor-sensory blocks, PFT, and hemidiaphragmatic excursion) were achieved by repeated measures ANOVA followed by Tukey's honestly significant difference test. Gender, ASA physical status, surgical side, and adverse events were compared by the Chi-square test. Statistical software (IBM® SPSS® Statistics version 21, IBM, Armonk, NY) was used for the analyses. $P < 0.05$ was considered statistically significant.

Results

A total of 75 patients were included (25 patients per group) in this study. However, eight subjects did not complete

Table 1 Demographic data

Variable	FCCEB	UCISB75	UCISB20	*P* value
No. of patients	25	25	25	n.s.
Age (year)	55.4 ± 8.1	56.2 ± 5.2	56.3 ± 8.5	n.s.
Gender (M/F)	11/12	9/13	14/8	n.s.
Height (cm)	159.3 ± 9.3	161.4 ± 10.8	162.9 ± 7.3	n.s.
Weight (kg)	61.2 ± 11.1	64.2 ± 11.8	65.5 ± 8.1	n.s.
Body mass index (kg/m^2)	23.98 ± 3.0	24.6 ± 3.0	24.6 ± 2.0	n.s.
ASA physical status (1/2/3)	8/13/2	6/15/1	7/13/2	n.s.
Surgical side (right/left)	20/3	18/4	13/9	n.s.
Preoperative pain score (rest/shoulder shrugging)	2.3 ± 1.9/6.0 ± 2.9	3.4 ± 2.9/6.5 ± 3.1	2.6 ± 2.2/5.8 ± 2.6	n.s.
Operative time (min)	84.1 ± 21.7	82.3 ± 22.9	85.9 ± 20.3	n.s.
Duration of anaesthesia (min)	127.4 ± 22.7	125.7 ± 18.5	128.2 ± 23.8	n.s.

Data are expressed as mean ± SD or number of patients (%)

FCCEB fluoroscopy-guided targeted continuous cervical epidural block, *UCISB75* ultrasound-guided continuous interscalene brachial plexus block with 0.75 % ropivacaine, *UCISB20* UCISB with 0.2 % ropivacaine, *ASA* American Society of Anesthesiologists, *n.s.* not significant

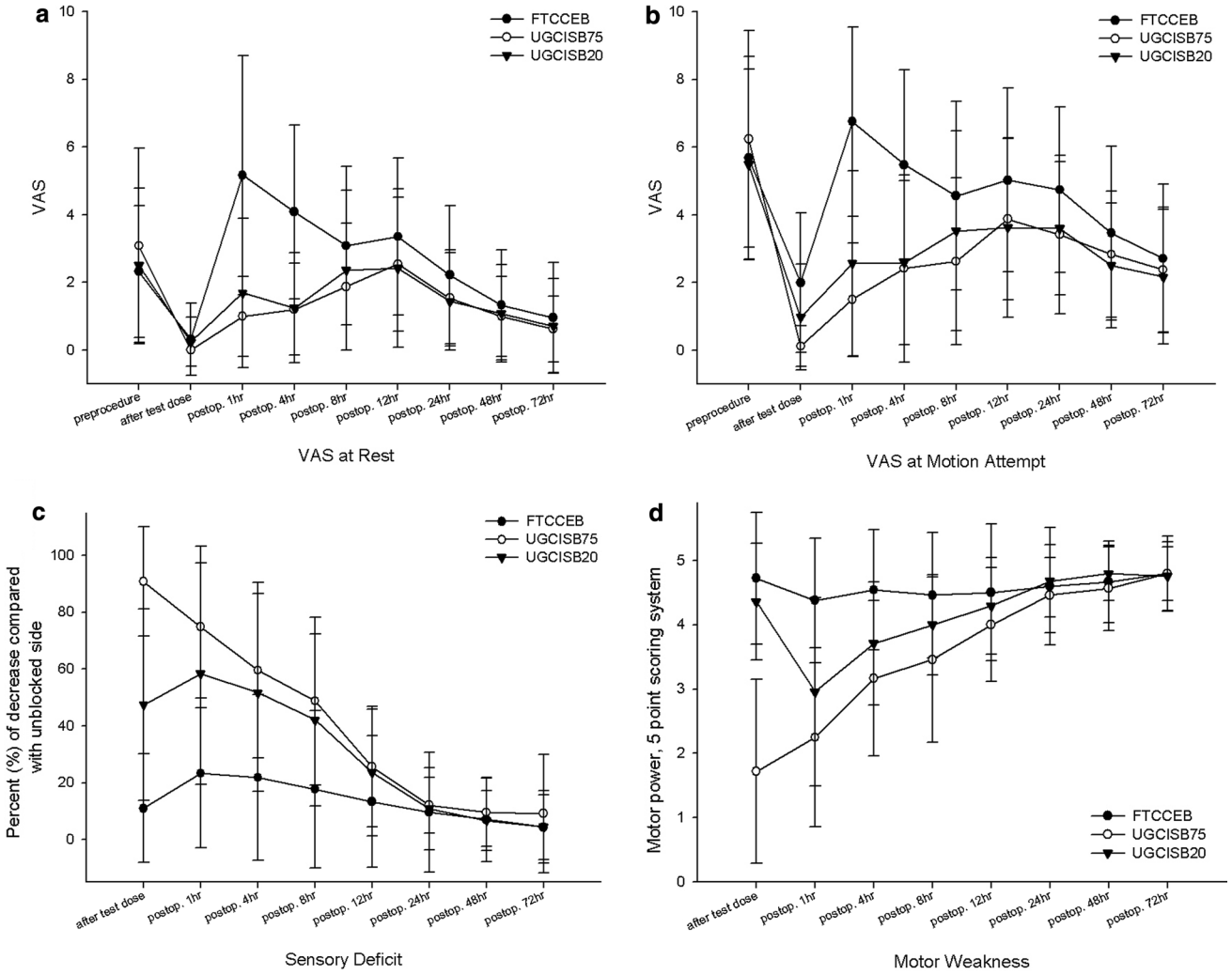

Fig. 2 Changes in pain scores and motor-sensory blocks. **a** VAS at rest, **b** VAS at motion attempt, **c** sensory deficit and **d** motor weakness between groups during 72 h. Reductions in pain severity and sensorimotor function of UCISB groups were more evident than those of FCCEB at all time points examined ($P < 0.05$). FCCEB, fluoroscopy-guided targeted continuous cervical epidural block; UCISB75, ultrasound-guided continuous interscalene brachial plexus block with 0.75 % ropivacaine; UCISB20, UCISB with 0.2 % ropivacaine; VAS, visual analog scale; VAS-R, VAS at rest; VAS at motion attempt (shoulder shrugging), VASM. Data are expressed as mean ± SD (cm)

the study. Two subjects in the FCCEB group withdrew because of intolerable nausea and paresthesia, respectively; three in the UCISB75 group withdrew because of catheter breakage, intolerable paresthesia, and respiratory discomfort, respectively; and three in the UCISB20 group withdrew because of PCA machine failure, accidental catheter removal, and intolerable paresthesia, respectively. All catheterizations were performed successfully without complications. In UCISB groups, no catheter migration and dislodgement were observed with the ultrasound-guidance. Significant differences in demographic data were not noted between groups (n.s.) (Table 1).

The UCISB group patients reported less pain than the FCCEB group patients at every postoperative time point examined ($P < 0.05$) (Fig. 2a, b). The number of boluses, analgesic supplements, and sleep disturbances was not significantly different between the groups (n.s.) (Table 2). Sensorimotor blocks were significantly higher in the UCISB groups than in the FCCEB group ($P < 0.05$) (Fig. 2c, d). They were normalized after discontinuation of PCA. VAS-R and VAS-M were poorly but significantly correlated with sensory deficit ($\rho = -0.158$, $\rho = -0.170$, $P < 0.001$) and motor weakness ($\rho = 0.105$, $\rho = 0.143$, $P < 0.015$).

Preprocedural hemidiaphragmatic excursion and PFT results were normal in all groups and similar between groups (n.s.). 20 min after the initial dose, all patients in the UCISB groups showed hemidiaphragmatic paresis and decreased PFT values but nearly normalized 24 h

Table 2 Adverse events, procedural discomfort, and patient satisfaction

Symptom	FTCCEB	UGCISB75	UGCISB20	*P* value
Nausea/vomiting[a]	12 (52.1)	1 (4.5)[c]	4 (18.2)	<0.05
Dizziness[a]	10 (43.5)	2 (9.1)	2 (9.1)	<0.05
Urinary retention[a]	5 (21.7)	2 (9.1)	2 (9.1)	n.s.
Horner's syndrome[a]	4 (17.4)	5 (22.7)	1 (4.5)	n.s.
Others[a]	1 (4.3) (Facial flushing)	None	1 (4.5) (Headache)	
Procedural discomfort[b]	2.0 (0.0–9.0)	2.0 (0.0–9.0)	1.0 (0.0–6.0)	n.s.
Satisfaction[b]	9.0 (0.0–10.0)	10.0 (8.0–10.0)	10.0 (8.0–10.0)	<0.05

FTCCEB fluoroscopy-guided targeted continuous cervical epidural block, *UGCISB75* ultrasound-guided continuous interscalene brachial plexus block with of 0.75 % ropivacaine, *UGCISB20* UGCISB with 0.2 % ropivacaine, *n.s.* not significant

[a] Data are expressed as number of patients (%)

[b] Data are expressed as median (range)

[c] One patient complained of nausea and vomiting from the day of admission onward, so she was excluded from this analysis

postoperatively ($P < 0.05$) (Fig. 3). All but one patient in the UCISB groups experienced little respiratory discomfort 20 min after the procedure (UCISB75: 0.2 ± 0.4, UCISB20: 0.1 ± 0.3, one UCISB75 subject complained of severe breathlessness). No subjects in the FCCEB group reported any respiratory discomfort. Decrease in oxygen saturation was not noted in any patients throughout the procedure.

No significant difference in procedural discomfort was noted (n.s.), but satisfaction scores were significantly lower in group FCCEB ($P < 0.05$) (Table 2). Nausea/vomiting and dizziness occurred more frequently in the FCCEB group ($P < 0.05$) (Table 2). No significant difference in the frequency of urinary retention or Horner's syndrome was noted between groups (n.s.) (Table 2). No catheter-related complications including infection occurred.

Discussion

The most important finding of our study was that UCISB provided greater pain relief with fewer complications and higher subject satisfaction than FCCEB following ARCR. The success rate of catheterization was 100 % in all groups. Pain severity (VAS-R and VAS-M) in UCISB groups was comparable to the values reported in other studies [13, 32, 41].

The use of CISB has been associated with an increased risk of nerve injury [41]. However, with the modifications made to the protocol (see "Materials and methods" section) and ultrasound visualization, patients complained little about intolerable paresthesia, and therefore, nerve injury could be avoided.

Fluoroscopic verification during epidural catheterization is important to verify that the catheter has not become coiled and/or failed to advance to the appropriate level [12, 36]. We inserted the needles at T4 pedicle level via the T2–3 interlaminar space and positioned it at C4 body level in the dorsolateral epidural space [35]. In the study of Tsui et al. [35, 36], patients with catheter placed at C4 level showed bicep and triceps twitching (C5–6) rather than diaphragmatic response (C4) during electric stimulation. Therefore, we placed the catheter tip at the C4 level to maximize analgesia and minimize side effects.

In this study, patients in the UCISB20 group reported significantly less pain and more sensorimotor blocks than those in the FCCEB group throughout the infusion period. A possible explanation is that the ropivacaine dose used in the groups was equal, but that it was smaller at the target site in the FCCEB group [16, 21, 29, 32, 41]. If the C5 nerve in groups FCCEB and UCISB20 was exposed to an equal dose of ropivacaine in a given time, a larger amount would contact the C5 nerve root along the interscalene groove than in the epidural space, in which the anaesthetic would diffuse from the target site to contralateral epidural space, and even thoracolumbar epidural space [16]. Further, as Iohexol® was injected via the catheter to confirm the location of the catheter tip, it might have acted as a barrier between the anaesthetic and dura [3, 26]. Therefore, group FCCEB would require relatively high ropivacaine doses as initial bolus and continuous infusion compared with group UCISB20.

Hemidiaphragmatic movement and ventilatory function decreased significantly in the UCISB groups than group FCCEB. It is possible because the phrenic nerve is susceptible to being incidentally anaesthetized due to its proximity to the interscalene groove. We positioned the catheters between the brachial plexus sheath and middle scalene fascia. Therefore, no ventral spread of ropivacaine occurred through the brachial plexus sheath to surround the anterior scalene [17]. However, phrenic nerve blockades were evident in all patients who underwent UCISB, during the immediate postoperative period as with other studies [22, 25, 29]. Little or mild respiratory discomfort was reported by all groups. Patients in group UCISB75 felt slightly greater respiratory discomfort than other groups (n.s.). It might be the result of larger dose of ropivacaine [29, 30]. One 56-year-old healthy man in group UCISB75 complained 8/10 of severe respiratory discomfort 10 min after the initial dose. Phrenic nerve blockade is associated with significant reduction in PFT (21–34 % decrease in FVC, 17–37 % decrease in FEV1, and 15.4 % decrease in PEFR) [17, 30, 38]. Therefore, caution should be exercised when treating patients with severe

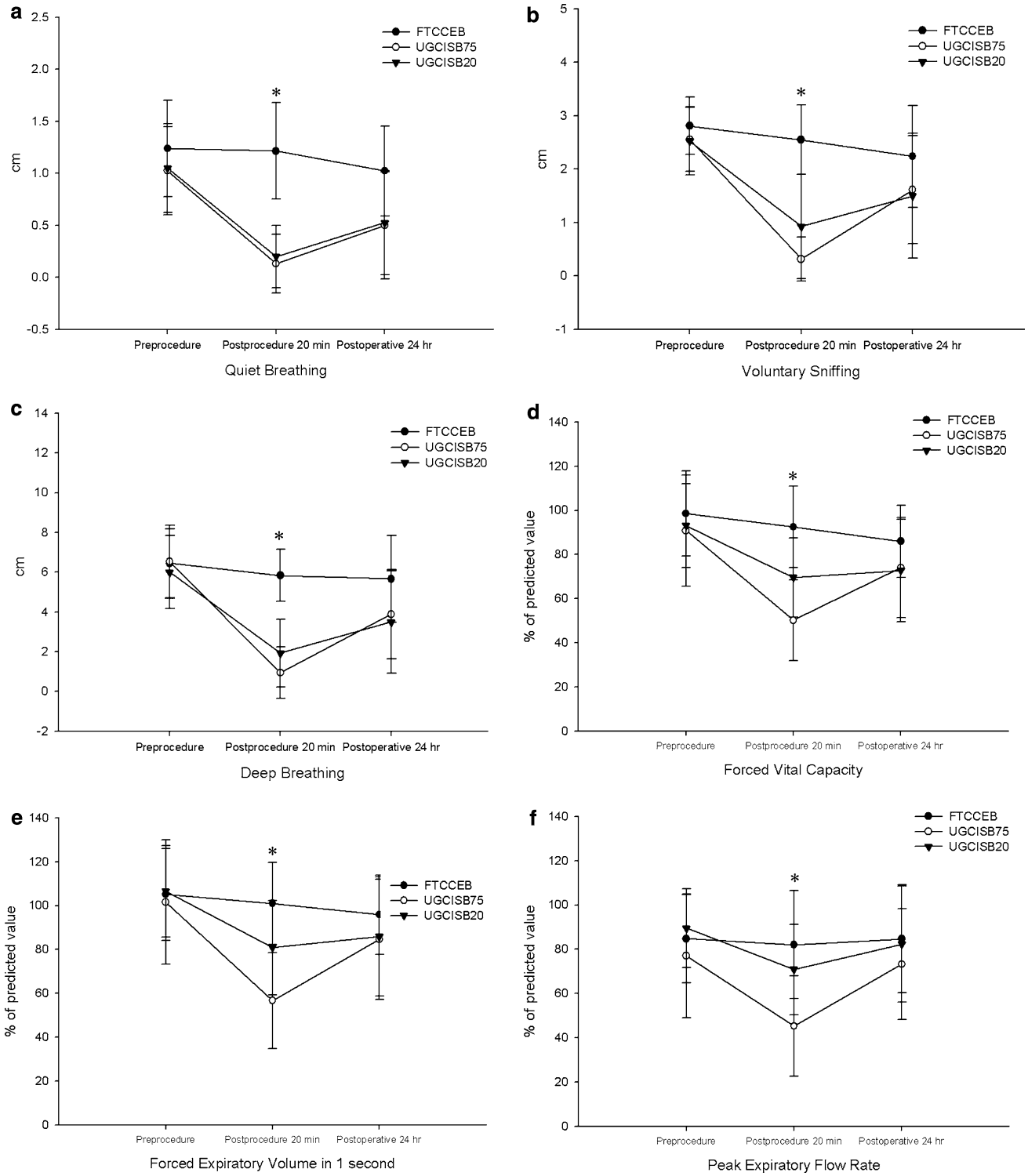

Fig. 3 Hemidiaphragmatic excursion and spirometry results. M-mode ultrasound findings of hemidiaphragmatic excursions during the following conditions: quiet breathing (**a**), voluntary sniffing (**b**), and deep breathing (**c**) changes over 24 h in the FCCEB, UCISB75, and UCISB20 groups. Spirometry revealed predicted FVC (**d**), predicted FEV1 (**e**), and predicted PEFR (**f**) changes in the FCCEB, UCISB75, and UCISB20 groups over 24 h. Groups UCISB75 and 20 showed significantly decreased diaphragmatic excursion and lower PFT values over time than group FCCEB ($P < 0.05$). FCCEB, fluoroscopy-guided targeted continuous cervical epidural block; UCISB75, ultrasound-guided continuous interscalene brachial plexus block with 0.75 % ropivacaine; UCISB20, UCISB with 0.2 % ropivacaine; FVC, forced vital capacity; FEV1, forced expiratory volume in 1 s; PEFR, peak expiratory flow rate; Preprocedure, before catheterization; Postprocedure 20 min, 20 min after administration of initial test dose of local anesthetics; Postoperative 24 hr, 24 h after termination of arthroscopic rotator cuff repair. Data are expressed as mean ± SD (cm or % of predicted value)

respiratory or neuromuscular disorders because even a 25 % reduction in FVC may result in respiratory failure. Furthermore, 0.2 % ropivacaine is recommended for the initial dose and continuous infusion with UCISB [17, 38]. Additionally, spirometry should be performed before CISB and any patient with values below normal should not undergo the procedure. One concern in CCEB is bilateral phrenic nerve blockade [4]. However, studies have shown that this is only a theoretical consideration, clinically significant phrenic nerve blockade does not occur, and spontaneous breathing is not significantly impaired even with high concentrations of local anaesthetic [4, 34, 40].

Significant risks related to epidural analgesia are dural puncture, epidural haematoma, abscess, and spinal cord injury [28, 40]. A close-claim analysis of medicolegal cases related to regional anaesthesia in the UK showed that the claim costs associated with epidural analgesia are far higher than those associated with peripheral analgesia [2], making it less attractive for general use [36]. Furthermore, although no serious complications occurred in the FCCEB group because we used fluoroscopic guidance, UCISB is thought to be safer and more effective than FCCEB for analgesia following ARCR because of lower risk of complications and greater analgesic potency.

This RCT has some limitations. First, the patients and investigators were not fully masked to the treatment groups, which could introduce bias into the results. Second, post-procedural measurements were obtained 20 min after the procedure. Ip et al. [17] found that shoulder pain subsided and sensory blockade occurred 5 min after the procedure. Yet, if measurements had been recorded 30 min after the procedure, sensorimotor blocks and respiratory depression would have been more evident.

Conclusions

Postoperative pain management with FCCEB caused less respiratory depression and sensorimotor blocks than UCISB, but had more side effects and poorer analgesic quality. Additionally, UCISB75 can cause severe respiratory distress in patients with lung disorders. Therefore, UCISB20 seems to be the best method for postoperative analgesia following ARCR.

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