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Costoclavicular block as a diaphragm-sparing nerve block for shoulder surgery: a randomized controlled trial

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Background: Distal nerve block approaches have been explored to reduce hemidiaphragmatic paresis (HDP) more effectively than interscalene block (ISB). However, these approaches are associated with a high incidence of HDP. The costoclavicular block (CCB) provides effective analgesia while reducing HDP. Here, we hypothesized that CCB would decrease the incidence of HDP compared to ISB while still providing effective pain relief after surgery.

Methods: Seventy patients who underwent arthroscopic rotator cuff repair were randomly allocated to receive either ultrasound-guided CCB (n = 35) or ISB (n = 35). Each group received 0.2% ropivacaine (20 ml CCB, 10 ml ISB). The primary outcome was the incidence of HDP, as measured using M-mode ultrasound. Diaphragmatic excursion, pulmonary function test results, opioid consumption, and pain scores were evaluated.

Results: Sixty-six patients were included. CCB group had a significantly lower incidence of HDP than those in the ISB group (5.9% vs. 84.4%, P < 0.001). The diaphragmatic excursion reduction was significantly more in the ISB (3.87 cm) group than in the CCB (0.25 cm) group (P < 0.001). The decrease in forced vital capacity and forced expiratory volume in 1 s from baseline was significantly greater in the ISB. There was no significant difference in opioid consumption between the two groups during the entire postoperative period.

Conclusions: Compared with ISB, CCB significantly reduced the incidence of HDP while maintaining effective analgesia and causing less pulmonary function impairment. CCB may be a viable option for diaphragmatic-sparing analgesia after shoulder surgery.

Keywords: Analgesia; Arthroscopy; Brachial plexus block; Costoclavicular; Nerve block; Pain, postoperative; Phrenic nerve; Shoulder; Thoracic outlet syndrome.

Introduction

Interscalene block (ISB) is widely used for pain control after shoulder surgery, but the reported incidence of hemidiaphragmatic paresis (HDP) caused by phrenic nerve palsy ranges from 16% to 100%, causing morbidity and mortality in patients with pulmonary complications [1–3]. Even in healthy patients, phrenic nerve palsy-induced diaphragmatic dysfunction has the potential to increase respiratory complications such as atelectasis [4]. Consequently, numerous studies have investigated diaphragmatic-sparing nerve blocks for preventing HDP. Low concentration, low volume, and extrafascial injection can significantly reduce the incidence of HDP [1,5–9]. More distal approaches based on the anatomical structure of the phrenic nerve pathway have also been studied

[1]. These approaches such as superior truncal block and supraclavicular block provide adequate analgesia for shoulder surgery while reducing HDP compared to ISB; however, they still show an incidence of over 50%–76% for HDP [10].

However, in the case of a more distal approach, such as the infraclavicular approach, because the suprascapular nerve has already branched off, it is not considered adequate for analgesia after shoulder surgery. There is a costoclavicular block (CCB) between the infraclavicular and supraclavicular approaches [11–13]. CCB can be used as an appropriate analgesic approach in shoulder surgery because it blocks the nerves that innervate the shoulder joint, including the suprascapular nerve. Based on this, we assumed that the CCB can be a diaphragm-sparing nerve block, making it a valuable option for postoperative pain management after shoulder surgery. We hypothesized that a CCB would result in a lower incidence of phrenic nerve palsy than an ISB. Therefore, we aimed to compare the incidence of HDP, pulmonary function, and analgesic efficacy including opioid consumption and pain scores.

Materials and Methods

This randomized, controlled, observer-blinded study was conducted at Daejeon St. Mary's Hospital, The Catholic University of Korea, Republic of Korea, and adhered to the tenets of the Declaration of Helsinki, 2013. Ethical approval (DC17EESI0032) was obtained from the Daejeon St. Mary's Hospital Institutional Review Board. The protocol was prospectively registered in the Clinical Trial Registry of Korea (KCT0002376). Written informed consent was obtained from all the participants.

Study design and participants

Patients aged 19–80 years, classified as American Society of Anesthesiologists physical status I to III, and scheduled for elective arthroscopic rotator cuff repair surgery were evaluated for eligibility. The exclusion criteria included clinically significant coagulopathy; infection at the injection site; allergy to local anesthetic (LA); severe cardiopulmonary disease; body mass index > 35; diabetic neuropathy or other neuropathies; patients receiving opioids for chronic analgesic therapy; those who declined intravenous patient-controlled analgesia (PCA); inability to comprehend the Numerical Rating Scale (NRS) score and PCA device; and patients expressing a preference or refusal for either an ISB or CCB.

Randomization

Patients were randomly assigned to receive ISB or CCB using a computer-generated random number table with randomized group information sealed in an opaque envelope that was numbered and used sequentially. Randomization was performed in the pre-anesthetic room by one of the research team that was not involved in the block procedure or evaluation (Dr. Chung).

Anesthetic procedures

Upon arrival in the operating room, standard monitoring and supplemental oxygen (via a face mask at 5 L/min) were consistently administered throughout the block procedure. The assigned block procedure was then performed according to the group allocation. Following the completion of the blockade, general anesthesia was induced using propofol (dosage: 1–2 mg/kg), rocuronium (0.6 mg/kg), and remifentanil (2–4 ng/ml). Anesthesia was maintained with desflurane at 4–6 vol% in conjunction with remifentanil at 0.01–0.05 μg/kg/min. After the surgery was completed, sugammadex was administered at a dose of 2–4 mg/kg, and the patient was extubated and transferred to the recovery room after confirming a train-of-four ratio of 95% or higher.

Block techniques

All blocks were conducted aseptically under real-time ultrasound (X-Porte®, Sonosite) by experts (Dr. Lee and Dr. Bang) with 10 years of experience, to eliminate performance bias. In the ISB group, 10 ml of 0.2% ropivacaine with 5 μg/ml epinephrine was administered, while in the CCB group, 20 ml of 0.2% ropivacaine with 5 μg/ml epinephrine was injected. The volume of ropivacaine used in each group was determined based on widely used clinical volumes [1,11].

ISB

In the supine position, with the head turned to the contralateral side, the lateral neck area was sterilized using chlorhexidine. Subsequently, a 6–15 MHz linear transducer was positioned parallel to the cricoid cartilage on the lateral neck, revealing a typical view of the ISB that visualizes the C5, C6, and C7 roots. The needle was inserted under real-time ultrasound guidance in the lateral-to-medial direction using an in-plane approach. The needle tip was positioned between the C5 and C6 roots, and a LA was injected following aspiration.

CCB

The patients were positioned in a supine position with the surgical arm abducted at ~60°. We initially placed a linear transducer directly above the middle third of the clavicle in a parallel orientation. Subsequently, the transducer was moved beneath the clavicle and tilted upwards to visualize the costoclavicular space more effectively. In the costoclavicular space, we confirmed the presence of the axillary artery below the subclavian muscle and visualized a cluster of three cords of the brachial plexus lateral to the artery. Using an in-plane technique, the block needle was inserted from the lateral to the medial direction, positioning the needle tip between the three cords.

Ultrasound assessment of diaphragmatic excursion and pulmonary function test

Diaphragmatic movement was assessed using M-mode ultrasonography before and 30 min after surgery. A 1–5 MHz curvilinear transducer was positioned in the subcostal area from the anterior to the midaxillary line, oriented medially, cranially, and dorsally. The diaphragmatic excursion (DE) was measured by instructing the participants to perform deep inspiration and expiration. We determined the presence of HDP by comparing the reduction in DE before and after the surgery. Complete HDP was defined as a reduction between 75% and 100%, partial HDP as a reduction ranging from 25% to 75%, and both scenarios were considered indicative of HDP occurrence. Conversely, patients with a decrease of less than 25% were deemed to not have experienced HDP.

Pulmonary function was evaluated using a desktop spirometer (Pony Fx®, Cosmed) at the bedside before surgery and 30 min after the patient was fully awakened from general anesthesia. We measured the forced expiratory volume in 1 s (FEV_1), forced vital capacity (FVC), and peak expiratory flow (PEF) three times each, selecting the best value from these measurements.

Postoperative pain management

After surgery, all patients were transferred to the post-anesthesia care unit (PACU) and managed until they met the discharge criteria. We assessed shoulder pain at rest using the NRS pain scores (0 = no pain, 10 = worst pain imaginable) at intervals of 8, 12, 24, and 48 h postoperatively, starting from the recovery room. After the patient arrived in the recovery room, we initiated the use of an intravenous PCA pump (Accumate1200®, Woo Young Medical). The intravenous PCA was programmed to administer a continuous infusion of 0.1 μg/kg/h of fentanyl while allowing additional bolus doses of 0.1 μg/kg based on the patient's demands, with a 7-min lockout interval. PCA automatically recorded the administered bolus amount, timing, and cumulative fentanyl dose at 30-min intervals. Subsequently, we downloaded and analyzed the data. Once patients in the ward became eligible for oral intake, all of them received a daily dose of 200 mg of celecoxib, along with tramadol (Paramacet®, DongaST) taken orally every 8 h as part of multimodal analgesia. Although PCA was used in both the recovery room and ward, in cases where patients reported pain levels of NRS 4 or higher, we administered intravenous tramadol (50 mg) or pethidine (25 mg) as rescue analgesia. These doses were converted to morphine-equivalent doses and included in the total opioid consumption.

Outcomes measures

The primary outcome was ipsilateral HDP. Secondary outcomes included resting pain scores assessed using the NRS at the PACU and at 2, 4, 8, 12, 18, 24, 32, and 48 h postoperatively; cumulative opioid consumption at 2, 4, 8, 12, 18, 24, 32, and 48 h postoperatively; changes in pulmonary function test results; and complications.

Statistical analysis

The sample size is based on an expected 70% incidence rate of HDP after an ISB in the previous study and an assumed lower rate with CCB [14]. Considering a clinical difference of 35%, a dropout rate of 10%, an alpha level of 0.05, and a power of 80%, we enrolled 35 participants in each group, resulting in a total of 70 participants.

Statistical analyses were conducted using SPSS® for Windows version 20 (SPSS Inc.). The normality of continuous variables was assessed using the Kolmogorov-Smirnov test, and an unpaired t-test was applied. Continuous data were expressed as mean ± standard deviation (SD) or median (Q1, Q3), depending on the distribution. Categorical data were analyzed using the chi-square test or Fisher's exact test. Statistical significance was set at P values < 0.05.

Results

Seventy participants (35 in each group) were enrolled. Among them, three participants in the ISB group were excluded because of difficulty in diaphragm visualization, and one participant in the CCB group was excluded because of severe pain (NRS score ≥ 7)

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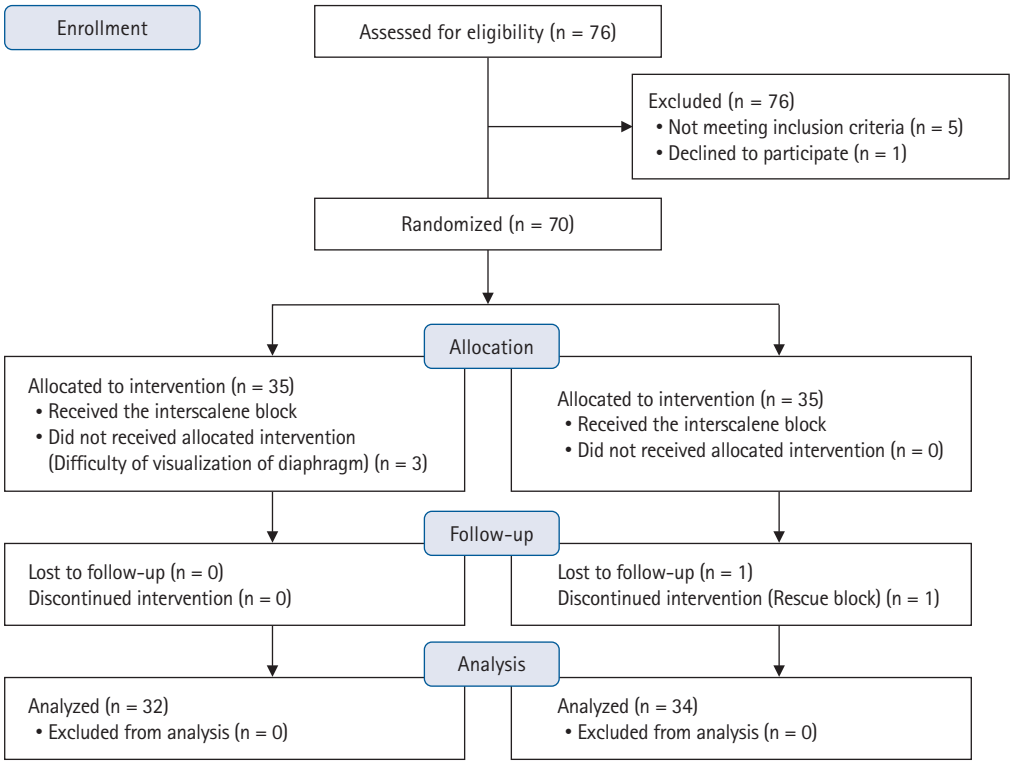

Fig. 1. Consolidated Standards of Reporting Trials (CONSORT) 2010 flow diagram.

in the recovery room, leading to a rescue block. Consequently, the study was completed and analyzed with 32 participants in the ISB group and 34 in the CCB group (Fig. 1).

The demographic characteristics are presented in Table 1. There were no significant differences between the two groups.

HDP

Baseline DE before block was similar between ISB and CCB groups (4.62 [3.6, 6.2] vs. 4.69 [4.4, 5.9]; P = 0.842). However, the DE measured in the recovery room differed significantly between ISB and CCB (0.77 [0.7, 1.0] vs. 4.92 [4.4, 5.9]; P < 0.001) (Table 2). The reduction in DE was 3.87 (2.0–5.6) in ISB, representing an 83.8% decrease from baseline, while in CCB, it was 0.25 (–0.1 to 0.8), indicating a 4.7% decrease. The difference between the two groups was statistically significant.

Furthermore, in the ISB group, patients experiencing HDP were categorized as normal/partial/complete (n = 5 [15.6%]/5 [15.6%]/22 [68.8%]), whereas in the CCB group, it was (n = 32 [94.1%], 0 [0%], and 2 [5.9%], respectively). Additionally, when partial and complete blocks were combined, the total HDP blocking ratios were 84.4% for ISB and 5.9% for CCB.

Table 1. Clinical Characteristics

	ISB group (n = 32)	CCB group (n = 34)
Age (yr)	63 ± 4.9	61 ± 7.2
Height (cm)	157.0 ± 8.6	159.6 ± 9.0
Weight (kg)	63.0 ± 11.3	63.2 ± 10.9
BMI (kg/m^2)	25.5 ± 3.8	24.6 ± 2.92
Sex		
Male	10 (31.2)	14 (41.1)
Female	22 (68.7)	20 (58.8)
ASA (I/II/III)	6/25/1	7/27/0
Side of surgery		
Right	17 (53)	18 (52)
Left	15 (46)	16 (47)
Anesthesia time (min)	144	138
Operation time (min)	94	90

Values are presented as mean ± SD, number (%) or number. ISB: interscalene block, CCB: costoclavicular block, BMI: body mass index, ASA: American Society of Anesthesiologists.

Pulmonary function and clinical outcomes

The baseline measurements of FEV_1, FVC, and PEF before the block showed no significant differences between the two groups. However, the post-block measurements of FEV_1 were 1.73 ± 0.50 vs. 2.18 ± 0.70, and FVC was 2.12 ± 0.67 vs. 2.67 ± 0.87, indicat-

Table 2. Diaphragmatic Excursion Related Data

	ISB group (n = 32)	CCB group (n = 34)	P value
HDP (%)			< 0.001*
Normal	5 (15.6)	32 (94.1)	
Partial/complete	5/22 (84.4)	0/2 (5.9)	
DE (cm)			
Preoperative	4.62 (3.6, 6.2)	4.69 (4.4, 5.9)	0.842
Postoperative	0.77 (0.7, 1.0)	4.92 (4.4, 5.4)	< 0.001*
Change of DE (cm)	3.87 (2.0, 5.6)	0.25 (−0.1, 0.8)	< 0.001*
Change of DE (%)	83.33 (69.4, 87.9)	4.74 (0, 11.9)	< 0.001*

Values are presented as number (%) or median (Q1, Q3). ISB: interscalene block, CCB: costoclavicular block, HDP: hemidiaphragmatic paralysis, DE: diaphragmatic excursion. *P < 0.01.

Table 3. The Results of Pulmonary Function Test

	ISB group (n = 32)	CCB group (n = 34)	95% CI	P value
PFT				
FEV_1 (L)				
Preoperative	2.19 ± 0.48	2.45 ± 0.69	−0.50 to 0.11	0.083[a]
Postoperative	1.73 ± 0.50	2.18 ± 0.70	−0.61 to 0.02	0.004[b]*
Amount of change	0.45 (0.2, 0.6)	0.14 (0, 0.3)		0.001[b]*
FVC (L)				
Preoperative	2.73 ± 0.69	3.05 ± 0.88	−0.61 to 0.19	0.116[a]
Postoperative	2.12 ± 0.67	2.67 ± 0.87	−0.73 to 0.08	0.007[a]*
Amount of change	0.55 (0.3, 0.8)	0.21 (0, 0.4)		0.002[b]*
$FEF_{25-75\%}$ (L)				
Preoperative	5.87 ± 1.70	6.59 ± 2.26	−1.85 to 0.14	0.150[a]
Postoperative	4.22 ± 1.76	4.99 ± 2.07	−1.34 to −0.61	0.112[a]
Amount of change	1.44 (1.2, 2.2)	1.33 (0.6, 2.5)		0.412[b]

Values are presented as mean ± SD or median (Q1, Q3). ISB: interscalene block, CCB: costoclavicular block, PFT: pulmonary function test, FEV_1: forced expiratory volume in the first second, FVC: forced vital capacity, $FEF_{25-75\%}$: forced expiratory flow between 25%–75% of FVC. [a]Independent t-test, [b]Mann–Whitney test. *P < 0.01.

ing a statistically significant decrease compared to baseline (Table 3). Furthermore, the reduction in FEV_1 and FVC measured in ISB vs. CCB was 0.45 (0.2, 0.6) vs. 0.14 (0, 0.3) and 0.55 (0.3, 0.8) vs. 0.21 (0, 0.4), respectively, demonstrating a greater decline in pulmonary function in ISB compared to CCB. In contrast, PEF was not significantly different between the two groups.

In the ISB group, two patients reported dyspnea; however, in both groups, there were no cases of hoarseness, Horner syndrome, or other respiratory complications.

Pain score and opioid consumption

There was no significant difference in cumulative opioid consumption between the two groups at 48 h after surgery, and no statistically significant differences were found in the pain scores, except for the scores measured in the recovery room (Table 4). The pain score measured 30 min after surgery in the recovery room was 2 (1, 2) for ISB and 3 (2, 3) for CCB, indicating higher pain scores in the CCB group.

Discussion

This study investigated HDP and pulmonary function between ISB and CCB and revealed an HDP rate of 5.9% in CCB and 84.4% in ISB. Additionally, DE decrease of 3.8 cm (83%) in ISB and 0.25 cm (4.7%) in ISB and CCB, respectively, compared with the baseline measured before the block. Pulmonary function in the CCB group demonstrated better preservation of FEV_1 and FVC than in the ISB group. However, there was no significant difference in postoperative opioid consumption between the two groups.

In our study, the observed HDP rate (5.9%) in the CCB group

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Table 4. Pain Score and Cumulative Opioid Consumption

	ISB group (n = 32)	CCB group (n = 34)	95% CI	P value
Pain score (VAS)				
PACU	2 (1, 2)	3 (2, 3)		< 0.001*
2 h	2 (2, 2.75)	2 (2, 2.25)		0.567
4 h	2 (2, 2)	2 (2, 2)		0.288
8 h	2 (2, 4.5)	2 (2, 3)		0.381
12 h	2 (2, 3)	2 (2, 3)		0.181
24 h	2 (2, 3)	2 (2, 3)		0.536
32 h	2 (2, 2.75)	2 (2, 3)		0.844
48 h	2 (2, 2.7)	2 (2, 2.25)		0.192
Cumulative opioid consumption (μg)				
2 h	36.61 ± 29.76	45.60 ± 38.19	−25.90 to 7.92	0.292
4 h	90.83 ± 83.96	87.45 ± 91.40	−39.86 to 46.62	0.876
8 h	222.28 ± 141.13	199.87 ± 200.35	−63.36 to 108.06	0.604
12 h	350.81 ± 200.15	344.20 ± 293.27	−117.63 to 130.84	0.916
24 h	578.04 ± 307.45	584.42 ± 394.93	−181.18 to 168.42	0.942
32 h	658.06 ± 344.57	656.43 ± 422.12	−188.54 to 191.81	0.986
48 h	742.09 ± 373.60	754.24 ± 437.71	−212.86 to 188.56	0.904

Values are presented as median (Q1, Q3) or mean ± SD. ISB: interscalene block, CCB: costoclavicular block, VAS: visual analogue scale, PACU: post anesthesia care unit. *P < 0.01.

was 78.5% lower than the HDP rate in the ISB group. Currently, diaphragmatic sparing nerve blocks, such as ISB, using strategies like low volume, low concentration, and extrafascial injection, are known to reduce HDP by 15%–34%, but none have achieved an HDP below 10% [1,2].

Furthermore, the supraclavicular block, one of the more distal approaches, has shown approximately 9%–60% HDP in studies targeting shoulder surgery [15,16]. Therefore, the 5.9% HDP rate observed in CCB suggests that it is a viable option for diaphragmatic sparing nerve block. Additionally, despite increasing interest among researchers, the recently studied superior trunk block reported an HDP rate of up to 76.3%, making CCB a favorable option for HDP reduction [10].

Typically, HDP resulting from phrenic nerve block after ISB, performed between C5 and C6, occurs due to rostral LA spread toward the C3-C5 nerve roots or anterior LA migration from the interscalene groove toward the phrenic nerve [1,7]. The phrenic nerve originates from C4, descending caudally while passing above the anterior scalene muscle, gradually distancing itself from the brachial plexus at a rate of ~0.4 mm per level [7]. Therefore, performing CCB with injection at the cord level of the brachial plexus makes it difficult to spread toward C3-5 roots, and also, since the phrenic nerve travels vertically along the anterior surface of the anterior scalene muscle, phrenic nerve palsy due to horizontal migration of LA is not expected to occur.

In our study, there was no significant difference between the two groups in terms of postoperative opioid consumption. In addition, there were no significant differences in postoperative pain scores between the two groups except in the recovery room. This suggests an association between the nerves dominating the shoulder joint and surrounding tissues. Anatomically, the anterior joint of the shoulder is innervated by the suprascapular, axillary, and lateral pectoral nerves, whereas the posterior joint is governed by the suprascapular and axillary nerves. Additionally, the rotator cuff and surrounding ligamentous tissues are controlled by the suprascapular, lateral pectoral, and subscapular nerves. Blocking these nerves through ISB is widely used to provide effective analgesia after shoulder surgery [1,17]. In contrast, CCB is theoretically considered unable to block the main nerve, the suprascapular nerve, as it has already branched off from the superior trunk. However, anatomically, the costoclavicular space is connected to the supraclavicular space, and the injected LA is believed to block the suprascapular nerve through rostral and cephalad to caudal spread.

A recent human cadaveric study also supports this hypothesis. Koyyalamudi et al. [18] injected 20 ml of dye (0.1% methylene blue) into the costoclavicular space of five cadavers and revealed cephalad to caudad spread, observing staining of the C7, C8, and T1 roots through the brachial plexus. All trunks, cords, and divisions of the brachial plexus, including the suprascapular nerve, were stained. Luo et al. [19] investigated the suprascapular nerve block ratio 30 min after ISB and CCB nerve blocks in 212 patients

and reported a block ratio of approximately 91% for ISB and 87% for CCB. Therefore, consistent with our results, several other studies have reported that CCB has the potential to be either non-inferior or equivalent to a postoperative analgesic method for shoulder surgery [20,21].

However, as mentioned earlier, our study, in contrast to other studies, demonstrated higher pain scores during the early postoperative period after CCB than after ISB. The pain scores in the recovery room were 1.87 for the ISB group and 2.70 for the CCB group, indicating that CCB may not provide adequate analgesia in the early postoperative period compared to ISB. Additionally, one participant in the CCB group complained of severe pain in the PACU that led to exclusion from the analysis. These findings suggest a deficiency in analgesia due to CCB during the early postoperative period. Similar to our findings, Jo et al. [21] also observed high pain scores in the early postoperative period. In this study, the CCB group showed higher pain scores at 1 h postoperatively than the superior trunk block group (2 [0, 3] vs. 0 [0, 0]), demonstrating results similar to ours.

However, in contrast to Aliste et al. [20] there were differences in our study regarding pain scores measured at 30 min in the PACU. Unlike the results of Aliste et al., we did not perform an intermediate cervical plexus block in either group, as it has the potential to cause a phrenic nerve block owing to its spread into the deep cervical space [20,22]. The supraclavicular nerve block obtained through the intermediate cervical plexus block (that originates from the superficial cervical plexus) can provide coverage for sensory innervation of the skin above the shoulder joint, addressing port-site incision pain. While ISB may induce a sensory block up to C2 and C3 due to cephalad spreading, residual pain at the port site may influence the pain scores in CCB. Additionally, in some cases, the anesthetic locally injected in the CCB may not have spread to the suprascapular nerve.

Our study has some limitations. In a prospective controlled study, it is common to measure variables under uniform conditions to ensure the same conditions between the two groups. Ideally, the volume of LA used should be identical. However, in our study, we used 10 ml for ISB and 20 ml for CCB. While many studies have used 20–30 ml for ISB, in diaphragmatic sparing ISB, a low volume of 10 ml has been used in diaphragmatic-sparing ISB. Moreover, a higher volume has been associated with increased phrenic nerve palsy, potentially introducing bias by exacerbating phrenic nerve palsy in ISB [1,5,6]. Furthermore, our hospital protocol typically utilizes a volume of 7–10 ml, so we opted for a commonly used clinical volume of 10 ml. Additionally, to minimize the potential impact of concentration on the phrenic nerve palsy rates, we maintained consistent concentrations between the two groups.

Second, only a single CCB injection was administered. Although the initial introduction of CCB recommended a technique that dispersed into three cords—posterior, lateral, and medial cords—our study employed a single-injection approach [11]. According to Monzó and Hadzic [23], in approximately 92.5% of 40 patients, there is an anatomical septum separating the posterior and medial cords from the lateral cord. However, despite the anatomical structure separating the lateral cord, the double injection technique has been reported to shorten the onset time initially but does not show a difference in success/failure rates [24]. Moreover, the previously mentioned cadaveric study demonstrated that a 20 ml single injection could block all trunks and cords, including the suprascapular nerve [18]. Therefore, even though we performed a single injection, we believe the impact of the septum would be minimal.

Furthermore, we did not define block success criteria based on the sensorimotor scale in this study. ISB has been the standard method for shoulder surgery for over 15 years in our hospital, and CCB has been used daily for surgical anesthesia in upper limb surgery. Both procedures were performed by two experts capable of performing both techniques, and the administration of LA spread was observed in real time using ultrasound. Furthermore, if a decrease in sensation was observed during the sensory check of the median, radial, ulnar, medial antebrachial, and musculocutaneous nerves after the nerve block, general anesthesia was administered. Therefore, we believe that there was no bias owing to technical errors.

Finally, the background infusion rate was set in PCA. This could potentially introduce a bias in cumulative opioid consumption. Although many studies have examined background infusion in morphine-based PCA, the necessity of background infusion in fentanyl-based PCA remains controversial. Additionally, the dose used in this study, 0.1 μg/kg/h, is a small, sub-analgesic dose.

In conclusion, CCB reduced HDP by approximately 87% compared to ISB and mitigated the reduction in FEV_1 and FVC. Moreover, there was no significant difference in opioid consumption between the two groups postoperatively and pain levels did not differ, except in the early period. We believe that CCB could be considered as an option for diaphragmatic-sparing nerve block in patients undergoing arthroscopic rotator cuff surgery.

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Conflicts of Interest

Seunguk Bang has been an editor for the Korean Journal of Anesthesiology since 2016. However, he was not involved in any process of review for this article, including peer reviewer selection, evaluation, or decision-making. There were no other potential conflicts of interest relevant to this article.

Data Availability

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

Author Contributions

Youngin Lee (Data curation; Investigation; Visualization; Writing – original draft; Writing – review & editing)
Seunguk Bang (Conceptualization; Data curation; Formal analysis; Funding acquisition; Writing – original draft; Writing – review & editing)
Jihyun Chung (Data curation; Writing – review & editing)
Min Suk Chae (Data curation; Formal analysis; Writing – review & editing)
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