

Local anesthetic volume in ultrasound-guided interscalene block and opioid consumption during shoulder arthroscopic surgery

A retrospective comparative study

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Abstract

Interscalene block (ISB) is commonly performed for regional anesthesia in shoulder surgery. Ultrasound-guided ISB enables visualization of the local anesthetic spread and a reduction in local anesthetic volume. However, little is known about the appropriate local anesthetic dose for surgical anesthesia without sedation or general anesthesia. The purpose of our study was to evaluate the appropriate local anesthetic volume by comparing intraoperative analgesics and hemodynamic changes in ISB in arthroscopic shoulder surgery.

Overall, 1007 patients were divided into groups 1, 2, and 3 according to the following volume of local anesthetics: 10–19, 20–29, and 30–40 mL, respectively. The use of intraoperative analgesics and sedatives, and the reduction in intraoperative maximum blood pressure and heart rate were compared through retrospective analysis.

Fentanyl was used in 55.6% of patients in group 1, which was significantly higher than in those groups 2 and 3 (22.3% and 30.7%, respectively); furthermore, it was also higher than those in groups 2 and 3 in dose-specific comparisons ($P < .05$). The percent of the maximum reduction in intraoperative systolic blood pressure and heart rate in group 3 was significantly higher than those in groups 1 and 2. Ephedrine administration was lower in group 2 than that in other groups ($P < .05$). The incidence of hypotensive bradycardic events was lowest (9.1%) at the local anesthetic volume of 24 mL as revealed by the quadratic regression analysis ($R^2 = 0.313$, $P = .003$).

Decreasing the local anesthetic volume to less than 20 mL for ultrasound-guided ISB as the sole anesthesia increases the opioid consumption during shoulder arthroscopic surgery. Local anesthetics >30 mL or increased opioid consumption with <20 mL of local anesthetics could increase the risk of cardiovascular instability intraoperatively. Our findings indicate that 24 mL of local anesthetic could be used to lower the incidence of hypotensive bradycardic events.

Abbreviations: CI = confidence intervals, DBP = diastolic blood pressure, HBE = hypotensive bradycardic events, HR = heart rate, ISB = interscalene block, MEAV = minimum effective anesthetic volume, SBP = systolic blood pressure, US-ISB = ultrasound-guided interscalene block.

Keywords: arthroscopic surgery, brachial plexus block, bradycardia, hypotension, shoulder, ultrasound

Editor: Joho Tokumine.

The authors have no funding and conflicts of interest to disclose.

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

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How to cite this article: Lim JA, Lim H, Lee JH, Kwak SG, Kim JH, Song SY, Roh WS. Local anesthetic volume in ultrasound-guided interscalene block and opioid consumption during shoulder arthroscopic surgery: A retrospective comparative study. *Medicine* 2021;100:27(e26527).

Received: 4 February 2021 / Received in final form: 31 May 2021 / Accepted: 15 June 2021

<http://dx.doi.org/10.1097/MD.00000000000026527>

1. Introduction

Interscalene block (ISB) is mainly used as regional anesthesia in the upper extremities or, especially, as anesthesia in shoulder surgery as well as postoperative pain control.

Winnie recommended that 40 mL of local anesthetic is required to increase the success rate of the brachial plexus block,^[1] and the anesthetic dose in clinical use is approximately 30–50 mL.^[2,3] The use of the ultrasonographic technique in ISB makes it possible to visualize the spread pattern of local anesthetics in real-time; the block was reported to be successful with a lower local anesthetic dose than the conventional volume.^[4] One study reported that the minimum effective anesthetic volume (MEAV) required for successful surgical anesthesia is 5 mL.^[5]

However, when performing ISB as the sole anesthesia, it may be insufficient to nerve block with MEAV; furthermore, there is a lack of evidence regarding the appropriate local anesthetic volume for surgical anesthesia. Appropriate dosage of local anesthetics allows for the complete block as a surgical anesthesia, while reducing the requirement of analgesics in the perioperative and postoperative periods, thus, reducing complications such as hypotensive bradycardic events (HBE).

Therefore, we compared the intraoperative consumption of analgesics according to the volume of local anesthetics in ultrasound-guided ISB (US-ISB) as anesthesia. Furthermore, we also compared the changes in vital signs to determine the frequency of HBE, 1 of the commonest intraoperative complications. The purpose of our study was to investigate the appropriate local anesthetics volume for ISB in arthroscopic shoulder surgery.

2. Methods

This study was approved by the Institutional Review Board of Daegu Catholic University Hospital (CR-20-229) and registered at Clinical Research Information Service (KCT0005807). To compare the intraoperative analgesic dosage and the change in vital signs according to the amount of local anesthetics in US-ISB in patients who underwent shoulder arthroscopic surgery patients, this retrospective analysis was performed based on anesthesia records of 1007 patients between October 2002 and March 2018.

We divided the patients into groups 1, 2, and 3 according to the following total dose of local anesthetics in ISB: 10–19, 20–29, and 30–40 mL, respectively.

Our standard techniques of US-ISB and vital sign monitoring intraoperatively were as follows. The patients were monitored intraoperatively using noninvasive arterial blood pressure, electrocardiography, and pulse oximetry. After laying the position in the supine position and turning the head to the opposite side as that of the procedure, the interscalene groove was identified and the neck was sterilized using an iodine solution and sterile drapes were applied.

The brachial plexus was initially identified at the supraclavicular level around the subclavian artery using a 5–13 MHz linear phased array probe of ultrasound (UST-5411, Hitachi Aloka Medical, Ltd), and the brachial plexus between the anterior and middle scalene muscles were identified by advancing the probe in the cephalad direction. A 50-mm 22-gauge insulated needle (Stimuplex Insulated B Braun Medical, Germany) was inserted from the lateral direction into the interscalene groove using the in-plane technique to visualize the entire needle. However, the anesthesiologist in group 1 performed the procedure from the medial to the lateral direction for his convenience. A 1:1 mixture of 1% mepivacaine and 0.25% ropivacaine was injected with frequent aspiration, and the diffusion pattern of local anesthetics was visually confirmed using ultrasound. The amount of local anesthetics used was documented based on the anesthesia records.

2.1. Our intraoperative management protocol

If ISB anesthesia was insufficient or the patient complained of pain or discomfort intraoperatively, fentanyl was administered. Additionally, midazolam and dexmedetomidine were administered if the pain did not improve even with repeated doses of fentanyl.

If a patient's systolic blood pressure was >170 mmHg or the arthroscopic surgical field was not secured due to bleeding intraoperatively, calcium channel blockers, such as nicardipine or diltiazem were administered. In contrast, if the intraoperative SBP was <90 mmHg, ephedrine was administered. If the heart rate was less than 50 beats per minute, atropine was used to treat and prevent HBE according to our guidelines.

2.2. Statistical analysis

Because none of the continuous variables were normally distributed based on the results of the Shapiro–Wilk test, all the continuous variables were presented as median (interquartile range). Categorical data were presented as the number of patients (percentage). Kruskal–Wallis test was used to compare the continuous variables between the 3 groups. Post-hoc Dunn test with Bonferroni correction of *P* values was used for multiple pairwise comparisons. Chi-square test was used to compare the categorical variables between the groups. A Spearman rank correlation analysis was used to investigate the correlation between local anesthetic volume and the dose of fentanyl used intraoperatively. A quadratic regression analysis was used to analyze the relationship between local anesthetic volume and the incidence of hypotensive bradycardic events. Two-tailed *P* < .05 was considered statistically significant. SPSS version 25.0 (IBM Corp., Armonk, NY, USA) was used for statistical analyses.

3. Results

Overall, 1624 patients underwent shoulder arthroscopic surgery under US-ISB. Of them, 617 people with incomplete anesthesia records were excluded; finally, 1007 people were analyzed. They were divided into 3 groups according to the dose of local anesthetics used in US-ISB (Fig. 1).

The demographic data of the patients in the 3 groups are summarized in Table 1; there was no statistical difference between the groups. There was also no difference in the past medical histories and preoperative medications including opioid consumption between the 3 groups (Table 2). In addition, all preoperative opioids were converted to oral morphine equivalents and divided into subgroups of 15, 30, and 60 mg. There was no significant difference between the subgroups.

The duration of operation was similar between the groups but the time between anesthesia and sitting position in the surgery was longer in groups 2 and 3 than that in group 1 (*P* < .05) (Table 3).

The amount and frequency of fentanyl during surgery were statistically higher in group 1 than in other groups. And the dose-specific comparison of fentanyl was also significantly higher in group 1 (*P* < .05). There was no significant difference in the frequency of the use of midazolam or dexmedetomidine (Table 4). Spearman rank correlation analysis revealed a significant correlation between local anesthetic volume and intraoperative fentanyl use (Spearman $Rho = -0.216$, *P* < .001). Table 5 summarizes the comparisons and analyses of the vital signs between groups intraoperatively. Compared to groups 1 and 2, the percent of the maximum reduction in intraoperative systolic blood pressure (*P* = .003) and heart rate (*P* = .008) in group 3 was significantly higher.

We compared the administration of vasoactive drugs between the groups. Ephedrine administration was lower in group 2 (*P* < .05), but the frequency of other drugs used was similar across all groups (Table 6). Quadratic regression analysis showed that the incidence of HBE lowest (9.1%) when 24 mL of local anesthetic was administered ($R^2 = 0.313$, *P* = .003) (Fig. 2).

4. Discussion

The purpose of this study was to evaluate the appropriate volume of local anesthetics to maintain surgical anesthesia without sedation or general anesthesia when performing US-ISB in arthroscopic shoulder surgery.

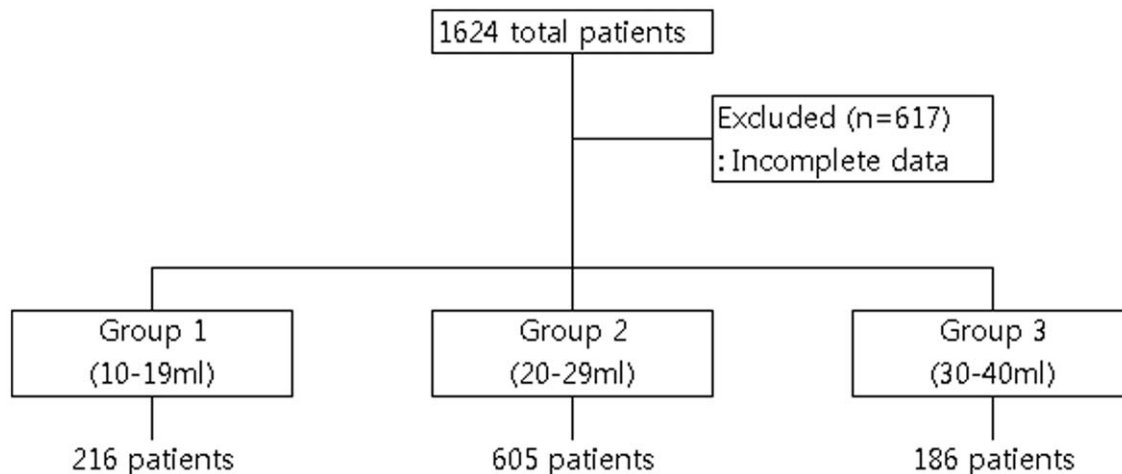


Figure 1. Flow chart of the patients. Parenthesis indicates the volume of local anesthetics.

In group 1, more than half of the patients received fentanyl intraoperatively whereas in groups 2 and 3, 22.6% and 30.7% of patients received fentanyl, respectively ($P < .05$). These statistically significant differences suggest that local anesthetics < 20 mL could increase the requirement of intraoperative analgesic with the possibility of an incomplete block.

The use of ultrasound has significantly contributed to reducing the amount of local anesthetic used when performing ISB compared with the conventional method.^[6,7] This has resulted in

studies on the volume of local anesthetics, especially MEAV, to maintain surgical anesthesia while minimizing complications such as phrenic nerve palsy.

Mittal et al^[8] determined that the minimum effective volume of 0.5% ropivacaine was 8.64 mL in 90% of patients who underwent ISB without deterioration in the block onset and duration. A similar study by Vandepitte et al^[9] found that effective dose 95% (ED95) of 0.75% ropivacaine was 7 mL for successful surgical anesthesia with ISB using a catheter.

Gautier et al reported that US-ISB for successful surgical anesthesia can be achieved with MEAV of 5 mL of 0.75% ropivacaine. However, the lower limit of the confidence interval (CI) does include a 25% failure rate (100%, 95% CI: 74.1%–100%).^[5]

Table 1
Demographic information.

	Group 1 (n=216)	Group 2 (n=605)	Group 3 (n=186)	P value
Age (yr)	61.0 (13)	59.0 (14)	60.5 (16)	.100
Height (cm)	161.6 (15)	164.0 (13)	164.0 (13)	.225
Weight (kg)	63.0 (15)	63.0 (16)	63.0 (16)	.436
Sex				.081
Male	105 (48.6)	338 (55.9)	110 (59.1)	
Female	111 (51.4)	267 (44.1)	76 (40.9)	
Types of surgery				.174
Elective	211 (97.7)	575 (95.0)	175 (94.1)	
Emergency	5 (2.3)	30 (5.0)	11 (5.9)	
Operation site				.153
Right	155 (71.8)	416 (68.8)	117 (62.9)	
Left	61 (28.2)	189 (31.2)	69 (37.1)	
ASA-PS				.658
I	130 (60.2)	355 (58.7)	103 (55.4)	
II	85 (39.4)	246 (40.7)	83 (44.6)	
III	1 (0.5)	4 (0.7)	0 (0)	
Preoperative diagnosis				.883
Rotator cuff tear	168 (78.5)	455 (75.8)	133 (73.5)	
Shoulder instability	26 (12.1)	63 (10.5)	19 (10.5)	
Calcified tendinitis	5 (2.3)	18 (3.0)	6 (3.3)	
Impingement syndrome	0 (0.0)	3 (0.5)	1 (0.6)	
SLAP or labral tear	2 (0.9)	16 (2.7)	5 (2.8)	
Frozen shoulder	0 (0.0)	1 (0.2)	0 (0.0)	
Pyogenic arthritis	13 (6.1)	44 (7.3)	17 (9.4)	

Values were presented by frequency (percent) or median (interquartile range). ASA-PS = American Society of Anesthesiologists physical status, SLAP = superior labrum anterior to posterior.

Table 2
Past medical history and preoperative medication.

	Group 1 (n=216)	Group 2 (n=605)	Group 3 (n=186)	P value
Hypertension	69 (31.9)	183 (30.3)	54 (29.0)	.813
Diabetes mellitus	26 (12.0)	69 (11.4)	23 (12.4)	.926
Tuberculosis	9 (4.2)	15 (2.5)	3 (1.7)	.255
Heart disease	4 (1.9)	14 (2.3)	4 (2.2)	.923
Pulmonary disease	5 (2.30)	7 (1.2)	4 (2.2)	.402
Liver disease	6 (2.8)	14 (2.3)	3 (1.6)	.736
Brain disease	5 (2.3)	16 (2.6)	4 (2.2)	.916
ECG-ischemia	2 (0.9)	20 (3.3)	7 (3.8)	.145
ECG-arrhythmia	1 (0.5)	17 (2.8)	3 (1.6)	.103
Chest X-ray abnormality	7 (3.2)	6 (1.0)	2 (1.9)	.056
Antihypertensive	67 (31.0)	163 (27.0)	46 (24.7)	.341
Diabetes mellitus medication	25 (11.6)	62 (10.3)	19 (10.2)	.852
Beta blocker	3 (1.4)	6 (1.0)	2 (1.1)	.890
Nitrates	0 (0.0)	2 (0.3)	0 (0.0)	.514
ACEI	0 (0.0)	1 (0.2)	0 (0.0)	.717
ARB	9 (4.2)	17 (2.8)	4 (2.2)	.459
Daily oral morphine equivalents	1/1/0	1/5/2	1/2/3	.524
dose of preoperative opioid	(0.5/0.5/0)	(0.2/0.8/0.3)	(0.5/1.1/1.6)	
	(15 mg/30 mg/60 mg)			

Data were expressed as the number of patients. Parentheses indicate percentage. ACEI = angiotensin-converting enzyme inhibitors, ARB = angiotensin II receptor blocker, ECG = electrocardiogram.

Table 3**Comparison of anesthesia characteristics.**

	Group 1 (n = 216)	Group 2 (n = 605)	Group 3 (n = 186)	P value	
Time from block start to sitting position (min)	10.0 (11)	10.0 (17)	14.0 (11)	<.05	1 < 2,3*
Time from sitting position to operation start (min)	38.5 (21)	41.0 (27)	40.0 (19)	.074	
Operation time (min)	82.0 (43)	86.0 (45)	84.5 (39)	.324	
Total amount of LA (mL)	14.0 (3)	25.0 (0)	34.0 (6)	<.05	1 < 2 < 3*
Ropivacaine (mL)	7.0 (2)	12.5 (0)	17.0 (3)	<.05	1 < 2 < 3*
Mepivacaine (mL)	7.0 (2)	12.5 (0)	17.0 (3)	<.05	1 < 2 < 3*

Values were presented by median (interquartile range).

* Multiple comparison results by Dunn procedure.

Table 4**Intraoperative administration of analgesics and sedatives.**

	Group 1 (n = 216)	Group 2 (n = 605)	Group 3 (n = 186)	P value	
Amount of fentanyl (μ g)	37.5 (100)	0.0 (0)	0.0 (50)	<.05	2,3 < 1*
Use of fentanyl	120 (55.6)	137 (22.6)	57 (30.7)	<.05	
Dosage of fentanyl				<.05	
None	96 (44.4)	468 (77.4)	129 (69.4)		
\leq 50 μ g	25 (11.6)	38 (6.3)	16 (8.6)		
51–100 μ g	88 (40.7)	94 (15.5)	39 (21.0)		
101–150 μ g	5 (2.3)	2 (0.3)	2 (1.1)		
151–200 μ g	2 (0.9)	2 (0.3)	0 (0.0)		
\geq 201 μ g	0 (0.0)	1 (0.2)	0 (0.0)		
Use of midazolam	2 (0.93)	3 (0.5)	3 (0.5)	.111	
Use of dexmedetomidine	3 (1.4)	12 (2.0)	12 (2.0)	.823	

* Multiple comparison results by Dunn procedure. Values were presented by frequency (percent) or median (interquartile range).

Table 5**Intraoperative vital signs.**

	Group 1 (n = 216)	Group 2 (n = 605)	Group 3 (n = 186)	P value	
Baseline SBP (mmHg)	146.0 (25)	141.0 (26)	142.0 (29)	.124	
Baseline DBP (mmHg)	80.5 (16)	81.0 (14)	80.0 (14)	.076	
Baseline HR (BPM)	68.0 (14)	67.0 (16)	69.0 (16)	.017	1,2 < 3*
Maximum SBP (mmHg)	160.0 (25)	158.0 (30)	162.0 (34)	.380	
Minimum SBP (mmHg)	120.5 (29)	125.0 (25)	121.0 (26)	<.05	1,3 < 2*
Maximum HR (BPM)	81.0 (17)	78.0 (23)	84.0 (21)	<.05	1,2 < 3*
Minimum HR (BPM)	60.0 (14)	62.0 (14)	61.0 (16)	.674	
Maximum reduction of SBP (%)	9.1 (14)	11.4 (12)	12.6 (14)	.003	1,2 < 3*
Maximum reduction of HR (%)	13.2 (21)	11.5 (22)	17.3 (24)	.008	1,2 < 3*

DBP = diastolic blood pressure, HR = heart rate, SBP = systolic blood pressure.

* Multiple comparison results by Dunn procedure. Values were presented by median (interquartile range).

Table 6**Intraoperative administration of vasoactive drugs.**

	Group 1 (n = 216)	Group 2 (n = 605)	Group 3 (n = 186)	P value
Nicardipine	68 (31.5)	187 (30.9)	48 (25.8)	.365
Diltiazem	8 (3.7)	12 (2.0)	7 (3.8)	.243
Ephedrine	46 (21.3)	74 (12.2)	42 (22.6)	<.05
Atropine	4 (1.9)	23 (3.8)	7 (3.8)	.375

Values were presented by frequency (percent).

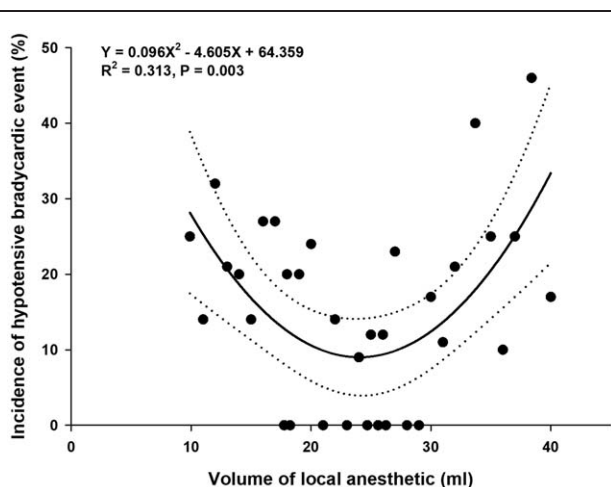


Figure 2. Quadratic regression analysis with the volume of local anesthetic as an independent variable and incidence of hypotensive bradycardic events as a dependent variable. In the regression model, the incidence was lowest (9.1%) with a local anesthetic volume of 24 mL. The solid line and 2 dotted lines represent the predictive values and their 95% confidence intervals, respectively.

The above studies have indicated that a much smaller dose of local anesthetics was required than that reported in our results. Additionally, since the dose was determined in an up-and-down method and the sample size is small, there is a limitation in defining the required dose of local anesthetics as sole anesthesia in ISB, especially, in a prospective study.^[4]

The MEAV of 0.75% ropivacaine in US-ISB for surgical anesthesia at 95% efficacy (MEAV 95) is suboptimal because it is extrapolated based on MEAV 50, which can result in unconfirmed estimates with wide confidence intervals. Since the sample size was small and the 95% CI was large, the effective volume should be carefully determined using the up-and-down method. Particularly, the method of repeatedly measuring the same dose or concentration in the next patient following a non-evaluable patient has the limitation that the estimated value will be definitely downwardly biased from the true value.^[10,11]

Riazi et al compared low-volume (5 mL) and standard-volume (20 mL) US-ISB in shoulder surgeries. They found that there were no significant differences in the use of intraoperative fentanyl, pain scores, and sleep quality. However, low-volume US-ISB resulted in reduced respiratory complications but 45% of the low-volume group still developed phrenic nerve palsy 30 min after the block.^[12]

Another study reported that decreasing the volume of local anesthetics in US-ISB from 20 to 10 mL did not reduce the incidence of hemidiaphragmatic paresis or impairment in pulmonary function. Additionally, there were no differences in the duration or quality of analgesia between the 2 groups.^[13]

In both studies, the use of low-dose local anesthetics did not completely reduce the incidence of complications, such as phrenic nerve palsy, the main objective of their studies. Additionally, there was no significant difference in the analgesic consumption or pain score between the low-dose and conventional-dose procedures. However, unlike our study in which only ISB was performed, these studies included ISB with general anesthesia, which itself may act as a limiting variable in evaluating the quality of anesthesia intraoperatively. Therefore, it can be interpreted

that the volume of local anesthetics can be reduced when general anesthesia and regional anesthesia are combined.

The quality of the intraoperative block with ISB as the sole anesthesia remains unclear.^[11] Therefore, we tried to evaluate the volume of local anesthetics required for ISB as the sole anesthesia, without general anesthesia or sedation, by comparing the intraoperative use of analgesics.

Previous studies have demonstrated the increased use of narcotics in patients who received inadequate ISB^[14] as well as a relationship between the success rate of anesthesia and intraoperative use of combined analgesic and sedative agents.^[15] Therefore, the higher use of intraoperative analgesics with sedatives could reflect a low quality of sensory and motor block intraoperatively.

When performing nerve block as the sole anesthesia, the duration of complete block is important for anesthetic appropriateness. The dose of local anesthetics is determined by the volume and concentration of the agent; each of these factors can affect the duration of anesthesia independently.^[16,17] When performing axillary brachial plexus block, a higher dose and concentration (1.5% mepivacaine) increases the duration of the motor and sensory block. And reducing the volume/dose of mepivacaine 1.5% from 40 to 15 mL results significant 18% decrease ($P < .005$) in the median duration of the blockade, but less decrease to 20 mL showed a modest change (5%) in block duration. Therefore, the optimal balance between volume and dose with maintaining block duration is 20 mL.^[18,19] This shows that more than a certain amount of volume is required to maintain the block duration adequately.

We used local anesthetics of mepivacaine and ropivacaine at 1:1 while keeping the concentration constant and compared the anesthetic adequacy based on the volume. There was no difference between groups 2 and 3 in fentanyl use; however, intraoperative fentanyl use was significantly reduced compared to group 1, which administered less than 20 mL of local anesthetics. Although the volume of local anesthetics required has gradually decreased with the use of ultrasound, we found that ≥ 20 mL could be required to maintain adequate anesthesia irrespective of the concentration of local anesthetics in ISB as the sole anesthesia. Among intraoperative complications related to ISB in shoulder surgery in the sitting position, cardiovascular instability, such as HBE, has been reported in 13%–29% of patients.^[20–22] Contributing factors for HBEs include intraoperative sedatives and analgesics, antihypertensives,^[23] and ISB itself^[24]; however, the relationship between HBE and local anesthetics volume has not been investigated.

In our study, the percent of the maximum reduction in systolic blood pressure and the heart rate in group 3 was significantly greater than those in the other groups (Table 5). Furthermore, the administration of ephedrine was also higher in group 3 than that of group 2 (Table 6). Considering that ephedrine administration is an indicator of HBE, the incidence of HBE can be reduced by almost half when local anesthetics are administered at 20–29 mL. Furthermore, it was confirmed that the local anesthetic volume with the lowest incidence of HBE was 24 mL through quadratic regression analysis, which is consistent with the above result.

However, the frequency of administration of ephedrine in group 1 was 21.3% and similar to that in group 3, which is believed to be due to frequent administration of fentanyl in group 1. Intraoperative fentanyl administration, especially more than 100 mcg, for incomplete ISB could act as a triggering factor for HBE.^[25]

Additionally, since the anatomic structure related to major complications is located in the anterior scalene muscle, it is more likely to be exposed when performing a medial approach. And it causes an increase in the incidence of complications, such as phrenic nerve palsy, Horner syndrome, and hoarseness. These symptoms are associated with vasovagal reflex reactions along with psychological anxiety, and these discomforts could increase the patient's analgesic demand.^[22] This fact could be also another evidence to supports the result in our study that the dose of fentanyl was higher in group 1 than in other groups.

There are several limitations to our study. First, a detailed description of ISB related complications and patient satisfaction about anesthetic adequacy was insufficient because of the retrospective study. Second, ISB was performed by 5 anesthesiologists, which may have led to more bias compared to ISB performed by a single anesthesiologist. However, considering that all the anesthesiologists had more than 10 years of experience with a nerve block and the use of ultrasound, this could have offset the bias to some extent. Third, all anesthesiologists could not evaluate consistently the degree or severity of symptomatic HBE. However, since the treatment was based on vital signs according to our institutional guidelines, the limitations of our study could be supplemented.

In conclusion, decreasing local anesthetics volume to <20 mL in US-ISB as the sole anesthesia increases opioid consumption during shoulder arthroscopic surgery. In addition to fentanyl consumption due to incomplete block with the low volume of local anesthetics, especially less than 20 mL, intraoperative hemodynamic instability is more likely to occur with more than 30 mL of local anesthetics. In particular, the low incidence of HBE could be expected when 24 mL of local anesthetic is used.

Author contributions

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