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Assessment of Diaphragmatic Function after Ultrasound Guided Interscalene Block with Different Volumes of Local Anesthetic in Patients Undergoing Shoulder Surgery

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Abstract

***Background*: Interscalene brachial plexus block (ISBPB) is effective for postoperative analgesia after shoulder surgery but is linked to diaphragm dysfunction. This study compare the impact of two volumes of bupivacaine (10 ml and 15 ml) on diaphragmatic function, oxygen saturation, pain control, and opioid requirements. *Aim:* To reduce the incidence of diaphragmatic paralysis following interscalene block in adult patients undergoing shoulder surgery. *Patients and Methods*: Adults (18-60 years) undergoing elective shoulder surgery were randomly divided into two groups: Group A (15 ml bupivacaine) and Group B (10 ml bupivacaine). Pre, intra, and post-operative assessments included diaphragmatic function, oxygen saturation, sedation score, motor power, pain control, and opioid requirements. *Results:* Patients in both groups showed no paradoxical diaphragmatic movement within the first 30 minutes. However, after 30 minutes, Group A (15 ml) had a significantly higher frequency of diaphragmatic paresis. No significant difference was found in postoperative pain and opioid consumption within 48 hours. *Conclusion:* Low volume interscalene block provides comparable analgesia to high volumes but is associated with a lower incidence of side effects and hemi-diaphragmatic paresis.**

Keywords: *Ultrasound, nerve block, bupivacaine, shoulder*

Introduction

Postoperative pain after arthroscopic shoulder surgery is severe, often rated 4 to 5 on the numeric pain rating scale [(1)]. Systemic analgesics have drawbacks, making effective local analgesia crucial. Interscalene brachial plexus block (ISBPB) offers effective analgesia but may lead to complications such as phrenic block [(2)]. ISBPB provides effective postoperative pain relief, minimizes the likelihood of nausea and vomiting, and reduces the need for opioids. Nevertheless, it carries the potential for serious complications, notably phrenic block [(3)]. In a study conducted by

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Abdelhaq et al. in 1991, it was observed that all instances of IBPB led to phrenic blockade, resulting in acute ipsilateral hemi-diaphragmatic paralysis (HDP) and subsequent impairment of pulmonary function [4]. Efforts to mitigate phrenic nerve block have involved employing ISB with reduced local anesthetic (LA) volumes and applying digital pressure to impede the upward spread of LA solution, either individually or in combination. However, none of these approaches have proven entirely effective in preventing phrenic nerve block [5]. In a study by Riazi et al., ultrasound guided ISB (USISB) was investigated using 5 mL of ropivacaine 0.5%. The findings revealed that in 55% of the patients, phrenic nerve block did not occur. This suggests that employing a smaller volume of bupivacaine may reduce the undesired effect of ipsilateral hemi-diaphragmatic paralysis without compromising pain relief or patient satisfaction [6]. Recent studies using ultrasound-guided ISBPB (USISB) have shown reduced phrenic block incidence, prompting investigation into optimal bupivacaine volumes [5]. We hypothesize that using a lower bupivacaine volume (10 ml) would minimize diaphragmatic impairment compared to a higher volume (15 ml) in elective shoulder surgery patients.

Patients and Methods:

Study type: Randomized control trial
Study setting: Operative theaters at Suez Canal University hospitals
Study population: Adult Patients undergoing shoulder surgery, 18-60 years old, scheduled for elective shoulder surgery under general anesthesia in combination with ISBPB, and classified as American Society of Anesthesiologists (ASA) physical status of II or I [7].
Presence of infection at the injection site, Body mass index exceeding 35 kg/m2 (BMI = kg/m2), International normalized ratio (INR) exceeding 1.5, use of anticoagulant medication, Significant psychiatric or cognitive conditions that may hinder the ability to provide consent or assess pain severity, uncontrolled respiratory disease or borderline respiratory conditions, preexisting neurological deficits or neuropathy affecting the brachial plexus, and history of chronic opioid abuse lasting more than six months were excluded.
Ethical approval was obtained. Patients randomized into Group A (15 ml bupivacaine) or Group B (10 ml bupivacaine). Intraoperative ISBPB performed using ultrasound. Postoperative assessment at 6, 12, 24, and 48 hours included HR, BP, SPo2, VAS score, diaphragmatic movement, and complications.
Data was collected, coded, and entered into a Microsoft Excel 2020, of the Microsoft Office Bundle of Microsoft Corporation, USA. Then analyzed using SPSS version 23 (Statistical Package for Social Sciences) Of IBM Corporation, USA. Normality was tested for the determination of the types of variables and hence the types of tests that were used (e.g., Kolomogrov-Sminrov test, Shapiro-Wilk test).

Results

The mean age of the patients in both groups was comparable. There was no statistically significant difference between patients in both groups regarding any

baseline characteristics as shown in (Table 1). patients who received high volume (group A) of bupivacaine had significantly higher frequency of paradoxical diaphragmatic movements compared to those who received low volume (group B) within the first 6 hours postoperatively. On the other hand, patients in both groups did not show any paradoxical diaphragmatic movements after 12hours postoperative. as shown in (Table 2). Table 3 showed that there was no statistically significant difference between high volume group (group A) and low volume group (group B) in regard to postoperative pain (VAS score) within the 48 hours postoperative. Table 4 showed that there was no statistically significant difference between high volume group (group A) and low volume group (group B) regarding mean postoperative opioid consumption within the 48 hours postoperative. patients who received high volume of bupivacaine had higher frequency of Horner syndrome compared to those who received low volume at the first 12 hours postoperatively. On the other hand, patients in both groups did not have post-operative Horner syndrome after 12 hrs. postoperative (Table 5).

Table 1. Baseline characteristics of the two studied groups

Variables	**Group (A) (15ml) (n=22)**	**Group (B) (10ml) (n=22)**	**test value**	**p-value**
Age (years), mean ± SD	38.31 ± 7.87	38.63 ± 8.40	231.5	0.805 [a]
Sex, n (%)				
Male	17 (77.3)	14 (63.6)	0.983	0.322 [b]
Female	5 (22.7)	8 (36.4)		
BMI, n (%)				
Normal	2 (9.1)	1 (4.5)	0.599	0.741 [c]
Overweight	8 (36.4)	10 (45.5)		
Obese	12 (54.5)	11 (50)		
Surgical duration, mean ± SD	1.84 ± 0.39	1.68± 0.53	150	0.090 [a]
ASA, n (%)				
1	19 (86.4)	18 (81.8)	0.170	0.680 [c]
2	3 (13.6)	4 (18.2)		
Chronic illness				
Diabetes	1 (4.5)	1 (4.5)	-	-
Hypertension	1 (4.5)	2 (9.1)	0.358	0.550
IHD	1 (4.5)	0 (0)	-	-
Type of surgery (%)				
Shoulder arthroscope	21(95.4)	22(100)		
Acromioclavicular (AC) Joint Repairs	1(4.5)			
Duration of surgery (%)				
1hour	0 (0)	0 (0)		

1.5 hours	18(81.1)	14 (63.3)	0.170	0.680 [c]
2 hours	4(18.1)	8 (36.3)	0.599	0.741 [c]
2.5 hours	0 (0)	0 (0)		
[a] p-values are based on Mann-Whitney U test. Statistical significance at P < 0.05 [b] p-values are based on Chi-square test. Statistical significance at P < 0.05 [c] p-values are based on Fisher exact test. Statistical significance at P < 0.05				

Table 2. Comparison between the two groups regarding post operative diaphragmatic movement

Diaphragmatic movement	**Number of patients**		**p-value**
	Group (A) (15ml) (n=22)	**Group (B) (10ml) (n=22)**	
ostoperative at recovery room			
Normal	19 (86.3)	21 (95.4)	0.294
Abnormal	3 (13.6)	1 (4.6)	
6 hr. postoperative			
Normal	21 (95.5)	22 (100)	0.312
Abnormal	1 (4.5)	0 (0)	
12 hr. postoperative			
Normal	21 (95.5)	22 (100)	0.549
Abnormal	1 (4.5)	0 (0)	
24 hr. postoperative			
Normal	22 (100)	22 (100)	-
Abnormal	0 (0)	0 (0)	
48hr. postoperative			
Normal	22 (100)	22 (100)	-
Abnormal	0 (0)	0 (0)	
[a] p-values are based on Mann-Whitney U test. Statistical significance at P < 0.05			

Table 3. Comparison between the two groups regarding VAS score during post-operative periods.

VAS score	**VAS score mean ±SD**		**p-value**
	Group (A) (15ml) (n=22)	**Group (B) (10ml) (n=22)**	
VAS postoperative at recovery room	0.45 ± 0.80	0.23 ± 0.52	0.291
VAS 6 hr. postoperative	1.41 ± 1.09	1.73 ± 1.42	0.326
VAS 12 hr. postoperative	1.82 ± 1.46	1.73 ± 1.42	0.999
VAS 24 hr. postoperative	2.45 ± 1.81	2.32 ± 1.58	0.951
VAS 48hr. postoperative	2.45 ± 1.81	2.32 ± 1.58	0.951
[a] p-values are based on Mann-Whitney U test. Statistical significance at P < 0.05			

Table 4. Comparison between the two groups regarding total amount of opioid consumption (mg)			
Variables	**Total amount of opioids (mg) mean ±SD**		**p-value**
	Group (A) (15ml) (n=22)	**Group (B) (10ml) (n=22)**	
Opioid use postoperative	86.36 ± 31.55	92.05 ± 31.23	0.561
Opioid use 6 hr. postoperative	100.0 ± 36.18	106.8 ± 31.03	0.478
Opioid use 12 hr. postoperative	117.04 ± 32.1	119.31 ± 25.5	0.855
Opioid use 24 hr. postoperative	120.4 ± 32.4	122.7 ± 26.6	0.846
Opioid use 48hr. postoperative	121.6 ± 33.8	125.1 ± 24.3	0.725
[a] p-values are based on Mann-Whitney U test. Statistical significance at P < 0.05			

Table 5. Comparison between the two groups in regard to occurrence of Horner syndrome			
Horner syndrome postoperative	**Number of patients**		**p-value**
	Group (A) (15ml) (n=22)	**Group (B) (10ml) (n=22)**	
Horner syndrome postoperative at recovery room			
Normal	17 (77.3)	21 (95.4)	0.078
Abnormal	5 (22.7)	1 (4.6)	
6 hr. postoperative			
Normal	17 (77.3)	22 (100)	**0.039***
Abnormal	5 (22.7)	0 (0)	
12 hr. postoperative			
Normal	19 (86.4)	22 (100)	0.290
Abnormal	3 (13.6)	0 (0)	
24 hr. postoperative			
Normal	22 (100)	22 (100)	-
Abnormal	0 (0)	0 (0)	
48hr. postoperative			
Normal	22 (100)	22 (100)	-
Abnormal	0 (0)	0 (0)	
[a] p-values are based on Chi-square test. Statistical significance at P < 0.05			

Discussion

This prospective interventional study assessed the incidence of diaphragmatic paralysis after interscalene block in adult patients undergoing shoulder surgery. Patients were enrolled according to the inclusion criteria and then divided randomly into two groups. Group A received 10ml of bupivacaine 0.5% in performance of ISBPB while group B was injected with 15 ml of bupivacaine 0.5%. Patients were assessed pre, intra and post-operative to evaluate diaphragm function, oxygen saturation, sedation score, motor power, pain control and opioid requirements. In the present

study, we found that patients in both groups did not have any paradoxical diaphragmatic movements within the first 30 minutes after interscalene block. It was also found that patients who received a high volume of bupivacaine had higher frequency of paradoxical diaphragmatic movements compared to those who received low volume within the first 6 hours postoperatively. On the other hand, patients in both groups did not have any paradoxical diaphragmatic movements at 12 hours and 24 hours postoperative monitoring. Renes et al. conducted a comparison between peripheral nerve stimulator (PNS) and ultrasound-guided (USG) interscalene brachial plexus block (ISB) using 10 mL of 0.75% bupivacaine. Their findings revealed a reduced occurrence of hemi-diaphragmatic (HD) palsy with the application of USG. The study concluded that utilizing low-volume ISB under ultrasound guidance could be effective in diminishing the incidence of HD paresis without compromising the efficacy of postoperative pain relief [8]. In a study by Riazi et al., forty patients undergoing shoulder surgery were randomly assigned to receive ultrasound-guided interscalene brachial plexus block (ISBPB) with either 5 or 20 ml of ropivacaine 0.5%. The study revealed a lower incidence of hemi-diaphragmatic (HD) palsy and respiratory complications with the use of 5 mL of local anesthetic compared to 20 mL in ultrasound-guided ISB [6]. However, in contrast, Stundner et al. conducted a randomized trial involving forty patients undergoing shoulder surgery who received ultrasound guided ISBPB with either 5 or 20 ml ropivacaine 0.5%. Their findings indicated that reducing the local anesthetic volume from 20 mL to 5 mL did not lead to a reduction in the incidence of diaphragmatic paresis or impairment of pulmonary function [9]. In contrast, Khanna et al. reported no significant difference in hemi-diaphragmatic paralysis between patients receiving high and low volume interscalene blocks (P= 0.894) [10]. This discrepancy in findings could be attributed to the use of different local anesthetics; while the present study utilized 0.5% bupivacaine, Khanna et al. used 0.75% ropivacaine. Zhai et al. had sixty patients undergoing elective arthroscopic shoulder surgery randomly allocated into two groups: before induction of general anesthesia, ultrasound guided ISBPB was performed using 0.5% ropivacaine 10 ml (Group A) or 0.25% ropivacaine 20 ml (Group B). The incidence of diaphragmatic paralysis, respiratory function, and reduction of pulse oxygen saturation at 30 min post-block were recorded and analyzed. Zhai et al. found similar incidence of HD palsy with 10 mL of 0.5% bupivacaine and 20 mL of 0.25% bupivacaine [11]. Different concentrations of the drug may have a role in altering the results of hemi diaphragmatic paralysis. Zhai et al. conducted a study with sixty patients undergoing elective arthroscopic shoulder surgery, randomly assigned to two groups. Before the induction of general anesthesia, ultrasound guided ISBPB was performed using either 0.5% ropivacaine 10 ml (Group A) or 0.25% ropivacaine 20 ml (Group B). The incidence of diaphragmatic paralysis, respiratory function, and reduction in pulse oxygen saturation at 30 minutes post-block were recorded and analyzed.

The study revealed a similar incidence of hemi-diaphragmatic palsy with 10 mL of 0.5% bupivacaine and 20 mL of 0.25% bupivacaine [11]. The different concentrations of the drug may have played a role in influencing the outcomes of hemi-diaphragmatic paralysis. Sala-Blanch et al. had twenty healthy patients undergoing ISB for orthopedic surgery of the upper extremity, randomly allocated to receive either 20 mL 1.5% mepivacaine while proximal digital pressure to the site of puncture was performed, or 40 mL 1.5% mepivacaine without digital pressure. compared 20 mL and 40 mL of 1.5% mepivacaine and found no difference in incidence of HD palsy [12]. Sala Blanch et al. conducted a study with twenty healthy patients undergoing interscalene block (ISB) for orthopedic surgery of the upper extremity. The participants were randomly assigned to receive either 20 mL of 1.5% mepivacaine with proximal digital pressure applied to the site of puncture or 40 mL of 1.5% mepivacaine without digital pressure. The study compared the incidence of hemi-diaphragmatic palsy and found no significant difference between the two groups [12]. In our study we found that there was no statistically significant difference between high volume group and low volume group in regard to postoperative pain within the 48 hours postoperative. We also found that there was no statistically significant difference between high volume group and low volume group in regard to postoperative opioid consumption within the 48 hours postoperative. Khanna et al. discovered that while the Visual Analog Scale (VAS) scores of the two groups were similar in the immediate postoperative period, a significant difference emerged at 6 hours and beyond. Using a larger volume of local anesthetic (LA) resulted in a notable increase in 24-hour fentanyl usage. These findings imply that, even though 15 ml of 0.75% ropivacaine may be more effective for intraoperative and immediate postoperative pain reduction, 10 mL of LA proves more efficacious for delayed postoperative pain relief [10].

Based on previous studies, the effectiveness of shoulder analgesia was observed for at least two hours after shoulder surgery with 50 mg of low dose ropivacaine diluted into 0.75% of 6.7 ml, 0.5% of 10 ml, and 0.25% of 20 ml. Furthermore, Zhai et al. found that interscalene nerve block with 50 mg of ropivacaine provided effective shoulder analgesia for at least 8 hours. They recommended enhanced pain management strategies, such as a reasonably high dose of local anesthetic, multimodal analgesia, or a continuous interscalene block, especially for procedures involving major rotator cuff tears, aligning with the current study's findings [11]. A study was done to assess the analgesic effectiveness of 10 ml versus 20 mL of 0.5% ropivacaine in nerve stimulator-guided interscalene brachial plexus block among patients undergoing arthroscopic shoulder surgery. Seventy patients classified as American Society of Anesthesiologists physical status classes 1 and 2, aged between 18 and 65 years, and undergoing unilateral arthroscopic shoulder surgery were randomly assigned to two groups [13]. In the study, Group A underwent a single shot interscalene block with 20 mL of 0.5% ropivacaine, while Group B received the same block

with 10 ml. The findings revealed that 20 mL of 0.5% ropivacaine exhibited greater efficacy than 10 mL in terms of postoperative analgesia. Despite both groups having comparable Visual Analog Scale (VAS) scores immediately after the operation, notable differences emerged at 6 hours and beyond. Furthermore, the 24-hour fentanyl consumption was significantly higher in the group with a lower volume of local anesthetic [13]. Using ultrasound guided interscalene block in our study may be the reason for the discrepancy in results. Ultrasound gives more precision to the regional block and may produce more accurate and effective block with reduced post operative pain postoperative. In our study, patients who received high volume of bupivacaine had higher frequency of Horner syndrome compared to those who received low volume at the first 12 hours postoperatively. Patients who received high volume of bupivacaine had higher frequency of shortness of breath compared to those who received low volume at the first 12 hours postoperatively. However, all patients did not need any intervention and symptoms resolved spontaneously by the first day post operative. Walid et al. documented a case involving Horner's syndrome following the administration of an ultrasound-guided infraclavicular brachial plexus block using 15 mL of bupivacaine 0.5%. The study highlighted that Horner's syndrome manifests in 100% of patients with an interscalene block of the brachial plexus and may also occur in individuals subjected to other types of supraclavicular blocks. As a precaution, anesthesiologists should be cognizant of this syndrome, and in the event of its occurrence, patients should receive reassurance and close monitoring [14].

Conclusion

The findings of this study suggest that the utilization of low volume interscalene blocks yields comparable analgesic effects to high volumes of interscalene blocks. Furthermore, the study indicates that low volumes are associated to a reduced incidence of side effects and hemi-diaphragmatic paresis.

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