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Effect of Two Different Injection Techniques of Local Anaesthetic in Ultrasound Guided Supraclavicular Brachial Plexus Block on Diaphragmatic Motility

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Abstract

Background: Deposition of local anesthetic (LA) caudal and posterolateral to brachial plexus might result in less hemidaiphragmatic paralysis. Objective was to compare the effect of two different injection techniques of 0.5% Ropivacaine in ultrasound guided supraclavicular brachial plexus block (BPB) on diaphragmatic motility.

Methods: A prospective randomized double-blinded comparative study was conducted among adults undergoing right upper limb surgery. In group A (n = 17), 20 mL 0.5% ropivacaine was injected caudal and posterolateral to the brachial plexus. In group B (n = 17), two aliquots each of 10 mL ropivacaine were injected at two separate locations within the plexus sheath. Diaphragmatic excursion and success of blockade were measured at 15 and 30 minutes.

Results: All patients in group B had sensory and motor blockade in both median and musculocutaneous nerve territories at 15 minutes while it was only in 10 patients (58.82%) in median nerve territory and 7 patients (41.18%) in musculocutaneous nerve territory in group A (P-value< 0.05). At 30 minutes, 17 (100%) patients in group B and 16 (94.12%) patients in group A had successful blockade (p-value>0.05). At 15 minutes, complete hemidiaphragmatic paralysis was seen in 10 (58.82%) patients in group B and three (17.65%) patients in group A (p-value<0.05). At 30 minutes, it was seen in 11 (64.71%) patients in group B and three (17.65%) patients in group A (p-value<0.05).

Conclusion: LA at two sites resulted in more hemidiaphragmatic paralysis with similar block success rate as compared to LA injection at a single site.

Keywords: Brachial plexus block; Diaphragm hemiparesis; Ropivacaine

Declarations

Ethics approval and consent to participate: Ethical approval obtained from the Institutional Review Committee, B.P. Koirala Institute of Health Sciences (Ref, No – IRC/1392/018). Written informed consent was taken from all the participants.

Consent for publication: Informed consent was obtained from patients for participation in research.

Availability of data and materials: The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request. All relevant data are within the manuscript.

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BACKGROUND

Brachial plexus block (BPB) is a valuable method of providing anesthesia for surgery of the arm, elbow, forearm and hand, having advantges of decreased length of hospitalization and superior pain management as well as fewer systemic effects [1]. Ultrasound (USG) guided supraclavicular BPB is usually the technique of choice as it allows the operator to visualize needle placement and its relation to the target nerves in real time [2, 3]. Hence, this helps in more precise delivery of the local anesthetic (LA) injection, use of reduced volume or dose of the LA, faster onset of action and excellent surgical anesthesia with fewer complications [4 - 6].

The safety and efficacy profile of the BPB depends largely on the accuracy of needle insertion into the surrounding structures [1]. Because of close proximity to the brachial plexus, phrenic nerve palsy (PNP) can occur during BPB resulting in ipsilateral hemidiaphragmatic paralysis. The incidence of PNP has been reported to be as high as 100% following interscalene brachial plexus block and 50% to 67% following supraclavicular block guided with nerve stimulation [7]. The occurrence of hemidaiphragmatic paresis during BPB is related to both volume of LA and the drug deposition site [8]. It is presumably due to the spread of LA directly to the phrenic nerve or due to the rostral spread of LA towards C3 to C5 spinal nerve roots [9].

Deposition of LA caudal and posterolateral to the brachial plexus might result in less hemidaiphragmatic palsy. No study has been conducted till now to compare the effects of two different injection techniques of LA in USG guided supraclavicular BPB on hemidiaphragmatic palsy. The objective of the study was to compare the effect of two different injection techniques of 0.5% ropivacaine in USG guided supraclavicular brachial plexus block on diaphragmatic motility.

METHODS

This was a prospective randomized double-blinded comparative study done among the patients undergoing right upper distal two-third limb surgery under supraclavicular BPB. It was conducted at routine operation theatre, B. P. Koirala Institute of Health Sciences, Dharan, Nepal during the period of April 2019 to March 2022. Ethical clearance was taken from Intuitional Review Committee of BPKIHS (IRC/1392/018) prior to initiation of the study. Study objectives were explained to the patients and written informed consent was taken before enrollment into the study.

Patients undergoing elective right upper limb surgery under supraclavicular brachial plexus block of either gender, aged between 18 to 65 years and American Society of Anesthesiologists Physical Status I and II were purposively enrolled in the study. Patient's refusal to participate, surgery of the left upper limb, patients weighing less than 40 kg, known allergy to ropivacaine, infection at the site of injection, patients with preexisting neurological deficit or respiratory diseases and patients with bleeding disorder or coagulopathy were excluded.

The patients were divided into either of the following two study groups:

i. Group A (n = 17): 20 mL of 0.5% ropivacaine was injected in a such manner that it remained confined caudal and posterolateral to the brachial plexus.

ii. Group B (n = 17): Two aliquots of 10 mL 0.5% ropivacaine were injected each at two separate locations within the plexus sheath.

The group allocation was done randomly via a computer-generated random number sequence. For blinding, envelopes were prepared with numbers indicating the sequence of the patient on outside of the envelope and the allocated group inside. Both the patient and the anesthesiologist (who assessed the study outcome) were blinded to the study group. The USG guided supraclavicular block was performed by an expert anaesthesiologist who was not involved in assessment of the outcome.

A self-designed proforma was used to collect the relevant data such as sociodemographic data (age, gender, weight, diagnosis, surgery), heart rate, respiratory rate, systolic blood pressure, diastolic blood pressure, mean arterial blood pressure, oxygen saturation, diaphragmatic excursion, sensory and motor blockade, pain on tourniquet application, complications, and grading of operative condition.

Pre-anesthetic evaluation of the eligible patients was done one day prior to the surgery. Routine non-invasive standard monitoring (electrocardiogram, non-invasive blood pressure, pulse oximetry) was started and the baseline values were recorded. Intravenous access was secured. The patients were positioned in slight oblique position, with the patient's head turned away from the side to be blocked. The skin was disinfected using povidone iodine. The high frequency (8-14 MHz) linear transducer of the portable ultrasound machine (Sonosite Edge II, SonoSite, Inc, USA) was wrapped in a sterile glove. Sterile lubricating jelly was used for the scan. The transducer was positioned in the transverse plane immediately superior to the clavicle at approximately its midpoint. It was tilted caudally to obtain a cross-sectional view of the subclavian artery. The subclavian artery was seen as anechoic,

hypodense, pulsatile and round structure. Its identity was further confirmed by color Doppler. The brachial plexus was seen lateral and superficial to the artery.

Under all aseptic precautions local infiltration of 1 mL 2% lidocaine was given at the needle insertion site. A 22-gauge, 5 cm block needle was then inserted in-plane toward the brachial plexus, in a lateral-to-medial direction. After a careful aspiration to rule out intravascular placement, 1 to 2 mL of sterile normal saline was injected to document the proper needle placement. In group A patients, 20 mL of the 0.5% ropivacaine was then injected in a such manner that it remained confined caudal and posterolateral to the brachial plexus. In group B patients, two aliquots of 10 mL 0.5% ropivacaine were injected each at two separate locations within the plexus sheath. The patients were then assessed for sensory and motor block at 15 and 30 minutes after the injection. Both sensory and motor blocks were graded in 3 point scale. Sensory block in the territories of median nerve (palmar surface of index finger), ulnar nerve (palmar surface of little finger), radial nerve (dorsal surface of first web space/thumb) and musculocutaneous nerve (lateral side of volar surface of forearm) were assessed by pinprick test using a 3-point scale: 0 - normal sensation, 1 - loss of sensation of pinprick (analgesia), 2 - loss of sensation of touch (anaesthesia). Motor block was evaluated by thumb flexion/opposition (median nerve), thumb extension (radial nerve), finger abduction (ulnar nerve) and elbow flexion with forearm in full supination (musculocutaneous nerve) on a 3-point scale for motor function: 0 - normal motor function, 1 - reduced motor strength but able to move, 2 - complete motor block.

After successful block, all patients received injection paracetamol 15mg/kg intravenous (i.v.) infusion and injection fentanyl 0.5mcg/kg i.v. before start of the surgery. Then surgery was permitted. When vascular tourniquet was applied, tourniquet inflation and deflation time were noted and discomfort or pain with its application if any was recorded in numerical rating scale. The pain was managed with injection fentanyl 0.5 mcg/kg i.v. bolus. Grading of the operating condition was done by the operating surgeon as very satisfactory, satisfactory and dissatisfied. Inadequate block requiring intraoperative analgesics, no blockade even after 30 minutes of drug administration and patient requiring general anaesthesia were taken as unsuccessful block.

Successful blockade was defined as complete sensory blockade (sensory block score = 2 in all four terminal nerve distributions) assessed 15 and 30 minutes after local anesthetic injection.

The assessment of diaphragmatic motility was done by the second anaesthesiologist who was not involved in performing the block. Diaphragmatic excursion was measured using ultrasonography (Sonosite Edge II, SonoSite, Inc, USA). With the patient in a supine position, a 4-MHz curvilinear ultrasound probe was used to scan subcostally between the right anterior axillary and midclavicular lines, using the liver as an acoustic window. The probe was directed medially, cephalad, and dorsally such that the beam was focused on the posterior third of the right hemidiaphragm. When optimal image was obtained, patients were be asked to perform a "deep breathing" (DB) maneuver, inhaling deeply through the mouth up to vital capacity and then exhaling slowly. Each patient performed three DB maneuvers. Diaphragmatic excursion from baseline was measured in centimeters using the digital calipers on the ultrasound machine interface in M-mode. Diaphragmatic excursions was measured before USG guided supraclavicular block and again at 15 and 30 minutes after block. Three readings of DB maneuver were taken at each observation period, and average of the three was recorded. Hemidiaphragmatic paralysis was categorized as complete (greater than 75% reduction in diaphragmatic excursion in the deep breathing test from baseline), partial (a 25% to 75% reduction indiaphragmatic excursions in the deep breathing test from baseline) and no (less than 25% reduction in diaphragmatic excursions in the deep breathing test from baseline).

The collected data were entered in Microsoft Excel 2010. Decsriptive statistics such as mean and standard deviation (SD) wer estimated for quantitative variables. Frequency and percentage were calculated for categorical variables. Independent t test was used to compare the mean values of two groups. Chi-square test was used to compare the effect of local anaesthetics and categorical variables. Data was analyzed using the Statistical Package for Social Science (version 11.5 for windows, SPSS) and p-value less than 0.05 was considered as statistical significant for all analysis.

The sample size was based on a pilot study conducted in 20 patients (10 in each group). Based on the result of this pilot study, considering 95% confidence interval and 80% of power and using the formula $n = (Z\alpha/2+Z\beta)2 * [P1(1-P1)+P2(1-P2)] / (P1-P2)2$ it was estimated that the required total sample size was 34. Hence, we allocated a total of 34 participants divided into two groups.

RESULTS

Both groups (A and B) were similar with respect to age, gender, weight and ASA PS, diagnosis and hemodynamic profiles **(Table 1).**

Table 1: Baseline socio-demographic profileof the patients (n=34). Values are presented as mean ± SD or number (%)

Variables		Group A (n = 17)	Group B (n = 17)	p-value
Age (Years)		31.94 ± 12.54	30.88 ± 11.82	0.80*
Gender	Male, n(%)	13 (76.47)	10 (58.82)	0.46$
	Female, n(%)	4 (23.53)	7 (41.18)	
Weight (Kg)		58.65 ± 8.90	55.71 ± 8.41	0.32*
ASA-PS	I	16 (94.12)	16 (94.12)	1.00$
	II	1 (5.88)	1 (5.88)	
Diagnosis	Below elbow	15 (88.24)	15 (88.24)	1.00$
	At elbow	2 (11.76)	2 (11.76)	
Pulse rate (per mins)		76.65 ± 6.95	74.65 ± 8.40	0.45*
Systolic BP (mmHg)		119.29 ± 12.82	125.06 ± 11.83	0.18*
Diastolic BP (mmHg)		70.59 ± 7.89	74.12 ± 6.18	0.15*
SpO2		98.06 ± 1.24	98.41 ± 0.79	0.33*
Respiration rate (per mins)		16.76 ± 2.10	16.65 ± 2.14	0.87*

* Student t test; $ Chi-square test
ASA-PS: American Society of Anesthesiologist's Physical Status; BP: Blood pressure

All patients in the group B had sensory blockade in median and musculocutaneous nerve territories at 15 minutes and 30 minutes after the BPB; however, in group A, only 10 (58.82%) patients had sensory blockade in median nerve territory at 15 minutes and 7 (41.18%) patients in musculocutaneous nerve territory at 15 minutes and it was statistically significant ($p < 0.05$) **(Tables 2).**

Table 2: Assessment of sensory blockade in median and musculo-cutaneous nerve block. Values are presented as number (%)

Observation time (minutes)	Characteristics	Group A (n = 17)	Group B\ (n = 17)	p-value
Median Nerve				
	Normal sensation	0 (0.0)	0 (0.0)	
15	Analgesia	7 (41.18)	0 (0.0)	**0.007**
	Anesthesia	10 (58.82)	17 (100.0)	
	Normal sensation	0 (0.0)	0 (0.0)	
30	Analgesia	1 (5.88)	0 (0.0)	>0.99
	Anesthesia	16 (94.12)	17 (100.0)	
Musculo-cutaneous Nerve				
	Normal sensation	2 (11.76)	0 (0.0)	
15	Analgesia	8 (47.06)	0 (0.0)	**0.001**
	Anesthesia	7 (41.18)	17 (100.0)	
	Normal sensation	1 (5.88)	0 (0.0)	
30	Analgesia	0 (0.0)	0 (0.0)	>0.99
	Anesthesia	16 (94.12)	17 (100.0)	

*Statistically significant at P-value < 0.05 (Chi-square t test).

In group B, 16 (94.12%) and 17 (100.0%) patients had sensory blockade in ulnar and radial nerve territories at 15 minutes after the BPB respectively; however, in group A, only 15 (88.24%) patients had sensory blockade in both ulnar and radial nerve territory at 15 minutes; however, it was statistically not significant ($p > 0.05$) **(Tables 3).**

Table 3: Assessment of sensory blockade in ulnar and radial nerve block. Values are presented as number (%)

Observation time (minutes)	Characteristics	Group A (n = 17)	Group B (n = 17)	p-value
Ulnar Nerve				
	Normal sensation	0 (0.0)	0 (0.0)	
15	Analgesia	2 (11.76)	1 (5.88)	>0.99
	Anesthesia	15 (88.24)	16 (94.12)	
	Normal sensation	0 (0.0)	0 (0.0)	
30	Analgesia	1 (5.88)	0 (0.0)	>0.99
	Anesthesia	16 (94.12)	17 (100.0)	
Radial Nerve				
	Normal sensation	0 (0.0)	0 (0.0)	
15	Analgesia	2 (11.76)	0 (0.0)	0.48
	Anesthesia	15 (88.24)	17 (100.0)	
	Normal sensation	0 (0.0)	0 (0.0)	
30	Analgesia	0 (0.0)	0 (0.0)	NA$
	Anesthesia	17 (100.0)	17 (100.0)	

*Statistically significant at P-value < 0.05 (Chi-square t test); $NA: Not applicable

All patients in group B had motor blockade in median and musculocutaneous nerve territories at 15 minutes after the BPB; however, in group A, only 10 (58.82%) patients had motor blockade in median nerve territory and it was statistically significant ($p < 0.05$). At 30 minutes after the BPB, 17 (100%) patients in group B and 16 (94.12%) patients in group A had successful motor blockade in median and musculocutaneous nerves; however, it was tatistically not significant ($p > 0.05$) **(Table 4).**

Table 4: Assessment of motor functions in median nerve (thumb flexion) and musculocutaneous nerve (elbow flexion). Values are presented as number (%)

Observation time (minutes)	Characteristics	Group A (n = 17)	Group B (n = 17)	p-value
Median Nerve (Thumb Flexion)				
	Normal motor function	1 (5.88)	0 (0.0)	
15	Reduced motor strength, but able to move fingers	6 (35.29)	0 (0.0)	0.012*
	Complete motor block	10 (58.82)	17 (100.0)	
	Normal motor function	1 (5.88)	0 (0.0)	
30	Reduced motor strength, but able to move fingers	0 (0.0)	0 (0.0)	>0.99
	Complete motor block	16 (94.12)	17 (100.0)	
Musculocutaneous nerve (elbow flexion)				
	Normal motor function	1 (5.88)	0 (0.0)	
15	Reduced motor strength, but able to move fingers	7 (41.18)	0 (0.0)	0.05
	Complete motor block	9 (52.94)	17 (100.0)	
	Normal motor function	1 (5.88)	0 (0.0)	
30	Reduced motor strength, but able to move fingers	0 (0.0)	0 (0.0)	>0.99
	Complete motor block	16 (94.12)	17 (100.0)	

*Statistically significant at P-value < 0.05 (Chi-square t test).

Similarly 12 (70.59%) patients in group A and 16 (94.12%) patietns in group B had motor blockade in ulnar nerve at 15 minutes after the BPB; however, it was statistically not significant ($p > 0.05$). Fourteen (82.35%) patients in group A and 17 (100%) patients in group B had motor blockade in radial nerve at 15 minutes after the BPB; however, it was statistically not significant ($p > 0.05$). All patient in both the groups had complete motor blockade at 30 minutes after BBB in all nerve territories ($p > 0.05$) **(Table 5).**

Table 5: Assessment of motor functions in ulnar nerve (finger abduction) and radial nerve (thumb extension). Values are presented as number (%)

Observation time (minutes)	Characteristics	Group A (n=17)	Group B (n=17)	p-value
Ulnar Nerve (Finger abduction)				
15	Normal motor function	0 (0.0)	0 (0.0)	0.17
	Reduced motor strength, but able to move fingers	5 (29.41)	1 (5.88)	
	Complete motor block	12 (70.59)	16 (94.12)	
30	Normal motor function	0 (0.0)	0 (0.0)	NA$
	Reduced motor strength, but able to move fingers	0 (0.0)	0 (0.0)	
	Complete motor block	17 (100.0)	17 (100.0)	
Radial nerve (Thumb extension)				
15	Normal motor function	0 (0.0)	0 (0.0)	0.07
	Reduced motor strength, but able to move fingers	3 (17.65)	0 (0.0)	
	Complete motor block	14 (82.35)	17 (100.0)	
30	Normal motor function	0 (0.0)	0 (0.0)	NA$
	Reduced motor strength, but able to move fingers	0 (0.0)	0 (0.0)	
	Complete motor block	17 (100.0)	17 (100.0)	

$NA: Not applicable

At 15 minutes, complete hemidiaphragmatic paralysis was seen in 10 (58.82%) patients in group B and only in three (17.65%) patients in group A and it was statistically significant ($p < 0.05$) **(Figure 1a).** At 30 minutes, complete hemidiaphragmatic paralysis was seen in 11 (64.71%) patients in group B patients and only in three (17.65%) patients in group A and it was statistically significant ($p < 0.05$) **(Figure 1b).**

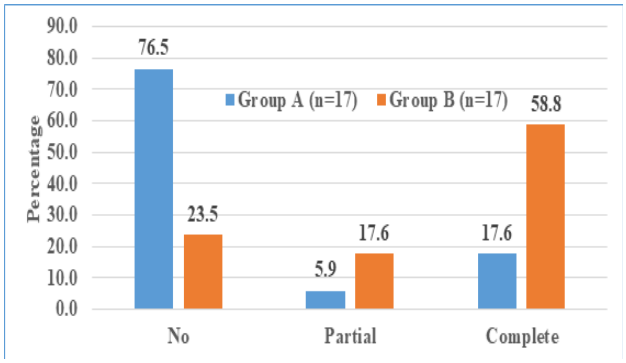

Figure 1a: Effect on diaphragmatic hemiparesis in group A and B patients at 15 minutes

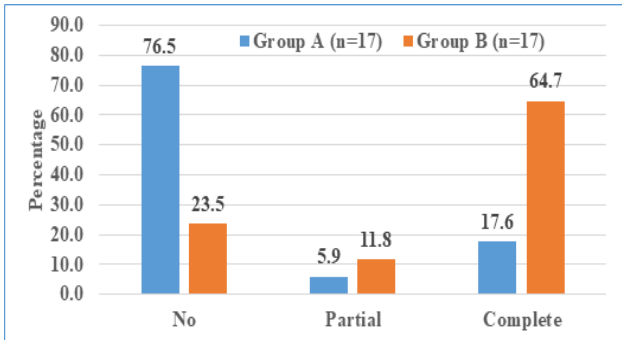

Figure 1b: Effect on diaphragmatic hemiparesis in group A and B patients at 30 minutes

Horner syndrome was present in four patients (23.53%) in group B and was absent in all patients in group A; however, it was statistically not significant ($p > 0.05$). Operating condition was very satisfactory in nine patients (52.94%) in group A and in 13 patients (76.47%) in group B; however, it was statistically not significant ($p > 0.05$) **(Table 6).** Oxygen saturation was measured in both groups after BPB. None of the patients were desaturated after the

Table 6: Effect on tornuqet pain, complications and operating condition in group A and B patients. Values are presented as number (%)

Variables		Group A (n = 17)	Group B (n = 17)	p-value
Torniquet pain	Yes	1 (5.88)	0 (0.0)	>0.99
	No	16 (94.12)	17 (100.)	
Horners syndrome	Present	0 (0.0)	4 (23.53)	0.1
	Absent	17 (100.0)	13 (76.47)	
Operating condition	Dissatisfied	1 (5.88)	0 (0.0)	0.075
	Satisfactory	9 (52.94)	4 (23.53)	
	Very satisfactory	7 (41.18)	13 (76.47)	

block.

DISCUSSION

In the present study, we have compared the effect of two different injection techniques of 0.5% Ropivacaine in USG guided supraclavicular BPB on diaphragmatic motility. It was interesting to find out that although the rate of successful blockade was similar in both the groups at the end of 30 minutes after BPB the incidence of complete hemidiphragmatic paralysis was significantly higher in group B as compared to group A at both 15 and 30 minutes of BPB. The inference of this finding is that single injection technique of LA confined to caudal and posterolateral to the brachial plexus resulted in less incidence of complete hemidiaphragmatic paralysis with similar success rate of the nerve blockade as compared to the double injection of LA at two separate locations within the brachial plexus sheath. This finding was similar to Renes et al in which they did not find any case of diaphragmatic hemiparesis with 100% success rate of the blockade when the LA was injected caudal and posterolateral to the brachial plexus [9]. Kang et al found that hemi-diaphragmatic paresis was around 67% when larger volume of LA was injected in nerve cluster versus 28% when larger volume of local anaesthetic was injected in corner pocket [10]. In another study by Petrar et al, 30mL of 0.5 % ropivacaine was deposited at multiple injection site and one third (34%) of the patients had complete hemidiaphragmatic paresis [11]. Only 10% of the patient had diaphragmatic hemiparesis when only 5mL of the solution was deposited in nerve cluster in another study [12]. These variation in diaphragm dysfunction could be due to the difference in volume of LA used, the injection techniques and the injection sites. The variation in individual's skill in delivery of the LA drug and the observer's variation in the assessment of the nerve function might have also influenced the outcome.

Although the success rate of sensory and motor blockade in both group patietns was similar at the end of 30 minutes after BPB, onset of anesthesia was delayed after 15 minutes of BPB in the group A patients as compared to the group B patients; this might be due to caudal and posterolateral deposition of LA that lead to delayed spread to the brachial plexus nerves. None of the patients in both groups desaturated after the block although some had diaphragmatic dysfunction. The patients with normal respiratory reserve can tolerate hemidiphragmatic dysfunction/ paralysis after BPB block; but patients with compromised respiratory reserve would not tolerate hemidiphragmatic dysfunction/paralysis after BPB block. Further study in patients with compromised respiratory reserve using the single injection BPB technique confined to caudal and posterolateral to the brachial plexus would establish the findings of the present study.

None of the patients in our study required any rescue block and in contrast to this, two patients received rescue block local infiltration in a study by Petrar et al [11]. Requirement of rescue block in their study case could be due to imprecise drug deposition site. Deposition of LA caudally and posterolateral can possibly prevent its rostral spread resulting in sparing of upper nerve roots. About one-fourth of the patients in group B had Horner syndrome as compared to the group A patients. This signifies that single injection technique of LA confined to caudal and posterolateral to the brachial plexus resulted in less complication and similar success rate of the nerve blockade as compared to the double injection of LA at two separate locations within the brachial plexus sheath. About 5.8% patients had tornuquet pain in group in our study and this was not in line with another study in which none of the patient had tourniquet pain [12]. The operating conditions were satisfactory/ very satisfactory in majority of the patients in both the groups. Hence, single injection technique seems to be superior than the double injection techniques used for USG guided supraclavicular BPB.

The present study had some limitations. Anatomical variation in the brachial plexus position as seen via USG might have an impact in our study since we had to deposit the LA agent in precise location. Arterial Blood Gas analysis could not be done and thus we were not able to estimate the level of respiratory compromise that could have been reflected by the changes in blood gas parameters. The total duration of hemidiaphragmatic paresis was also not studied. We did not have any equipments or tools to measure the extent of spread of local anaesthetic. We didn't study about the relative changes that could have occurred in the contralateral lungs and the diaphragm as a result of hemidiaphragmatic paralysis.

CONCLUSION

Single injection technique of LA confined to caudal and posterolateral to the brachial plexus resulted in less incidence of complete hemidiaphragmatic paralysis with similar success rate as compared to the double injection technique of LA at the two separate locations within the plexus sheath during supraclavicular brachial plexus block.

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