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Original article

Assessment of the Incidence of Diaphragmatic Paralysis by Ultrasound After Different Volumes of Supraclavicular Block

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Abstract:

Background: Ipsilateral diaphragmatic paralysis, caused by the retrograde diffusion of the local anesthetic (LA) inside the neural sheath, occurs after supraclavicular blocks, like interscalene blocks. Therefore, we have tried using ultrasonography (US) to evaluate diaphragmatic paralysis after varying volumes of supraclavicular brachial plexus blocks (SCB) Aim: to use an ultrasound to compare the diaphragmatic paralysis incidence with varying amounts of LA volumes used in supraclavicular brachial plexus block. **Methods:** In a randomized controlled clinical study, sixty patients with American Society of Anesthesiologists (ASA) Physical Status I, II&III were randomly assigned to take LA of 25 ml of 0.25% bupivacaine or 30 ml of 0.25% bupivacaine. An in-plane supraclavicular block was conducted under ultrasound guidance. Before and at 30, 45, and 60 minutes after administering the block, diaphragmatic thickness was measured using a linear transducer set to 10 MHz, and diaphragmatic excursion was measured using a curvilinear 3.5 MHz transducer. **Results:** While the diaphragmatic thickness fraction was negligible about the volume, there was a decrease in diaphragmatic excursion in the group that received 30 mL of diaphragmatic excursion reduction. The T-test was used to analyze the pre- and post-block data. In group 2, which received a larger volume, there was less than a 0.05 chance that diaphragmatic excursion would diminish. indicating statistical significance. **Conclusion:** findings imply that even in cases of supraclavicular brachial plexus block, there is a higher chance of unintentional phrenic nerve blocking. The incidence is higher at higher volumes, and the ensuing hemidiaphragmatic paralysis is volume dependent.

Key words: Brachial plexus block, diaphragmatic paralysis, phrenic nerve palsy, supraclavicular

Introduction

Over the last decade, ultrasound (US)-guided brachial plexus blockade using local anesthetics (LA) has seen significant refinement, offering safer and more precise regional anesthesia options, particularly for upper extremity surgeries [1,2]. While these techniques share foundational principles with landmark- and nerve stimulation-guided approaches, ultrasound guidance enhances visualization and accuracy [3].

Regional anesthesia offers substantial benefits over general anesthesia, especially in patients with decreased functions of cardiopulmonary systeme [4]. However, the interscalene approach is accompanied by a universal phrenic nerve paralysis incidence due to the close anatomical relationship between the brachial and phrenic nerves [5,6]. This complication is typically attributed to blockade of the C3–C5 nerve roots, either through direct infiltration within the anterior scalene fascia or through retrograde spread of large-volume local anesthetic [7].

Alternative approaches such as the axillary block avoid this risk but may not provide complete anesthesia for all upper limb procedures [8]. The supraclavicular approach, by anesthetizing the trunks of the brachial plexus as they traverse lateral to the subclavian artery, offers dense anesthesia suitable for most upper limb surgeries [9]. However, despite being anatomically more caudal, it does not eliminate the risk of phrenic nerve involvement [10]. In fact, unintentional hemidiaphragmatic paresis remains a concerning side effect that can lead to clinically significant respiratory compromise in susceptible patients [11].

Current methods to detect phrenic nerve paralysis vary, and no single standardized protocol exists [12]. Ultrasonography has emerged as a preferred tool due to its non-invasive nature, real-time visualization, and high sensitivity in assessing diaphragmatic motion [13,14]. Prior studies suggest that reducing the local anesthetic volume may mitigate the risk of phrenic nerve blockade [15–17].

This study was designed to investigate the incidence and extent of diaphragmatic paralysis following ultrasound-guided supraclavicular brachial plexus blocks using two different volumes of 0.25% bupivacaine. By employing ultrasonography, we aimed to quantify changes in diaphragmatic motion and thickness over time and to explore whether volume reduction correlates with decreased phrenic nerve involvement.

Subjects and Methods

Following ethical approval and clinical trial registration, a prospective, randomized controlled study was conducted from July to December 2018 at Anesthesia Department- Benha University. A total of sixty patients, at age of 20 to 65 years old and classified as American Society of Anesthesiologists (ASA) Physical Status I–III, were enrolled after taking written informed consent. All participants were scheduled for elective upper extremity surgeries under regional anesthesia.

Exclusion criteria included contraindications to regional anesthesia, allergy to local anesthetics, requirements for sedation or general anesthesia, block failure, or the presence of acute or chronic pulmonary disease as (Bronchial asthma and COPD).

Patients were randomly assigned into two groups using a computer-generated to generate a random number list randomization sequence concealed within opaque, sealed envelopes opened by the study investigator, and the method of blinding is double blinding, including participants and assessors. Group 1 received 25 mL and Group 2 received 30 mL of .25% bupivacaine via a supraclavicular brachial plexus block under US guidance.

Patients were positioned supine with their heads turned contralaterally. A high-frequency (12 MHz) linear ultrasound prob

(Sonosite Edge II) was placed in the coronal oblique plane at the midclavicular level to visualize the subclavian artery, brachial plexus, first rib, and pleura. Using an in-plane, posterior-to-anterior needle approach, the local anesthetic was deposited into the “corner pocket” adjacent to the brachial plexus.

Diaphragmatic function was assessed using ultrasonography at baseline (15 minutes prior to the block) and at 30-, 45-, and 60-minutes post-block. Diaphragmatic excursion and thickness fraction were measured using both B-mode & M-mode ultrasound. The average of three consecutive respiratory cycles was used to calculate excursion amplitude and thickness values.

Excursion OF diaphragm was measured with a 3.5 MHz probe in the intercostal view using M-mode, while thickness was measured using a 10 MHz probe placed at the mid-to-anterior axillary line in the ninth intercostal space. Thickness fraction was calculated as the ratio of inspiratory to expiratory thickness, expressed as a percentage.

Paralysis was determined by excursion and thickness values: an excursion <1.5 cm or a thickness fraction <15% indicated high probability of diaphragmatic dysfunction (paralysis), and values above these thresholds, 1.5–2.5 cm or 15–20%, were considered normal.

The outcome was the incidence of hemidiaphragmatic paralysis. and in some cases, outcomes include developing dyspnea & orthopnea. the correlation of paralysis with demographic variables such as age, sex, and body mass index (BMI). Data were analyzed using the student’s t-test, with statistical significance defined as a p-value <.05. Graphs and tables were generated using Microsoft Excel and Word **(Figure1,2).**

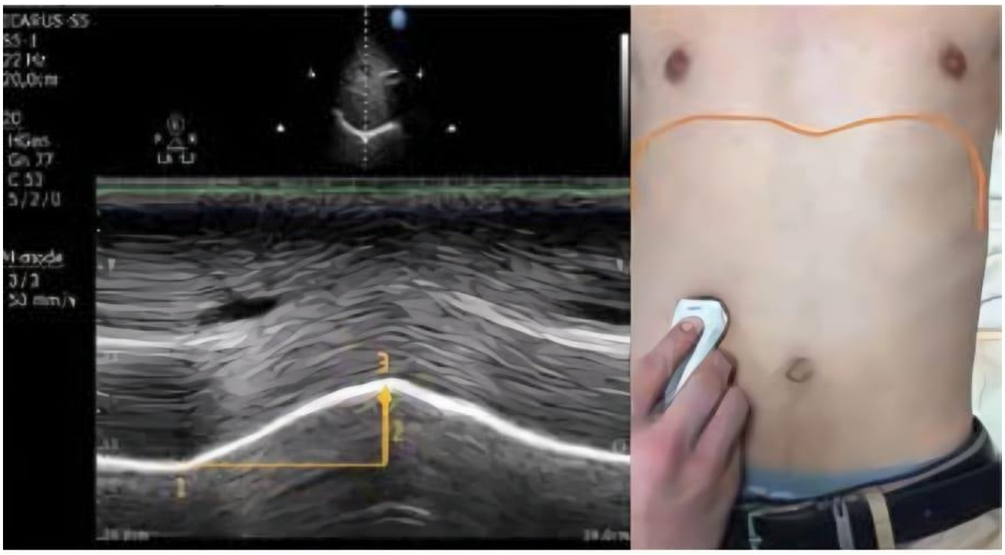


Figure1. M-mode US of the diaphragm 1) Diaphragm at the end of expiration 2) Diaphragm movement 3) Diaphragm at end of inspiration

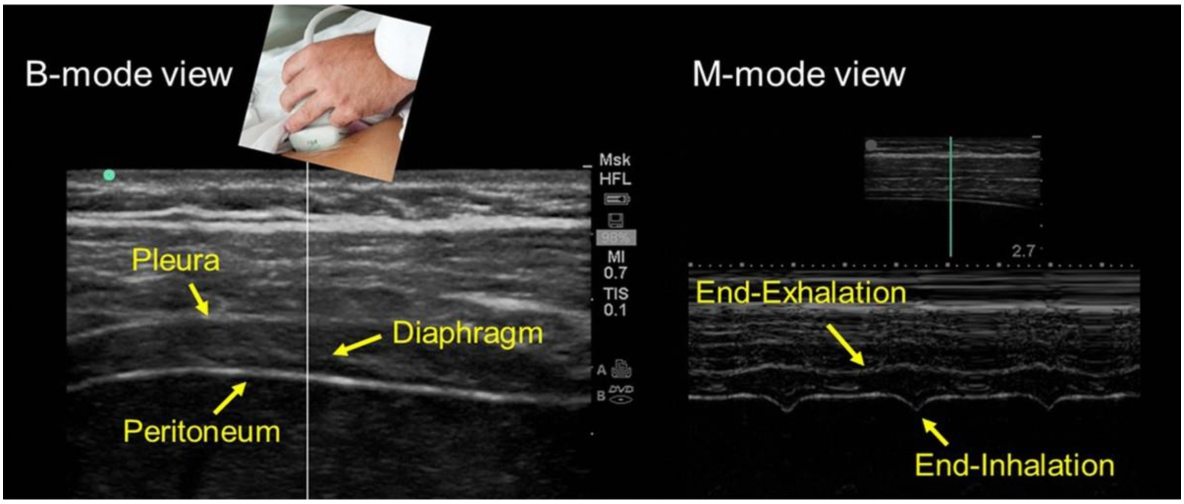


Figure 2. Diaphragmatic thickness by M-mode and B-mode ultrasound

Approval code: MD 4-6-2023

Statistical Analysis

Data management and statistical analysis was done using SPSS version 28 (IBM, Armonk, New York, United States). Quantitative data were assessed for normality using the Kolmogorov–Smirnov test. According to normality, quantitative data were summarized either mean and standard deviation or median and range. Categorical data were summarized as numbers and percentages. Quantitative data were compared between any two unpaired groups using unpaired t-test or Mann-Whitney U test. Comparison between same group during different points of time was done using Homogeneity test for repeated measures. Categorical data were compared using Chi-square and Fisher's exact. All statistical tests were two-sided. P values less than or equal to 0.05 were considered significant.

Sample size justification:

We used G*Power 3.1.9.7 to calculate sample size. Based on a previous study done by Johnson and Daniel, 2022. with a power of 80% and α-error 0.05. A two-tailed t-test was used. The calculated effect size was 0.77. Twenty-eight patients in each group were determined. We considered thirty patients in each group to overcome the dropout.

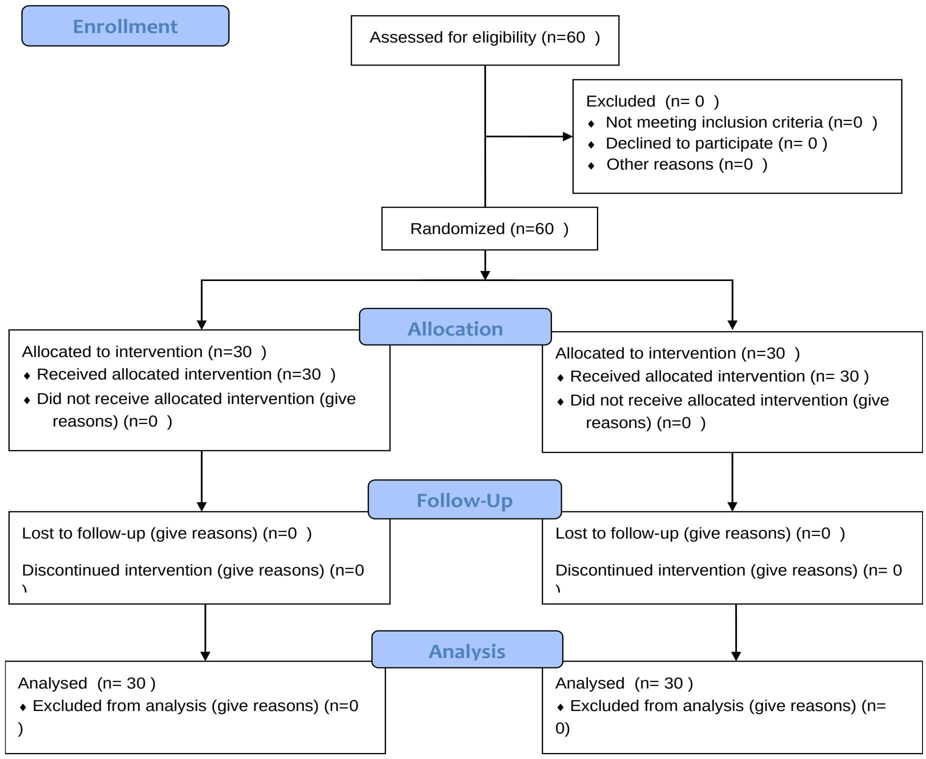
Missing data:

In our study, all planned diaphragmatic excursion (DE) and thickness fraction measurements were successfully obtained in all 60 patients at each time point. No ultrasound assessments were incomplete or excluded due to technical failures.

Since no data were missing, no imputation methods were required.

Results

CONSORT 2010 Flow Diagram



Our study comprised sixty patients. They were divided into two groups at random. The two groups' demographics in terms of age, sex, and BMI were similar (Table 1). Every patient's upper limb experienced sufficient neurological blockages.

Both groups had similar baseline values for heart rate, saturation, diaphragmatic excursion, mean arterial blood pressure, and thickness fraction (Tables 2,3,4,5,6).

Table 1: Demographic terms

	Group 1	Group 2	P-value
Age (yrs.)	36.10±8.05	34.94±12.67	0.673
Sex (M: F)	17:12	26:6	0.053
BMI (Kg/m^2)	28.53±.986	28.28 ± .888	0.33
ASA (I: II)	24:5	25:7	0.87

Table 2: Mean arterial blood pressure before and after block.

MAP (mmHg)	Group 1	Group 2	P-value
15 before block	70.41±10.618	67.94±11.069	0.377
30 min after block	66.76 ±9.553	65.63 ±11.233	0.674
45 min after block	66.28 ±8.392	68.00 ±10.510	0.485
1 hr. after block	64.34±8.04	67.00 ±9.890	0.25

Table 3: Heart rate before and after block

HR (beat/min)	Group 1	Group 2	P-value
15 before block	79.93 ± 10.928	73.63±11.967	0.036
30 min after block	78.17± 11.212	73.81± 11.131	0.133
45 min after block	78.21 ± 11.321	75.69 ± 12.597	0.416
1 hr after block	80.97 ± 13.25	76.56 ± 14.341	0.21

Table 4: Spo2 before and after block

SPO_2 %	Group 1	Group 2	P-value
15 before block	98.86±0.990	98.88±1.38	0.96
30 min after block	98.9±1.04	98.5±1.01	0.13
45 min after block	98.3±0.966	98.69±1.33	0.63
1 hr after block	99 ±0.743	98.88 ± 1.289	0.64

Table 5: Diaphragmatic excursion before and after block

DE (cm)	Group 1	Group 2	P-value
15Min before	2.45 ± 0.192	2.67 ± 0.194	<0.001
30 min after block	2.43 ± 0.213	2.08 ± 0.289	<0.001
45 min after block	2.44±0.201	1.52±0.554	<0.001
1 hr. after DE	2.50± 0.430	1.140 ± 0.700	<0.001
% of patients with complete paralysis (DE < 1.5cm)	0	26 (78%)	<0.001

Table 6: Diaphragmatic thickness fraction before and after block

TF %	Group 1	Group 2	P-value
15 Min before	24.1 ± 2.04	25.34± 1.55	0.09
30 min after block	24.31 ± 2.10	25.06 ± 1.93	0.15
45 min after block	24.69 ±2.28	25.31 ± 1.89	0.24
1hr after	24.24 ± 2.08	26.19 ± 8.12	0.21

When comparing the before block, 15 minutes, 30 minutes, and 45 minutes after block values in both groups, there is a significant difference in diaphragmatic excursion (P > .001, .001, .001 in groups 2). The incidence of complete diaphragmatic paralysis (DE< 1.5cm) in group 1 is 0% and in group 2 is 78% and about an insignificant difference in the diaphragmatic thickness fraction (P = 0.15, 0.24, and 0.21 in groups 1 and 2, respectively) .The lack of significant change in contradicts prior studies has Potential explanations include: (1) Our sample size (n=60) may have been underpowered to detect small DTF changes, (2) most of our patients' TF measurements in most of our patient were in the lateral position which improve diaphragmatic TF by make less abdominal compression, better expansion of lung and improve diaphragmatic visualization. (Table 5, 6). (Figure 3, 4)

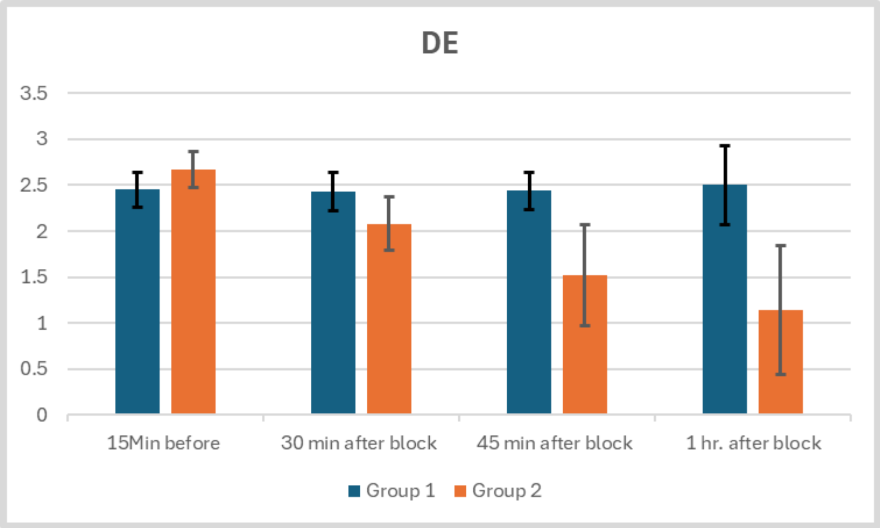


Figure 3: Diaphragmatic excursion at 15 min before block and 30 min,45 min & 1 hour after block

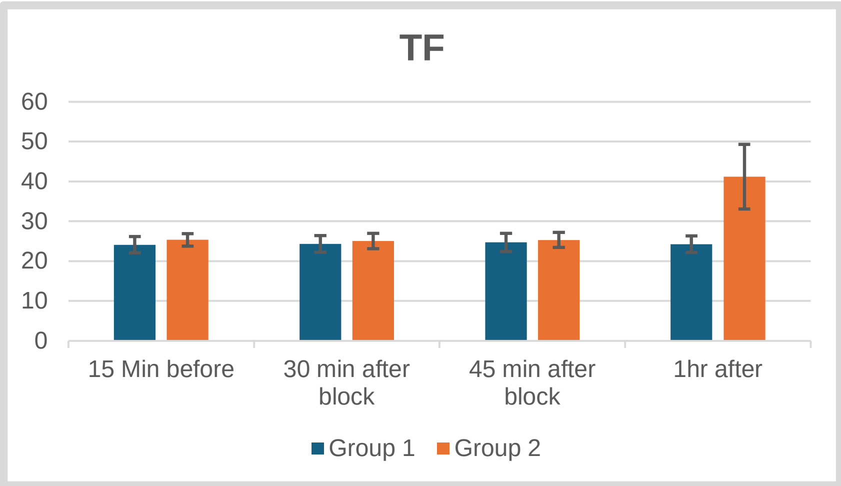


Figure 4: Diaphragmatic thickness fraction at 15 min before block and 30 min ,45 min & 1 hour after block

Many facilities aim for an average local anesthetic volume of 20–30 ml, even though there is no consensus on the minimum volume of medication necessary for SCB. Although the use of US-guided nerve blocks is lower than that of nerve stimulation techniques, they nonetheless consume larger volumes—up to forty milliliters. In this study, we used US-guided SCB to compare two volumes of twenty-five & 30 mL and record the paralysis incidence of diaphragm. Diaphragmatic paralysis has historically been evaluated with computed tomography, magnetic resonance imaging, fluoroscopic sniff testing, and chest radiography. They are not used much in the operating room, though. An easy and accurate method for diagnosing diaphragmatic paralysis is ultrasonography. Diaphragmatic excursion and thickness fraction values in M-mode

The ultrasound was employed in our investigation to assess diaphragmatic paralysis.

The hidden incidence of diaphragmatic paralysis in different SCB volumes was revealed by this investigation. Complete paralysis was not common in the 25 mL group; instead, it was more common in the 30 mL group. Consequently, the hemidiaphragmatic paralysis increases in volume.

Sample size justification:

We used G*Power 3.1.9.7 to calculate sample size. Based on previous study done by Johnson and Daniel, 2022. with a power of 80% and α- α-error 0.05. Two tailed t- test was used. The calculated effect size was 0.77. Twenty-eight patients in each group were determined. We considered thirty patients in each group to overcome the dropout.

Missing data:

In our study, all planned diaphragmatic excursion (DE) and thickness fraction measurements were successfully obtained in all 60 patients at each time point. No ultrasound assessments were incomplete or excluded due to technical failures.

Since no data were missing, no imputation methods were required**.**

Discussion

One of the primary advantages of ultrasound-guided peripheral nerve blocks is the ability to monitor the spread of local anesthetic in real time, allowing for precise deposition around the target nerves. This visual control significantly reduces the volume of anesthetic required, which in turn minimizes the risk of systemic toxicity and unintended complications [14,15].

In recent years, considerable attention has been directed toward defining the minimum effective volume (MEV) for supraclavicular brachial plexus blocks (SCB) under ultrasound guidance. Duggan et al. [16] employed the Dixon and Massey up-and-down method and determined the minimum effective volume for 50% and 95% of patients to be 23 mL and 42 mL, respectively. However, this method's applicability to routine clinical practice remains debatable [17].

Building on this, Jeon et al. [18] randomized 120 patients to receive varying volumes of 1% mepivacaine. Their findings suggested that a 30 mL volume provided successful blockade in 90% of cases. Similarly, Fang et al. [19] identified 0.257% as the lower effective ropivacaine concentration of in 90% of patients. A study by Jadranka Pavičić Šarić et al. [20] highlighted age-related variability, reporting an MEV95 of 44.52 mL in younger patients versus only 16.49 mL in older individuals, indicating that age is a relevant factor in volume titration.

Historically, supraclavicular blocks performed with nerve stimulator guidance, such as in Mak et al's study [2], showed a 50% incidence of complete hemidiaphragmatic paralysis using .5% bupivacaine at .5 mL/kg. Notably, even lower volumes (20–30 mL) were associated with 40–45% incidence of reduced or absent diaphragmatic motion, emphasizing the consistent risk of phrenic nerve involvement. [21]

In a retrospective analysis at Showa University Hospital
(Jaban), Ueshima & Otake [22] observed no diaphragmatic paralysis with 10 mL of levobupivacaine, while incidences rose to 14.6% and 29.4% in the 15 and 20 mL groups, respectively. However, these findings were based on chest radiography—a less sensitive method compared to ultrasound.

In contrast, our study employed diaphragmatic ultrasonography, offering more sensitive and dynamic assessment of phrenic nerve function. We found the hemidiaphragmatic paralysis incidence was more in the 30 mL group compared to the 25 mL group, supporting the hypothesis that volume plays a key role in phrenic nerve involvement.

Interestingly, despite radiologically confirmed diaphragmatic dysfunction, none of the patients experienced significant clinical deterioration. Vitals mesurements like oxygen saturation, heart rate, and mean arterial blood pressure remained stable across both groups. This aligns with previous findings that phrenic nerve paralysis, although frequent, may be well tolerated in patients with normal pulmonary reserve.

While interscalene blocks are commonly associated with phrenic nerve involvement, they are often used with low volumes to reduce this risk ,High incidence of hemidiaphragmatic paralysis Up to 100% of patients develop temporary phrenic nerve palsy with a 30 mL volumeThis is due to the close proximity of the phrenic nerve to the brachial plexus at the interscalene level (C5–C7) roots,while the incidence of hemidiaphragmatic paralysis in SCB is less as The phrenic nerve is more anterior and medial at this level, and somewhat further from the injection site. However, their reliability in providing surgical anesthesia for the entire upper limb remains variable. Several modalities, including fluoroscopy and pulmonary function testing, have been explored to detect phrenic nerve impairment, yet ultrasound remains the most practical and sensitive bedside tool.

Clinical implications:

Our findings emphasize the importance of cautious volume selection in SCB, especially in patients with preexisting pulmonary compromise. Further research is warranted to precisely determine the minimal effective volume that ensures adequate surgical anesthesia while preserving diaphragmatic function. So, usage of 25ml of Lamay balance efficacy and safty in patients with normal pulmonary reserve.

Limitations:

Acknowledge the single-center design, homogenous population (ASA I, II&III), and lack of long-term follow-up.

Conclusion

This study shows that US-guided supraclavicular brachial plexus blocks are associated with a significant, volume-dependent risk of ipsilateral diaphragmatic paralysis. While even the lower volume of 25 mL resulted in a less incidence of phrenic nerve involvement, the 30 mL volume was linked to a notably higher diaphragmatic dysfunction. Importantly, these radiologic findings did not translate into clinically significant respiratory compromise in our study population. Nevertheless, caution is advised, particularly in patients with limited pulmonary reserve. Our results underscore the need for further research aimed at identifying the lowest effective anesthetic volume that balances efficacy with safety. ensure anonymity, but complete anonymity cannot be guaranteed.

Sponsorship and financial assistance

Nil

Conflicts of interest

No existing conflicts of interest.

References

1. Ayoub J, Cohendy R, Dauzat M, Targhetta R, De la Coussaye JE, Bourgeois JM, et al. Non-invasive quantification of diaphragm kinetics using M-mode sonography. Can J Anaesth. 1997;44(7):739–44.

2. Ayoub J, Metge L, Dauzat M, Lemerre C, Pourcelot L, Préfaut C, et al. Diaphragm kinetics coupled with spirometry: mode ultrasonographic and fluoroscopic study; preliminary results. J Radiol. 1997;78(7):563–8.

3. Boon AJ, Sekiguchi H, Harper CJ, Strommen JA, Ghahfarokhi LS, Watson JC, et al. Sensitivity and specificity of diagnostic ultrasound in the diagnosis of phrenic neuropathy. Neurology. 2014;83(14):1264–70.

4. Boussuges A, Rives S, Finance J, Brégeon F. Assessment of diaphragmatic function by ultrasonography: current approach and perspectives. World J Clin Cases. 2020;8(12):2408–24.

5. Casati A, Baciarello M, Di Cianni S, Danelli G, De Marco G, Leone S, et al. Effects of ultrasound guidance on the minimum effective anaesthetic volume required to block the femoral nerve. Br J Anaesth. 2007;98(6):823–7.

6. Duggan E, Beheiry HE, Perlas A, Lupu M, Nuica A, Chan VW, et al. Minimum effective volume of local anesthetic for ultrasound-guided supraclavicular brachial plexus block. Reg Anesth Pain Med. 2009;34(3):215–8.

7. Fang G, Wan L, Mei W, Yu HH, Luo AL. The minimum effective concentration (MEC90) of ropivacaine for ultrasound-guided supraclavicular brachial plexus block. Anaesthesia. 2016;71(6):700–5.

8. Houston JG, Fleet M, Cowan MD, McMillan NC. Comparison of ultrasound with fluoroscopy in the assessment of suspected hemidiaphragmatic

movement abnormality. Clin Radiol. 1995;50(2):95–8.
9. Jeon DG, Kim SK, Kang BJ, Kwon MA, Song JG, Jeon SM. Comparison of ultrasound-guided supraclavicular block according to various volumes of local anesthetic. Korean J Anesthesiol. 2013;64(6):494–9.
10. Marhofer P, Schrogendorfer K, Wallner T, Koinig H, Mayer N, Kapral S. Ultrasonographic guidance reduces the amount of local anesthetic for three-in-1 blocks. Reg Anesth Pain Med. 1998;23(6):584–8.
11. Matamis D, Soilemezi E, Tsagourias M, Akoumianaki E, Dimassi S, Boroli F, et al. Sonographic evaluation of the diaphragm in critically ill patients: technique and clinical applications. Intensive Care Med. 2013;39(5):801–10.
12. McCauley RG, Labib KB. Diaphragmatic paralysis is evaluated by phrenic nerve stimulation during fluoroscopy or real-time ultrasound. Radiology. 1984;153(1):33–6.
13. Orebaugh SL, Williams BA, Bigeleisen PE. The up-down methodology and practical peripheral nerve blockade. Reg Anesth Pain Med. 2010;35(5):480–1.
14. Pavičić Šarić J, Vidjak V, Zenko J, Bogdanović Dvoršča M, Vončina V, Paklar N. Comparison of minimum effective volume of local anesthetic for ultrasound-guided supraclavicular block (MEAV95) in elderly and middle-aged patients. Period Biol. 2015;117(2):273–7.
15. Raju PKBC, Coventry DM. Ultrasound-guided brachial plexus blocks. Continuing Educ Anaesth Crit Care Pain. 2014;14(5):185–91.
16. Riazi S, Carmichael N, Awad I, Holtby RM, McCartney CJ. Effect of local anaesthetic volume on the efficacy and respiratory consequences of ultrasound-guided interscalene brachial plexus block. Br J Anaesth. 2008;101(4):549–56.
17. Sarwal A, Walker FO, Cartwright MS. Neuromuscular ultrasound for evaluation of the diaphragm. Muscle Nerve. 2013;47(3):319–29.
18. Scott S, Fuld JP, Carter R, McEntegart M, MacFarlane NG. Diaphragm ultrasonography as an alternative to whole-body plethysmography in pulmonary function testing. J Ultrasound Med. 2006;25(2):225–32.
19. Talts KH, Sharrock NE, Wender PF. One hundred percent incidence of hemidiaphragmatic paresis associated with interscalene brachial plexus anaesthesia as diagnosed by ultrasonography. Anesth Analg. 1991;72(4):498–503.
20. Ueshima H, Otake H. Incidence of phrenic nerve paralysis after ultrasound-guided supraclavicular brachial plexus block. J Clin Anesth. 2019; 56:37–8.
21. Urmey WF, Irwin MG, Ooi CG, Chow BF. Incidence of diaphragmatic paralysis following supraclavicular brachial plexus block and its effect on pulmonary function. Anaesthesia. 2001;56(4):352–6.
22. Xu WD, Gu YD, Lu JB, Yu C, Zhang CG, Xu JG. Pulmonary function after complete unilateral phrenic nerve transection. J Neurosurg. 2005;103(3):464–7.

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