Original Article

# Ultrasonographic evaluation of incidence of diaphragmatic paralysis following different volumes of supraclavicular brachial plexus block- A prospective randomized double blinded study


**ABSTRACT**

**Background:** Ipsilateral diaphragmatic paralysis occurs following supraclavicular blocks such as interscalene blocks, supposedly attributable to the backward diffusion of the local anesthetic (LA) inside the neural sheath. Hence, we have made an attempt to assess diaphragmatic paralysis with ultrasonogram (US) following different volumes of supraclavicular brachial plexus blocks (SCB).

**Aim:** To compare the incidence of diaphragmatic paralysis with different volumes of supraclavicular brachial plexus block using ultrasonogram.

**Methods:** Sixty patients with American Society of Anesthesiologists (ASA) Physical Status I and II were randomized to receive 20, 25, or 30 mL of 0.375% bupivacaine in a double-blinded fashion, and supraclavicular block was performed using ultrasound guidance in an in-plane technique. Diaphragmatic excursion and velocity were studied using a curvilinear 3.5 MHz transducer before and 20 min after giving the block.

**Results:** The incidence of reduction in diaphragmatic excursion and velocity in the group receiving 30 mL was 45% and 45%, respectively, which was higher, whereas it was 47.5% and 32.5% in the 25 mL group and 40% and 25% in the 20 mL group, respectively, which were still lower. Pre- and post-block data were studied using T-test, Kruskal–Wallis test, and Mann–Whitney *U* test. The probability of reduction in diaphragmatic excursion and velocity in each group was <0.05, which was statistically significant.

**Conclusion:** Our results suggest that there is a greater risk of inadvertent phrenic nerve blockade even in supraclavicular brachial plexus block. The resulting hemidiaphragmatic paralysis is volume dependent, and the overall incidence is higher at greater volumes. Hence, caution is required against compromised perioperative lung function in patients with preexisting cardiorespiratory dysfunction.



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


## Introduction

Over the last decade, local anesthetic (LA) blockade of the brachial plexus using ultrasound (US) guidance has unfolded the mystery of peripheral nerve blocking techniques in regional anesthesia comparable to landmark guidance and neuro-stimulation techniques for upper extremity surgeries.


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As with most regional anesthetic techniques, it offers unquestionable advantage on top of general anesthesia and is time and again preferred in the management of patients with cardiorespiratory diseases. However, this is not risk-free, and studies have demonstrated that brachial plexus blocks at the level of interscalene has a 100% incidence of phrenic nerve paralysis.[1] The potential explanations could be a C3, C4, and C5 nerve root block caused by retrograde ascend of the larger volumes of local anesthetic when given as blind injections or a firsthand blockade of the phrenic nerve inside the anterior scalene fascia because of its proximity to the brachial plexus. This can be circumvented using the axillary approach; woefully, not all upper extremity surgeries could be accomplished by an axillary block.

The supraclavicular approach anesthetizes the brachial plexus as the three trunks pass over the first rib lateral to the subclavian artery and on the whole yields a complete block of the upper limb. Although the incidence of phrenic nerve involvement in supraclavicular brachial plexus block (SCB) is theoretically less owing to the caudal application of block, this is not free of phrenic nerve involvement, and the resulting hemidiaphragmatic paresis can cause significant pulmonary dysfunction warranting caution.[2,3] This phrenic nerve paralysis manifests from none to comparably severe, relying more often on the presence of preexisting pulmonary dysfunction. The assessment of phrenic nerve involvement is difficult, and there is no specific guide to assess the grade of phrenic nerve involvement.[4] Researchers have shown that phrenic nerve blockade can undoubtedly be reduced by decreasing the injected volumes.[5] Hence, in this study, we have assessed diaphragmatic paralysis with ultrasonogram following different volumes of supraclavicular brachial plexus blocks to evaluate phrenic nerve involvement.

The primary objective was to quantify the incidence of diaphragmatic paralysis following phrenic nerve involvement in different volumes of supraclavicular brachial plexus block. Diaphragm paralysis are studied by nerve conduction studies, fluoroscopy, ultrasonogram, electrodiagnostic studies, etc. The rationale for using ultrasonogram for phrenic nerve study over other techniques is because of the high specificity and sensitivity of ultrasound in studying diaphragmatic mobility and avoidance of radiation hazards.[4,6-9]

## Methodology

After clinical trial registration (CTRI Trial REF/2018/08/015501), a prospective randomized double-blind study was carried out after obtaining institutional ethical committee clearance and written informed consent on 60 subjects between July 2018 and December 2018. American Society of Anesthesiologists (ASA) Physical Status I and II patients listed for elective upper extremity surgery belonging to age group 20–60 years were entailed in this study. The study was conducted as per consort guidelines [Figure 1] and followed the ethical guidelines of the Declaration of Helsinki. Those who had coexisting acute or chronic pulmonary dysfunction, had contraindication for regional anesthesia, are allergic to local anesthesia, failed block, and need sedation or general anesthesia were excluded.

The 60 patients posted for upper limb surgeries were recruited and were randomized by closed envelope technique into three groups, namely, group A, B, and C, with 20 patients in each group. The groups received 20, 25, and 30 mL of 0.375% bupivacaine supraclavicular brachial plexus block, respectively, using ultrasound guidance in an in-plane technique. The subjects were made to lie supine and head turned to the opposite side. A high-frequency linear transducer 12 MHz (Sonosite Edge II) is positioned in the coronal oblique plane on the rear of the mid-clavicle to procure the short-axis view showing the subclavian artery, brachial plexus, first rib, and cervical pleura, and the needle is then advanced in an in-plane approach directed from the posterior to the anterior to reach the corner pocket, and the desired volume of local anesthetic is injected.

Sonographic evaluation of the diaphragm was done before 20 min after giving the block. Diaphragmatic paralysis was assessed by diaphragmatic excursion and velocity. They were done at baseline zero min (T0) and 20 min (T 20) after accomplishing the block. Diaphragmatic movements were measured from freeze frames on B mode and tracings obtained with M mode using a 3.5 MHz ultrasound probe (Sonosite Edge II). The values of excursion and velocity were determined from the average of three consecutive breathing measurements.

The diaphragm excursion was calculated by tracing the amplitude of diaphragmatic excursion on the long axis of the M-mode tracings from baseline to the point of maximum inspiration with the intercostal view while the patient lies supine [Figure 2].

The diaphragm velocity was captured during the sniff maneuver with a 3.5 MHz transducer using M mode in the anterior subcostal view while having the patient in supine position [Figure 2]. Velocity was then calculated using the formula, velocity = a/b cm/s, where a is the amplitude (cm) and b is time (sec).[4,10,11]

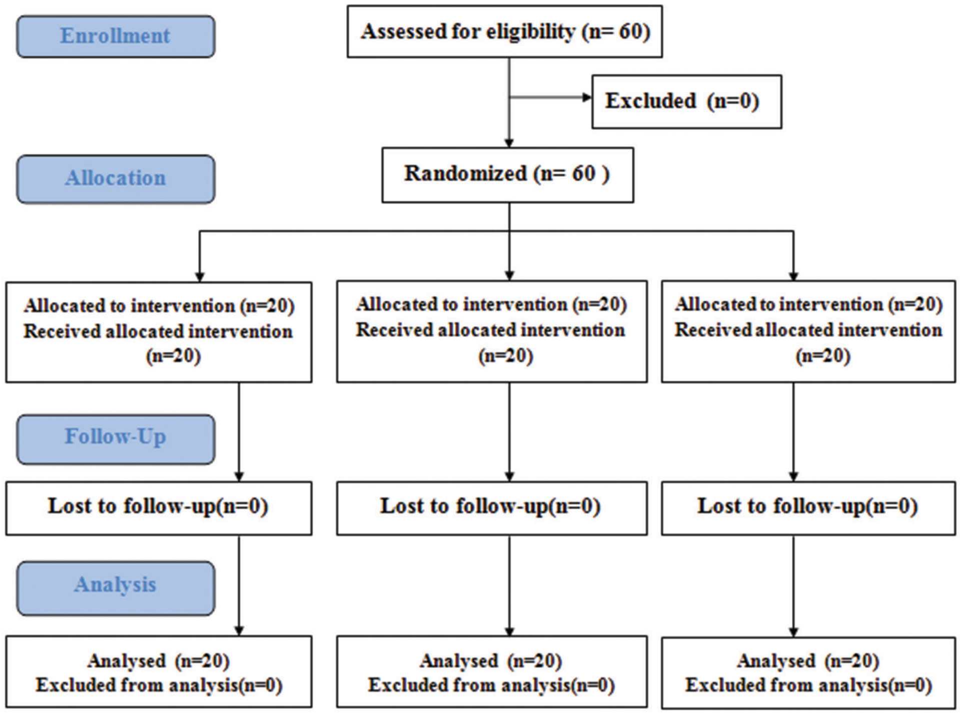


**Figure 1: Consort flowchart describing the study design**

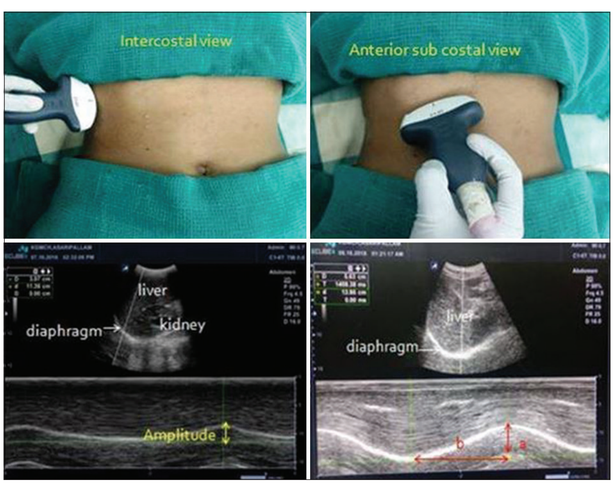


**Figure 2: i) Intercostal view showing diaphragmatic excursion calculation. ii) Anterior subcostal view showing calculation of diaphragmatic velocity (a = amplitude; b = time)**

The grading of diaphragmatic paralysis was done by two methods as follows. In the first method, the amplitudes of excursion and velocity after the block were taken for grading the diaphragmatic paralysis. Diaphragmatic excursion of < 1.5 cm indicates complete paralysis; 1.5–2.5 cm, partial paralysis; and > 2.5 cm, no paralysis. Furthermore, diaphragmatic velocity of <0.5 cm/sec is defined as complete paralysis; 0.5–1.5 cm/sec, partial paralysis; and >1.5 cm/sec, no paralysis.[4,12,13]

In the second method, the percentage of reduction in the amplitude of diaphragmatic excursion and velocity after the block was compared with the pre-block values. If the reduction in excursion and velocity following the block is >75% when compared with the pre-block values, then it is taken as complete paralysis; similarly, a reduction of 25%–75% in both parameters is taken as partial paralysis, and a reduction of <25% in both parameters from the pre-block values is considered no paralysis.

The primary outcome was monitored using diaphragm excursion and velocity for the incidence of hemidiaphragmatic paralysis, and the secondary outcomes were measured using the change in oxygen saturation (SPO2) and respiratory rate as markers of severe respiratory compromise. Demographic data, including age, sex, and body mass index (BMI), were also analyzed.

With respect to our main objective, a pilot study was conducted with five patients in each group. The sample size was calculated to be 20 in each group using the formula, $(U + V)^2 (\sigma_1^2 + \sigma_2^2)/(M_1 - M_2)^2$, based on the mean difference in diaphragmatic excursion of 1.27, standard deviation of 1.68 with a power of 95%, and significance level of 1%. The SPSS Statistics software version 23 was used for the analysis of the data. The data obtained was subjected to statistical analysis using Student's T test, Kruskal–Wallis test, and Mann–Whitney U test. Microsoft Word and Excel have been used to generate graphs and tables. A $P$ value $< 0.05$ was considered statistically significant.

## Results

We included 60 patients in our study. They were randomly allocated into three equal groups. Demographics regarding age, sex, and BMI were comparable between the three groups [Table 1]. All patients achieved adequate neurological blocks in the upper limbs.

The baseline values of respiratory rates, saturation, diaphragmatic excursion, and velocity were comparable between all the three groups [Table 2].

There is a significant difference in the excursion ($P = 0.022$, 0.005, 0.005 in group A, B, C respectively) and velocity ($P = 0.241$, 0.005, and 0.005 in group A, B, and C, respectively) values in all the three groups when the pre- and post-block values were compared [Table 3] [Figure 3]. The incidence of diaphragmatic paralysis based on diaphragmatic excursion in the three groups are as follows: A, 40%; B, 47.5%; and C, 45% [Table 3]. The incidence of diaphragmatic paralysis based on diaphragmatic velocity in the three groups are as follows: A, 25%; B, 32.5%; and C, 45%. However, when both diaphragmatic excursion and diaphragmatic velocity parameters were combined, the overall incidence of diaphragmatic paralysis in the three groups are as follows: A, 32.5%; B, 40%; and C, 45%.

The difference in mean excursion values are insignificant between groups A and B ($P = 0.072$), B and C ($P = 0.055$), and A and C ($P = 0.125$) [Table 3]. Similarly, the difference in mean velocity values are also insignificant between groups A and B ($P = 0.069$), B and C ($P = 0.054$), A and C ($P = 0.121$).

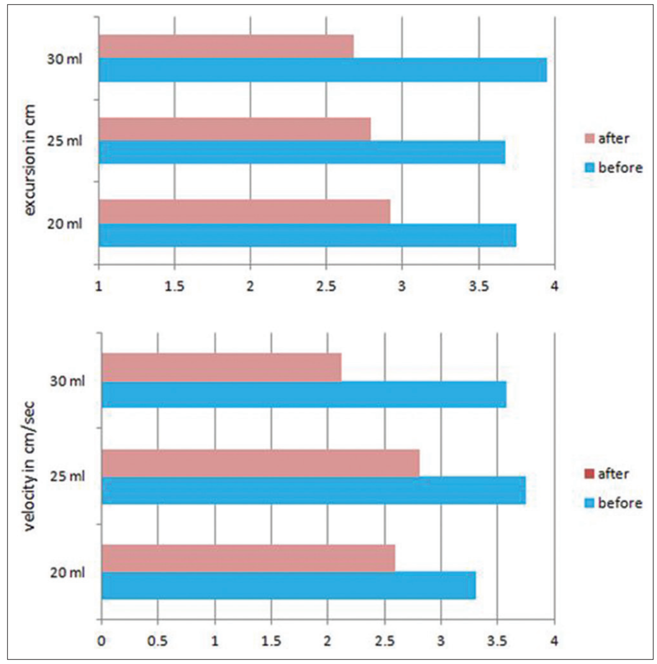


**Figure 3: Changes in diaphragmatic excursion and velocity before and after block with different volumes of local anesthetic**

**Table 1: Demographic data and comparison of pre and post block parameters**

| Parameter | | Group A | Group B | Group C |
|---|---|---|---|---|
| Mean age in years | | 38 | 42 | 41 |
| Sex (no) | Male | 8 | 11 | 10 |
| | Female | 12 | 9 | 10 |
| BMI | | 26.5 | 28 | 25.9 |
| Respiratory rate | Baseline | 15.3±0.91 | 15.4±0.82 | 15.38±1.42 |
| | 20 min | 15.3±1.2 | 15.55±0.56 | 17.75±0.75 |
| | | $P$=0.3 | $P$=0.08 | $P$=0.12 |
| SPO2 (%) | Baseline | 99.7±0.32 | 99.6±0.65 | 99.8±0.21 |
| | 20 min | 99.6±0.86 | 99.6±0.98 | 99.5±0.67 |
| | | $P$=0.09 | $P$=0.2 | $P$=0.15 |
| Diaphragm excursion (cm) | Baseline | 3.75±1.54 | 3.68±2.01 | 3.95±1.83 |
| | 20 min | 2.92±1.13 | 2.79±1.98 | 2.68±2.12 |
| | | $P$=0.022 | $P$=0.005 | $P$=0.005 |
| Diaphragm velocity (cm/sec) | Baseline | 3.31±1.81 | 3.75±0.99 | 3.58±1.69 |
| | 20 min | 2.58±2.94 | 2.8±1.06 | 2.11±2.56 |
| | | $P$=0.241 | $P$=0.005 | $P$=0.005 |

## Discussion

The supreme perk of real-time sonography at the time of peripheral nerve blockade is that the local anesthetic could be deposited under direct vision, allowing the performer to evenly distribute the drug encircling the target nerve. This considerably lowers the volume of the required local anesthetic to successfully block a nerve,[14,15] thereby reducing the risk complications and local anesthetic toxicity.

There is a constant search for minimum effective volume in US-guided supraclavicular block. Duggan *et al.*[16] (2009) found that the minimum volume needed for an ultrasonogram-guided supraclavicular block was 23 mL in 50% of patients and 42 mL in 95% of patients using Dixon and Massey up and down method (DUDM). Since the outcome of the DUDM was inconsistent from the clinical practice,[17] Dae Geun Jeon *et al.*[18] (2013) studied 120 patients by randomizing them into four groups to receive 35, 30, 25, and 20 mL supraclavicular blocks with 1% mepivacaine and achieved 90% success with 30 mL 1% mepivacaine. Fang *et al*. (2016)[19] demonstrated that the minimum effective concentration of ropivacaine in 90% of subjects was 0.257% w/v. Jadranka Pavičić Šarić *et al*.[20] (2015) determined the minimum effective anesthetic volume in 95% of patients to be 16.49 mL (95% CI: 12.23–20.75 mL) in older patients and 44.52 mL (95% CI: 19.05–69.99 mL) in younger patients (95% CI: 0.7–55.3 mL, $P = 0.044$).

Although no consensus on the minimum volume of drug required for SCB has been derived, many centers go for an

**Table 2: Grading and incidence of diaphragmatic paralysis**

| Grading | | | Group A 20 mL ($n$=20) | Group B 25 mL ($n$=20) | Group C 30 mL ($n$=20) |
|---|---|---|---|---|---|
| | | | **Diaphragm excursion** | | |
| Grading 1 | 1.5 cm | Complete paralysis | 0 | 1 (5%) | 2 (10%) |
| | 1.5-2.5 cm | Partial paralysis | 8 (40%) | 7 (35%) | 6 (30%) |
| | >2.5 cm | No paralysis | 12 (60%) | 12 (60%) | 12 (60%) |
| Incidence | | | 40% | 40% | 40% |
| Grading II | >75% | Complete paralysis | 0 | 0 | 0 |
| | 25-75% | Partial paralysis | 8 (40%) | 11 (55%) | 10 (50%) |
| | <25% | No paralysis | 12 (60%) | 9 (45%) | 10 (50%) |
| Incidence | | | 40% | 55% | 50% |
| Overall incidence (excursion) | | | 40% | 47.5% | 45% |
| | | | **Diaphragm velocity** | | |
| Grading 1 | 0.5 cm/sec | Complete paralysis | 0 | 0 | 0 |
| | 0.5-1.5 cm/sec | Partial paralysis | 0 | 3 (15%) | 6 (30%) |
| | >1.5 cm/sec | No paralysis | 20 (100%) | 17 (85%) | 14 (70%) |
| Incidence | | | 0% | 15% | 30% |
| Grading II | >75% | Complete paralysis | 0 | 1 (5%) | 2 (10%) |
| | 25%-75% | Partial paralysis | 10 (50%) | 9 (45%) | 10 (50%) |
| | <25% | No paralysis | 10 (50%) | 10 (50%) | 8 (40%) |
| Incidence | | | 50% | 50% | 60% |
| Overall incidence (velocity) | | | 25% | 32.5% | 45% |
| Overall incidence (combined excursion and velocity) | | | 32.5% | 40% | 45% |

**Table 3: Comparison of parameters between groups**

| Comparison of mean difference between groups | Group A and B | Group B and C | Group A and C |
|---|---|---|---|
| Diaphragm excursion | $P$=0.072 | $P$=0.055 | $P$=0.12 |
| Diaphragm velocity | $P$=0.069 | $P$=0.054 | $P$=0.12 |

average local anesthetic volume of 20–30 mL.[21] However, in developing countries where US-guided nerve block usages are less compared with nerve stimulation technique, they still use higher volumes up to 40 mL. In this study, we compared three volumes of 20, 25, and 30 mL with US-guided SCB and noted the incidence of diaphragmatic paralysis.

Traditionally, chest radiography, fluoroscopic sniff testing, computed tomography, and magnetic resonance imaging were used to assess diaphragmatic paralysis. However, in the operation theater, their usage is limited. Ultrasonography is a rather simple and precise tool for interpreting diaphragmatic paralysis. In our study, we have used diaphragmatic excursion and velocity values in M-mode US to assess diaphragmatic paralysis.

Mak *et al.*[2] (2000) performed a nerve stimulator-guided supraclavicular brachial plexus block using 0.375% bupivacaine 0.5 mL/kg and found that 50% of patients had complete paralysis of the ipsilateral hemidiaphragm, 17% of patients had diminished diaphragmatic movement, and the remaining 33% of patients had unaltered diaphragmatic movement. In this study, the average volume used, which was based on weight, is 25–30 mL (weight: 50–60 kg). In our study, the incidence also varied between 40% and 45% in 20 and 30 mL volume.

In a retrospective study conducted at Showa University Hospital, Japan, Ueshima and Otake[22] (2019) found that none had diaphragmatic paralysis in the 10 mL levobupivacaine group and that 14.6% in the 15 mL group and 29.4% in the 20 mL group had diaphragmatic paralysis. However, in this study, postoperative chest radiograph was used to assess diaphragmatic paralysis. In our study, there was a 32.5% incidence of diaphragmatic paralysis in the 20 mL group, which is higher, as we have used more sensitive US-guided assessment of diaphragmatic paralysis.

This study unraveled the hidden incidence of diaphragmatic paralysis in various volume of SCB that will be helpful in patients with compromised lung functions. There was no incidence of complete paralysis in the 20 mL group, and the incidence of complete paralysis was minimal in the 25 and 30 mL group; the incidence of partial paralysis is significantly higher in all three groups A, B and C [20, 25, 30 mL].

Therefore, the higher the volume, the more the hemidiaphragmatic involvement, which may compromise the lung function of patients with preexisting pulmonary dysfunction. Surprisingly, this sequelae often appear to be fairly insignificant in healthy patients, as respiratory rate and saturation remained almost constant.

Many diaphragm sparing blocks are performed with minimum volume, of which most of them are interscalene blocks that often provide good postoperative analgesia. The incidence of block failures and the efficacy of surgical analgesia are yet to be quantified. These studies have used various other tools, such as fluoroscopy and pulmonary function tests, to quantify phrenic nerve involvement. We, in our study, wanted to elicit the effect of supraclavicular brachial plexus blocks (20–30 mL) on phrenic nerve involvement using ultrasonography.

Our study is limited by the fact that the lung function test was not assessed. The measurement of Peak expiratory flow rate would have been more helpful if it was combined with the US assessment of diaphragmatic paralysis. Since a 32.5% incidence of diaphragmatic paralysis was noted even with 20 mL volume, future studies are needed to find out the minimum effective volume of LA in SCB without affecting diaphragmatic function.

## Conclusion

Our results suggest that there is a greater risk of inadvertent phrenic nerve blockade even in supraclavicular brachial plexus block. The resulting hemidiaphragmatic paralysis is volume dependent, and the overall incidence is higher at greater volumes, and the incidence is evident even at a smaller volume of 20 mL (32.5%). Although these patients did not have any significant clinical complications, caution is required against compromised perioperative lung function in patients with preexisting cardiorespiratory dysfunction.

### Declaration of patient consent

The authors certify that they have obtained all appropriate patient consent forms. In the form, the patient(s) has/have given his/her/their consent for his/her/their images and other clinical information to be reported in the journal. The patients understand that their names and initials will not be published and that due efforts will be made to conceal their identity, but anonymity cannot be guaranteed.

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Nil.

### Conflicts of interest

There are no conflicts of interest.

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