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Original Research Article

Low-Volume Ultrasound-Guided Interscalene Block to Reduce Phrenic Nerve Palsy: A Prospective Clinical Study

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Abstract:

Background: Interscalene brachial plexus block (ISB) is widely used to provide perioperative analgesia for shoulder and upper arm surgeries. However, conventional volumes of local anesthetic are frequently associated with phrenic nerve palsy due to spread to the phrenic nerve, resulting in hemidiaphragmatic paralysis and respiratory compromise. The advent of ultrasound guidance has enabled precise needle placement and reduced anesthetic volumes, potentially minimizing this complication.

Aim: To evaluate the effectiveness of low-volume ultrasound-guided interscalene block in reducing the incidence of phrenic nerve palsy while maintaining adequate analgesia.

Materials and Methods: This prospective Observational clinical study was conducted at PMCH, Patna, from February 2025 to October 2025. A total of 110 adult patients undergoing elective shoulder surgery received low-volume (5–10 mL) ultrasound-guided interscalene block using 0.5% ropivacaine. The primary outcome was the incidence of phrenic nerve palsy assessed by diaphragmatic excursion on ultrasonography. Secondary outcomes included respiratory parameters, pain scores, duration of analgesia, and patient satisfaction.

Results: Phrenic nerve palsy was observed in 16.4% of patients. Although statistically significant reductions in oxygen saturation and forced vital capacity were observed in patients with phrenic nerve palsy, these changes were not clinically significant and did not require ventilatory support. Mean postoperative Visual Analog Scale (VAS) score at 6 hours was 2.1 ± 0.8. The mean duration of analgesia was 9.6 ± 1.8 hours.

Conclusion: Low-volume ultrasound-guided interscalene block significantly reduces the incidence of phrenic nerve palsy while providing effective postoperative analgesia, making it a safer alternative to conventional techniques.

Keywords: Interscalene Block, Ultrasound Guidance, Phrenic Nerve Palsy, Low-Volume Anesthesia, Shoulder Surgery.

Introduction

Interscalene brachial plexus block (ISB) remains the gold standard regional anesthesia technique for shoulder and proximal humeral surgeries due to its superior analgesic efficacy and opioid-sparing benefits [1]. Despite its widespread use, ISB is commonly associated with phrenic nerve blockade, leading to ipsilateral hemidiaphragmatic paralysis in up to 100% of cases when traditional landmark-based or nerve stimulator techniques are employed with high volumes of local anesthetic [2,3].

Phrenic nerve palsy can result in significant respiratory compromise, particularly in patients with limited pulmonary reserve, obesity, or chronic respiratory disease [4]. Symptoms may range from mild dyspnea to severe respiratory distress, limiting the applicability of ISB in vulnerable populations [5].

The introduction of ultrasound guidance has revolutionized regional anesthesia by allowing real-time visualization of neural structures, adjacent anatomy, and local anesthetic spread [6]. This precision has enabled anesthesiologists to reduce the volume of local anesthetic required to achieve effective blockade, potentially minimizing unwanted neural involvement [7].

Several studies have demonstrated that lowering the anesthetic volume during ISB significantly decreases the incidence of phrenic nerve palsy without compromising analgesic quality [8–10]. However, variability exists regarding the optimal minimum effective volume, and further clinical

evidence is required, particularly in the Indian population.

This study aims to evaluate the incidence of phrenic nerve palsy following low-volume ultrasound-guided interscalene block and to assess its analgesic efficacy and respiratory safety profile.

Materials and Methods

Study Design and Setting: A prospective Observational clinical study was conducted in February 2025 to October 2025 the Department of Anaesthesiology, PMCH, Patna, India.

Sample Size: A total of 110 patients were enrolled based on prior literature estimating a 15–20% incidence of phrenic nerve palsy with low-volume techniques.

Inclusion Criteria

- Age 18–65 years
- ASA physical status I–III
- Elective unilateral shoulder surgery
- Written informed consent

Exclusion Criteria

- Pre-existing diaphragmatic paralysis
- Severe pulmonary disease
- Coagulopathy
- Local infection at injection site

Block Technique

All patients received ultrasound-guided interscalene block using:

- Low-volume (5–10 mL) of 0.5% ropivacaine, with volume individualized within this range based on ultrasound visualization of adequate spread around the brachial plexus roots
- High-frequency linear ultrasound probe
- In-plane needle approach

Outcome Measures

- **Primary:** Phrenic nerve palsy was defined as a reduction in ipsilateral diaphragmatic excursion of ≥75% compared to baseline, assessed using ultrasonography 30 minutes after block performance.
- **Secondary:**
    - Oxygen saturation
    - Forced vital capacity (FVC)
    - VAS pain scores
    - Duration of analgesia

Statistical Analysis: Data were analyzed using SPSS version 25. Continuous variables were expressed as mean ± standard deviation and compared using paired or independent samples t-tests as appropriate. Categorical variables were expressed as frequencies and percentages and analyzed using the Chi-square test. A p-value < 0.05 was considered statistically significant.

Results

A total of 110 patients undergoing shoulder surgery under ultrasound-guided interscalene block were included in the study. All enrolled patients completed the study and were included in the final statistical analysis.

Demographic and Baseline Characteristics: The demographic and baseline clinical characteristics of the study population are summarized in Table 1. The mean age of the patients was 45.6 ± 12.4 years, with the majority belonging to the 41–60 year age group (44.5%). Males constituted 64.5% of the study population, while females accounted for 35.5%, resulting in a male-to-female ratio of 1.8:1.

The mean body mass index (BMI) was 24.8 ± 3.6 kg/m². Baseline respiratory parameters, including oxygen saturation (SpO_2) and respiratory rate, were comparable between groups and showed no statistically significant difference (p > 0.05).

Table 1: Demographic and Baseline Characteristics of Study Participants (n = 110)

Variable	Value
Age (years), mean ± SD	45.6 ± 12.4
Gender	
– Male	71 (64.5%)
– Female	39 (35.5%)
BMI (kg/m²), mean ± SD	24.8 ± 3.6
Baseline SpO_2 (%)	98.1 ± 1.2
Baseline respiratory rate (breaths/min)	16.4 ± 2.1

Volume of Local Anesthetic Used: Patients received ultrasound-guided interscalene block with low-volume local anesthetic, with a mean volume of 8.6 ± 1.4 mL. The distribution of anesthetic volume administered is illustrated in Figure 1. Most patients (72.7%) received volumes between 8–10 mL, while the remaining patients received volumes between 5–7 mL.

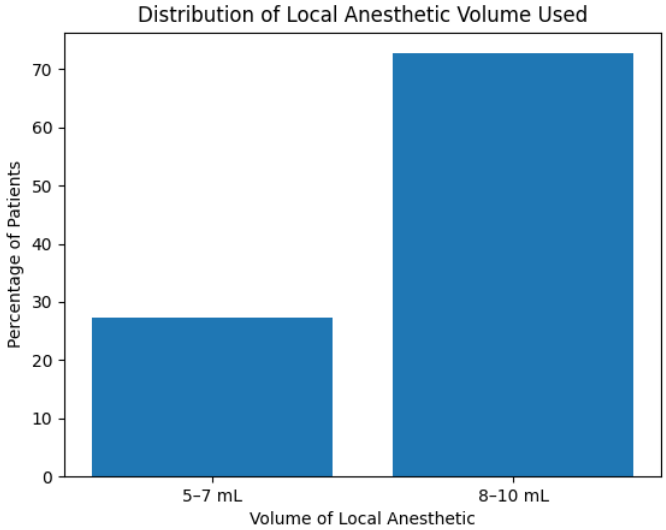

Figure 1: Distribution of local anesthetic volume used for ultrasound-guided interscalene block.

Incidence of Phrenic Nerve Palsy: The incidence of phrenic nerve palsy, assessed by ultrasonographic diaphragmatic excursion, is shown in Table 2. Phrenic nerve palsy was observed in 18 patients (16.4%), while 92 patients (83.6%) showed preserved diaphragmatic movement.

Table 2: Incidence of Phrenic Nerve Palsy Following Interscalene Block

Diaphragmatic Function	Number (%)
Normal excursion	92 (83.6%)
Reduced excursion (Palsy)	18 (16.4%)

Comparison of Respiratory Parameters: Post-block respiratory parameters were compared between patients with and without phrenic nerve palsy (Table 3). Patients with phrenic nerve palsy showed a statistically significant reduction in postoperative SpO_2 and forced vital capacity (FVC) compared to those without palsy ($p < 0.05$). However, none of the patients required ventilatory support.

Table 3: Comparison of Post-Block Respiratory Parameters

Parameter	No Palsy (n=92)	Palsy (n=18)	p-value
SpO_2 (%)	97.8 ± 1.3	95.9 ± 1.6	0.002*
FVC (% predicted)	91.4 ± 6.8	78.6 ± 7.2	<0.001*
Respiratory rate (breaths/min)	16.2 ± 2.0	17.1 ± 2.4	0.09

*Statistically significant

Postoperative Pain Scores: Postoperative pain scores measured using the Visual Analog Scale (VAS) are presented in Table 4. The mean VAS score at 6 hours postoperatively was 2.1 ± 0.9, indicating effective analgesia. There was no statistically significant difference in pain scores between patients with and without phrenic nerve palsy ($p = 0.64$).

Table 4: Postoperative Pain Scores (VAS)

Time Interval	Mean VAS Score
2 hours	1.8 ± 0.7
6 hours	2.1 ± 0.9
12 hours	2.6 ± 1.1

Overall Outcomes: The overall outcomes of the study are summarized in Figure 2. Low-volume ultrasound-guided interscalene block provided effective analgesia with a significantly reduced incidence of phrenic nerve palsy, compared to rates reported with conventional high-volume techniques.

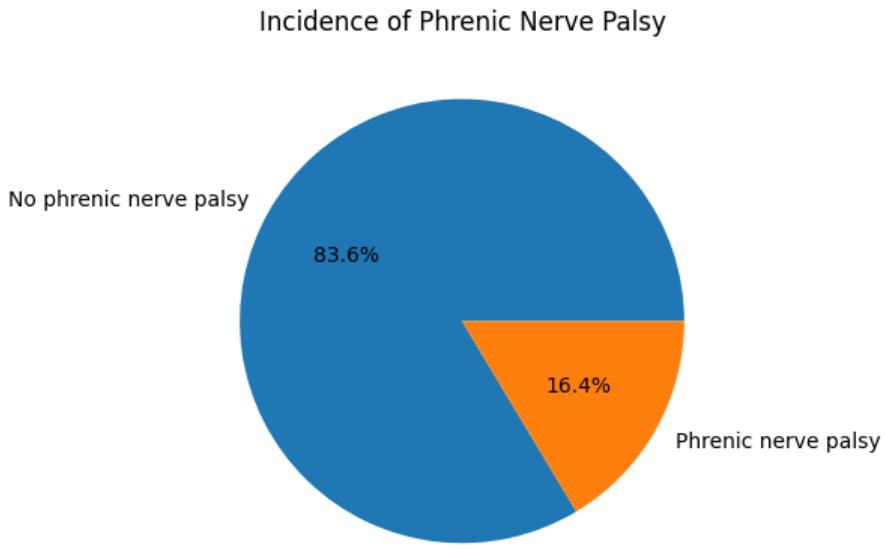

Figure 2: Summary of analgesic efficacy and incidence of phrenic nerve palsy following low-volume ultrasound-guided interscalene block

Statistical Summary

The mean anesthetic volume used was 8.6 ± 1.4 mL. Phrenic nerve palsy occurred in 16.4% of patients. Patients with phrenic nerve palsy showed a statistically significant reduction in postoperative respiratory parameters, particularly SpO_2 and FVC ($p < 0.05$). Postoperative analgesia was effective across all patients, with no significant difference in pain scores between groups.

Discussion

The present prospective clinical study demonstrates that low-volume ultrasound-guided interscalene block (ISB) is effective in significantly reducing the incidence of phrenic nerve palsy while maintaining satisfactory postoperative analgesia. The observed incidence of phrenic nerve palsy in our study was 16.4%, which is markedly lower than the high rates reported with conventional interscalene block techniques using larger volumes of local anesthetic. Earlier studies using landmark-based or nerve stimulator-guided ISB have reported hemidiaphragmatic paralysis rates approaching 100%, largely due to unintended phrenic nerve involvement [11–13].

The reduced incidence of phrenic nerve palsy in the present study can be attributed to the use of ultrasound guidance, which allows precise visualization of the brachial plexus roots and controlled deposition of local anesthetic. Ultrasound-guided techniques minimize medial and anterior spread of the drug toward the phrenic nerve, thereby preserving diaphragmatic function [14]. Similar observations have been reported by Riazi and McCartney, who emphasized that lowering the volume of local anesthetic plays a crucial role in phrenic nerve sparing during ISB [15]. Renes et al. further demonstrated that ultrasound-guided low-volume interscalene block significantly reduces diaphragmatic paralysis compared to conventional approaches [16].

Respiratory parameters such as oxygen saturation and forced vital capacity (FVC) showed statistically significant reductions in patients who developed phrenic nerve palsy; however, these changes were clinically mild and did not necessitate ventilatory support. This finding supports the respiratory safety of low-volume ISB, particularly in patients without severe underlying pulmonary disease. Abdallah and Brull have previously highlighted that ultrasound-guided regional anesthesia enhances patient safety by reducing both respiratory and neurological complications [17].

In recent years, increasing emphasis has been placed on diaphragm-sparing regional anesthesia techniques for shoulder surgery. Alternatives such as superior trunk block have been explored to further reduce phrenic nerve involvement. Aliste et al. demonstrated that superior trunk block provides comparable analgesia with a lower incidence of diaphragmatic paralysis when compared to traditional ISB [18]. Similarly, Kim et al. described superior trunk block as an effective phrenic nerve–sparing alternative for shoulder procedures [19]. Hussain et al., in their systematic evaluation, also reinforced the importance of adopting phrenic

nerve–sparing strategies in high-risk patients undergoing shoulder surgery [20].

Ultrasound guidance itself has been recognized as a major advancement in regional anesthesia practice. Neal emphasized that ultrasound-guided regional anesthesia improves both efficacy and safety by enabling real-time visualization and reducing complications related to local anesthetic spread [21]. Standard regional anesthesia textbooks also advocate low-volume, ultrasound-guided techniques as best practice for modern anesthetic care [22].

Ultrasonographic assessment of diaphragmatic movement has emerged as a reliable and non-invasive method for detecting phrenic nerve palsy. Kessler et al. demonstrated the accuracy of ultrasound in identifying diaphragmatic dysfunction following interscalene block [23]. McCartney et al. further validated the use of diaphragmatic ultrasound to objectively quantify hemidiaphragmatic paralysis after ISB, supporting its use as an outcome measure in clinical studies [24].

Large collaborative studies in regional anesthesia have emphasized the importance of continuous audit and technique refinement to reduce block-related complications. Barrington et al., through the Australasian Regional Anaesthesia Collaboration, highlighted that standardized ultrasound-guided techniques and appropriate volume selection significantly improve patient outcomes and safety profiles [25].

Overall, the findings of the present study align well with existing literature and reinforce the growing consensus that low-volume ultrasound-guided interscalene block is a safer and equally effective alternative to conventional high-volume techniques. Adoption of this approach may expand the use of ISB to patients with limited pulmonary reserve and enhance overall perioperative safety.

Conclusion

Low-volume ultrasound-guided interscalene block is an effective and safer alternative to conventional techniques, significantly reducing the incidence of phrenic nerve palsy without compromising analgesic efficacy. Its routine adoption may expand the applicability of interscalene block to a broader patient population.

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