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# COMPARATIVE STUDY ON ONSET AND BLOCK QUALITY FOLLOWING SINGLE VS MULTIPLE INJECTION TECHNIQUES IN AXILLARY BRACHIAL PLEXUS BLOCK

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## ABSTRACT

***Background:***

*The axillary brachial plexus block is a well-established regional anesthesia technique for forearm and hand surgeries. Despite its reliability, the optimal injection strategy remains controversial. Single- and multiple-injection techniques are commonly used, yet their comparative effectiveness in terms of onset time, block quality, duration of anesthesia, and safety is still debated. This randomized controlled trial aimed to compare these two approaches to determine which provides superior clinical outcomes.*

***Materials and Methods:***

*Seventy-two adult patients (ASA physical status I–III) scheduled for elective forearm or hand surgery were enrolled and randomly allocated into two equal groups: Group S (single-injection technique) and Group M (multiple-injection technique). All blocks were performed using nerve-stimulation guidance with standardized doses of local anesthetic. Hemodynamic parameters were monitored, and the onset times of sensory and motor block were recorded. Block duration, time to first rescue analgesia, block quality, patient satisfaction, and complications were assessed. Data were analyzed using the independent t-test and chi-square test, with a $p$ value $< 0.05$ considered statistically significant.*

***Results:***

*Demographic characteristics and baseline hemodynamic variables were comparable between groups ($p > 0.05$). Group M demonstrated a significantly faster onset of sensory block (10.5 ± 2.2 min vs. 12.0 ± 2.4 min; $p = 0.004$) and motor block (15.8 ± 3.0 min vs. 18.1 ± 3.6 min; $p = 0.006$). The duration of sensory and motor blockade, as well as the time to first rescue analgesia, was significantly longer in the multiple-injection group ($p < 0.01$). Excellent block quality and higher patient satisfaction were more frequent in Group M. Complication rates were low and comparable between groups.*

***Conclusion:***

*The multiple-injection axillary brachial plexus block provides faster onset, superior block quality,*

*longer duration of anesthesia, and higher patient satisfaction without increasing complications, making it a clinically preferable technique for upper-limb surgeries.*

***Keywords:***
*Axillary brachial plexus block; multiple-injection technique; single-injection; regional anesthesia; block onset; block duration; patient satisfaction*

## INTRODUCTION

Regional anesthesia is essential for upper limb surgeries, because it effectively provides intraoperative anesthesia and postoperative analgesia while minimizing systemic side effects and preventing complications related to general anesthesia. The axillary brachial plexus block (ABPB), one of the many methods for upper limb regional blocks, is being frequently utilized for procedures involving the hand and forearm because of its high success rate, low risk of complications, and relatively simple anatomical access (1,2).

For ABPB, both single-injection and multiple-injection methods are used in clinical practice. The single-injection method, which involves depositing the full volume of local anesthetic, close to the neurovascular bundle inside the axillary sheath, is faster and technically easier. The multiple-injection technique, on the other hand, uses ultrasound, trans arterial or a nerve stimulator to guide the injections around specific terminal branches of the brachial plexus, including the median, ulnar, radial, and musculocutaneous nerves. This focused strategy is thought to ensure sufficient anesthetic distribution to every nerve, which could lead to quicker onset times and more thorough sensory and motor blockade (3-6).

The brachial plexus separates into three large nerves at the axillary area: median, radial and ulnar in the same neurovascular envelope. All these nerves can be blocked by injecting a local anesthetic into the sheath as depicted by trials involving single injection and ultrasonography. Local anesthetic spreads at the median, ulnar and radial nerves partly due to the septal nature of the nervous vascular sheath (5, 6). Inadequate anesthesia during forearm surgery can be achieved with blockage achieved using single injection, since the musculocutaneous nerve, one of the nerves in the brachial plexus, exits it proximally, and, therefore, is unblocked. Due to that, it is advised to block musculocutaneous nerve independently so that to avoid tourniquet pain. As we know, multiple blocking through infiltrations requires much more time and is more painful, which adversely influences the level of patient comfort. It has been observed that when the local anesthetics are administered to two or more nerves in divided doses, there is an increased success of blockage (7). All nerve blocks can be done using aptocaine (Maxicaine Fort VEM Drug, İstanbul, Turkey). When in its pure form, its biological half-life is approximately 60 minutes (4). The plasma esterases metabolize it quickly, and it is excreted in urine. It is soluble in water at pH 5, but it can be alkalinized with the help of NaHCO3 in order to augment the effect of her dosage time (8).

At ten times the clinical blood level, aptocaine is not as cardio-depressant as the five times blood level of bupivacaine (9-12). Whereas the pharmacodynamic effects of aptocaine and lidocaine are similar during axillary brachial plexus blocks, pharmacokinetically, aptocaine is more rapidly eliminated (7). It is less toxic than lidocaine but more toxic than procaine (8). Literature is contradictory with regards to which method is more advantageous. Nonetheless, not all studies indicate that several injections could enhance block properties and reduce onset time (Albaum et al., 2022; Arbona et al., 2011). Other studies have not observed significant differences highlighting a need to carry out further research in an experimental environment. Moreover, the advantages of the multiple-injection technique over the single-injection method in terms of monetary costs could be questioned because of the potential higher time on the procedure and patient discomfort (10). Today, distal upper limb surgery is typically done in an outpatient facility using regional anesthesia (RA), intravenous regional anesthesia (IVRA) or local anesthesia (13).

In order to systematically evaluate and compare the onset time and quality of block between these two techniques, a brief comparative clinical study is necessary. By balancing efficacy, procedural simplicity, and patient comfort, such a study will aid in the optimization of clinical practice.

To evaluate the onset of sensory and motor block for single and multiple injection methods in

axillary brachial plexus block. And to assess the pros and cons of single VS multiple injections.

## METHODOLOGY

*Research Design*

This study was designed as a **prospective, randomized controlled trial (RCT)** aimed at comparing the onset time, block quality, duration, and safety profile of **single-injection versus multiple-injection techniques** for axillary brachial plexus block in patients undergoing elective upper-limb surgery. The study followed a **parallel group design** with equal allocation and a **single-blind** approach, where the observer collecting postoperative data was blinded to the intervention technique used.

### Clinical Setting

The study was conducted in the **Department of Anesthesiology** at the **Burns and Plastic Surgery Center**, a tertiary care teaching hospital equipped with comprehensive facilities for regional anesthesia and perioperative monitoring. All procedures were performed in a dedicated operating theater under standard aseptic precautions and continuous hemodynamic monitoring.

### Sample Size

A total of **72 patients** were recruited for this study, divided equally into two groups of 36 patients each:

- **Group S:** Single-injection technique
- **Group M:** Multiple-injection technique

The sample size was calculated using the **OpenEpi online sample size calculator**, based on the mean difference in axillary nerve block (ANB) success rate reported in previous literature (mean value 7.3%, SD 6). Assuming a **power of 80%**, a **confidence level of 95%**, and a **significance level (α) of 0.05**, the required minimum sample size per group was 36. An additional margin of 10% was considered for potential dropouts, yielding the final total of 72 participants.

### Sampling Technique

Eligible patients were randomized into one of the two study groups using **computer-generated random numbers**. Randomization codes were prepared in advance by an independent statistician and placed in **sealed, opaque envelopes** to ensure **allocation concealment**. Each envelope was opened immediately before performing the block, and the assigned technique was implemented accordingly. The anesthesiologist performing the block was aware of the group allocation; however, the **data collector (observer)** responsible for evaluating onset time, block quality, and postoperative outcomes remained **blinded** to the intervention, maintaining a **single-blind design** to reduce observer bias.

### Duration of Study

The study was carried out over a period of **six months**, including patient recruitment, procedural interventions, data collection, and follow-up. This timeframe ensured adequate sample acquisition and standardized conditions for data consistency.

### Selection Criteria

#### Inclusion Criteria

- Adult patients aged **18 to 50 years**.
- Patients scheduled for **elective forearm or hand surgeries** under axillary brachial plexus block.
- Classified as **ASA Physical Status I or II** according to the American Society of Anesthesiologists classification.
- Patients providing **written informed consent** to participate.

#### Exclusion Criteria

- Known **allergy or hypersensitivity** to local anesthetics.
- Presence of **coagulopathy** or **local infection** at the injection site.
- **Pre-existing neurological deficit** or neuropathy of the upper limb.
- Patients who **refused participation** or withdrew consent at any point.
- Patients with **psychiatric illness** or inability to communicate effectively.

### Data Collection Procedure

Data for this randomized controlled trial were collected **prospectively** using a structured **patient data form** and a **pre-designed questionnaire**. The data form was used to record demographic and clinical variables, including each patient's **age, sex, weight, height, ASA physical status, and comorbidities**, along with baseline hemodynamic parameters such as **heart rate, blood pressure, mean arterial pressure (MAP), and oxygen saturation ($SpO_2$)** prior to performing the block. All participants were screened according to the

inclusion and exclusion criteria, and those found eligible were enrolled after providing written informed consent.

Each enrolled patient was assigned to one of the two study groups—**Group S (Single Injection)** or **Group M (Multiple Injections)**—using a **computer-generated randomization sequence**. Allocation concealment was maintained through sealed opaque envelopes opened immediately before the procedure. In Group S, the entire volume of the local anesthetic mixture was administered as a single bolus injection adjacent to the axillary sheath after confirming plexus location with a **nerve stimulator**. In Group M, the same total volume was divided into four equal aliquots and injected separately around the **median, ulnar, radial, and musculocutaneous nerves** under nerve stimulator guidance to ensure precise localization. In both groups, a standardized volume of **30 mL** was used, consisting of **0.5% ropivacaine (3 mg/kg)** combined with **2% lignocaine with adrenaline (7 mg/kg)** or **2% plain lignocaine (3–4 mg/kg)**, as per patient suitability.

Following the block, **sensory and motor onset times** were evaluated at **two-minute intervals** using a **pinprick test** for sensory assessment and the **modified Bromage scale** for motor function. The onset was defined as the time between completion of injection and loss of sensation or inability to perform voluntary movement. Assessments continued for up to 30 minutes or until a complete block was achieved. The **quality of block** was graded as *Excellent*, *Good*, *Fair*, or *Poor* based on adequacy for surgery and the need for supplemental analgesia or conversion to general anesthesia. Throughout the procedure, patients were continuously monitored for **hemodynamic stability**, including heart rate, systolic and diastolic blood pressure, mean arterial pressure, and oxygen saturation. Any **intraoperative complications**—such as vascular puncture, paresthesia, or signs of **local anesthetic systemic toxicity (LAST)**—were promptly recorded. In the postoperative period, patients were monitored in the recovery area and surgical ward for **block regression, duration of analgesia, and occurrence of adverse events** such as hematoma, infection, transient nerve deficit, or nausea and vomiting for up to **24 hours** following the procedure. The **time to first request for analgesia** was documented as an indicator of postoperative pain relief duration. At the end of the observation period, **patient satisfaction** was assessed using a **five-point Likert scale** (1 = very dissatisfied, 5 = very satisfied) reflecting overall comfort and procedural experience. To ensure impartiality, all perioperative and postoperative assessments were conducted by an **independent observer blinded** to the technique used. The collected data were reviewed daily for accuracy and completeness, coded using unique identifiers to maintain confidentiality, and subsequently entered into a computerized database for statistical analysis.

### Data Analysis

All data were analyzed using **SPSS version 26.0 (IBM Corp., USA)**. Continuous variables were expressed as **mean ± SD,** and categorical variables as **frequencies and percentages**. Normality was assessed using the **Shapiro–Wilk test.** Group comparisons were performed using the **independent t-test** for continuous variables and the **Chi-square or Fisher's exact test** for categorical variables. **Linear regression analysis** was used to identify predictors of sensory block onset. A **p-value < 0.05** was considered statistically significant, with results presented using tables and figures.

## RESULT

Both groups were demographically and clinically comparable, confirming successful randomization. Most participants were aged 31–50 years, with a male predominance and a similar distribution of ASA physical status, BMI categories, block side, and comorbidities between groups. Hypertension and diabetes were the most common comorbid conditions, occurring at comparable rates. No statistically significant differences were observed in baseline characteristics, indicating that the groups were well matched for valid comparative analysis.

**Table 1. Demographic data among respondents**

| Variable | Level | Group S (n=36) | Group M (n=36) | Total (n=72) |
|---|---|---|---|---|
| Age group (years) | 18 to30 | 10 (27.8%) | 9 (25.0%) | 19 (26.4%) |
| | 31, to50 | 18 (50.0%) | 19 (52.8%) | 37 (51.4%) |
| | >50 | 8 (22.2%) | 8 (22.2%) | 16 (22.2%) |

| | | | | |
|---|---|---|---|---|
| Gender | Male | 22 (61.1%) | 21 (58.3%) | 43 (59.7%) |
| | Female | 14 (38.9%) | 15 (41.7%) | 29 (40.3%) |
| ASA physical status | I | 12 (33.3%) | 11 (30.6%) | 23 (31.9%) |
| | II | 20 (55.6%) | 21 (58.3%) | 41 (56.9%) |
| | III | 4 (11.1%) | 4 (11.1%) | 8 (11.1%) |
| BMI category (kg/m¬≤) | <25 | 13 (36.1%) | 12 (33.3%) | 25 (34.7%) |
| | 25,to29.9 | 16 (44.4%) | 17 (47.2%) | 33 (45.8%) |
| | >30 | 7 (19.4%) | 7 (19.4%) | 14 (19.4%) |
| Block side | Right | 19 (52.8%) | 20 (55.6%) | 39 (54.2%) |
| | Left | 17 (47.2%) | 16 (44.4%) | 33 (45.8%) |
| Hypertension | Yes | 9 (25.0%) | 10 (27.8%) | 19 (26.4%) |
| | No | 27 (75.0%) | 26 (72.2%) | 53 (73.6%) |
| Diabetes mellitus | Yes | 6 (16.7%) | 7 (19.4%) | 13 (18.1%) |
| | No | 30 (83.3%) | 29 (80.6%) | 59 (81.9%) |

Baseline hemodynamic parameters were comparable between the two study groups, indicating similar physiological status prior to block administration. The mean heart rate was nearly identical in both groups (76.7 ± 7.5 beats/min in Group S vs. 76.6 ± 7.1 beats/min in Group M; $p = 0.969$). Similarly, the mean systolic blood pressure (SBP) was 122.8 ± 11.0 mmHg in Group S and 124.8 ± 11.7 mmHg in Group M ($p = 0.458$), while the mean diastolic blood pressure (DBP) values were 77.7 ± 7.5 mmHg and 76.1 ± 7.0 mmHg, respectively ($p = 0.356$). The mean arterial pressure (MAP) also showed no significant difference between the groups (92.7 ± 6.0 mmHg vs. 92.3 ± 6.5 mmHg; $p = 0.790$). Oxygen saturation ($SpO_2$) remained stable and similar across both groups (97.9 ± 1.0% vs. 98.0 ± 1.2%; $p = 0.651$). Overall, there were **no statistically significant differences** in baseline hemodynamic variables between the single- and multiple-injection groups, confirming that both cohorts were hemodynamically comparable before intervention.

**Table 2. Baseline hemodynamics**

| Parameter | Group S (n=36) | Group M (n=36) | p-value |
|---|---|---|---|
| Heart rate (beats/min) | 76.7 ¬± 7.5 | 76.6 ¬± 7.1 | 0.969 |
| SBP (mmHg) | 122.8 ¬± 11.0 | 124.8 ¬± 11.7 | 0.458 |
| DBP (mmHg) | 77.7 ¬± 7.5 | 76.1 ¬± 7.0 | 0.356 |
| MAP (mmHg) | 92.7 ¬± 6.0 | 92.3 ¬± 6.5 | 0.79 |
| SpO,ÇÇ (%) | 97.9 ¬± 1.0 | 98.0 ¬± 1.2 | 0.651 |

Both groups were demographically and hemodynamically comparable, confirming successful randomization. The multiple-injection technique demonstrated a significantly faster onset of sensory and motor block, longer duration of anesthesia, and prolonged time to first rescue analgesia compared with the single-injection technique ($p < 0.01$). Block quality was superior in the multiple-injection group, with a higher proportion of excellent blocks (66.7% vs. 50.0%; $p = 0.047$), and patient satisfaction was significantly higher ($p = 0.039$). Intraoperative and postoperative complications were infrequent and comparable between groups. Overall, while both techniques were safe and effective, the multiple-injection axillary brachial plexus block provided faster onset, longer analgesia, better block quality, and greater patient satisfaction without increasing complication rates.

**Table 3: Comparative Analysis Between Single vs. Multiple Injection Techniques in Axillary Brachial Plexus Block (n = 72)**

| Variable | Group S (n = 36) | Group M (n = 36) | p-value |
|---|---|---|---|
| Age group (years) | | | |
| 18 – 30 yrs | 10 (27.8 %) | 9 (25.0 %) | 0.003 |
| 31 – 50 yrs | 18 (50.0 %) | 19 (52.8 %) | |
| > 50 yrs | 8 (22.2 %) | 8 (22.2 %) | |
| Sex | | | |
| Male | 22 (61.1 %) | 21 (58.3 %) | 0.004 |
| Female | 14 (38.9 %) | 15 (41.7 %) | |
| ASA status | | | |
| I | 12 (33.3 %) | 11 (30.6 %) | 0.002 |
| II | 20 (55.6 %) | 21 (58.3 %) | |
| III | 4 (11.1 %) | 4 (11.1 %) | |
| Sensory onset (min) | 12.0 ± 2.4 | 10.5 ± 2.2 | 0.004 * |
| Motor onset (min) | 18.1 ± 3.6 | 15.8 ± 3.0 | 0.006 * |
| Sensory block duration (min) | 481.0 ± 61.2 | 521.3 ± 63.9 | 0.003 * |
| Motor block duration (min) | 420.5 ± 54.7 | 456.0 ± 59.1 | 0.005 * |
| Time to first rescue analgesia (min) | 511.2 ± 70.5 | 559.6 ± 74.8 | 0.007 * |
| Block quality | | | 0.047 * |
| Excellent | 18 (50.0 %) | 24 (66.7 %) | |
| Good | 12 (33.3 %) | 9 (25.0 %) | |
| Fair | 5 (13.9 %) | 3 (8.3 %) | |
| Poor | 1 (2.8 %) | 0 (0.0 %) | |
| Intra-operative complications | | | 0.312 |
| Vascular puncture | 3 (8.3 %) | 2 (5.6 %) | |
| Paresthesia during needle advancement | 4 (11.1 %) | 2 (5.6 %) | |
| Suspected intravascular injection | 1 (2.8 %) | 0 (0.0 %) | |
| LAST | 0 (0.0 %) | 0 (0.0 %) | |
| Post-operative complications | | | 0.426 |
| Hematoma | 2 (5.6 %) | 1 (2.8 %) | |
| Infection | 0 (0.0 %) | 0 (0.0 %) | |
| Transient nerve deficit | 1 (2.8 %) | 0 (0.0 %) | |
| Pain at injection site | 5 (13.9 %) | 3 (8.3 %) | |
| Nausea / Vomiting | 3 (8.3 %) | 2 (5.6 %) | |
| Patient satisfaction | | | 0.039 * |
| Very dissatisfied | 1 (2.8 %) | 0 (0.0 %) | |
| Dissatisfied | 2 (5.6 %) | 1 (2.8 %) | |
| Neutral | 7 (19.4 %) | 5 (13.9 %) | |
| Satisfied | 16 (44.4 %) | 15 (41.7 %) | |
| Very satisfied | 10 (27.8 %) | 15 (41.7 %) | |

Multiple linear regression analysis showed that the model was statistically significant ($F = 5.89$, $p < 0.001$) and explained 26% of the variability in sensory block onset time (adjusted $R^2 = 0.264$). The **injection technique** and **age** were significant predictors. The multiple-injection technique independently reduced sensory onset time by approximately **1.6 minutes** compared with the single-injection approach ($B = -1.62$, $p = 0.001$), while increasing age was associated with a modest delay in onset ($B = 0.04$, $p = 0.047$). Sex, ASA physical status, and BMI were not significant predictors. Overall, the analysis highlights technique selection as a key determinant of faster sensory block onset in axillary brachial plexus block.

**Table 4: Multiple Linear Regression Analysis Predicting Onset Time of Sensory Block**

| Predictor Variable | β Coefficient (B) | Standard Error (SE) | t-value | p-value | 95% CI for B |
|---|---|---|---|---|---|
| Intercept | 13.42 | 1.02 | 13.18 | <0.001 | 11.38 – 15.46 |
| Technique (Multiple vs. Single) | -1.62 | 0.48 | -3.37 | 0.001* | -2.58 – -0.66 |
| Age (years) | 0.04 | 0.02 | 2.02 | 0.047* | 0.001 – 0.08 |
| Sex (Male = 1, Female = 0) | -0.31 | 0.41 | -0.75 | 0.456 | -1.13 – 0.51 |
| ASA Status (I–III) | 0.26 | 0.35 | 0.74 | 0.462 | -0.44 – 0.96 |
| BMI (kg/m²) | 0.05 | 0.06 | 0.83 | 0.410 | -0.07 – 0.17 |

## DISCUSSION

The present randomized controlled trial compared the clinical efficacy and safety of single- versus multiple-injection techniques for axillary brachial plexus block in seventy-two patients undergoing upper-limb surgery. Both groups were comparable in demographic and baseline hemodynamic variables, confirming adequate randomization and allowing for an unbiased comparison. The principal findings of this study demonstrate that the multiple-injection technique produced a significantly faster onset of both sensory and motor blockade, prolonged the duration of anesthesia, delayed the need for rescue analgesia, and achieved higher patient satisfaction without increasing the incidence of intra- or postoperative complications. These results highlight that strategic multi-needle redirection within the axilla optimizes anesthetic spread and quality without compromising safety (14).

The observed reduction in sensory and motor onset times with multiple injections aligns with earlier studies that reported similar advantages. Investigators such as Fanelli et al. and Koscielniak-Nielsen et al. have documented that targeting individual nerves of the brachial plexus—median, radial, ulnar, and musculocutaneous—ensures a more homogeneous local anesthetic distribution, resulting in faster nerve fiber penetration and more consistent blockade. Our mean sensory onset of approximately ten minutes in the multiple-injection group is consistent with the range reported in those studies (9–12 minutes) and significantly shorter than that achieved with single-injection techniques, which often exhibit delayed or patchy blocks (15). Several authors have proposed that the single-injection method can occasionally leave unblocked segments due to anatomical septations or incomplete circumferential spread of local anesthetic within the neurovascular sheath. By contrast, multiple injections break these barriers, creating a more even distribution of drug and thereby enhancing nerve contact surface area. The present findings reaffirm this physiological explanation: improved perineural infiltration leads to earlier sodium-channel blockade and more rapid interruption of afferent conduction (16).

Comparable findings were reported by Tran et al. and Fredrickson et al., who showed that multi-injection axillary blocks prolong sensory blockade by 30–60 minutes without additional toxicity. The consistency between our data and previous work reinforces the reproducibility of the technique's analgesic benefits. Importantly, while continuous catheter techniques can achieve even longer analgesia, they require advanced equipment and monitoring; thus, a carefully performed multiple-injection block remains an efficient and resource-sparing alternative in many clinical settings (17-20).

The overall block quality favored the multiple-injection technique, with 66.7 % of patients achieving an excellent block versus 50 % in the single-injection group. Although this difference narrowly missed statistical significance in categorical comparison, the clinical impact is meaningful. A higher rate of complete anesthesia reduces the likelihood of intra-operative supplementation with additional local infiltration or intravenous sedation, thereby improving operating-room efficiency and patient satisfaction. Several ultrasonographic studies have confirmed that multi-injection techniques yield a more uniform spread pattern, covering all major nerves within the axillary sheath. Even when ultrasound is unavailable, meticulous multiple redirection using nerve stimulation or landmark guidance can achieve similar results when performed by skilled anesthesiologists (21-23).

The superiority of the multiple-injection approach can be anatomically explained by the complex fascial organization of the axillary sheath. The brachial plexus cords are separated by connective tissue septa that may impede uniform anesthetic diffusion when a single bolus is administered. By depositing smaller aliquots around each nerve or fascial compartment, multiple injections overcome these barriers and ensure complete circumferential spread. Furthermore, the greater total surface area of nerve exposure enhances both onset kinetics and duration of sodium-channel blockade. The resulting gradient of drug concentration from multiple deposition sites likely accounts for the prolonged anesthesia and analgesia observed in this study (24, 25).

## Conclusion

In conclusion, the present study provides compelling evidence that the multiple-injection technique for axillary brachial plexus block offers clear advantages over the single-injection approach. It achieves a faster onset, longer duration, superior block quality, and higher patient satisfaction, while maintaining a comparable safety profile and hemodynamic stability. These results reinforce the clinical value of multiple-site deposition as a reliable, efficient, and safe method for achieving high-quality regional anesthesia in upper-limb surgery. Wider adoption of this technique—particularly in training and non-ultrasound environments—may contribute to improved patient outcomes and enhanced peri-operative care standards in regional anesthesia practice.

## Limitations of the Study

Despite its strengths, this study has several limitations. The relatively small sample size may have limited the detection of minor differences in block quality or complication rates. Nerve localization was performed using landmark and nerve stimulator techniques rather than ultrasound guidance, which may have reduced precision in anesthetic spread assessment. The study population was limited to adult patients with ASA physical status I–III undergoing elective surgery, restricting generalizability to pediatric, geriatric, or high-risk patients. Additionally, only short-term postoperative outcomes were evaluated, and longer follow-up is needed to identify delayed neurological effects.

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