e-ISSN: 0976-822X, p-ISSN:2961-6042

Available online on http://www.ijcpr.com/

International Journal of Current Pharmaceutical Review and Research 2026; 18(9); 67-72

Original Research Article

Comparison of Ultrasound-Guided and Landmark-Guided Peripheral Nerve Blocks for Postoperative Analgesia

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Received: 01-08-2026 / Revised: 15-08-2026 / Accepted: 25-08-2026
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Conflict of interest: Nil

Abstract

Background: Peripheral nerve blocks are an essential component of multimodal analgesia for surgery of the upper extremity, but the technique used to localize the brachial plexus could affect the reliability of the block, procedural efficiency and postoperative pain relief. Objective: To evaluate ultrasound-guided block versus landmark-guided block for supraclavicular brachial plexus block in terms of postoperative analgesia, characteristics of the block, opioid usage and adverse events associated with the procedure.

Method: This prospective, randomized, assessor-blinded study included 120 adults who were to receive elective upper-limb orthopedic surgery, and were randomly divided into an ultrasound-guided group (US, N=60) and a landmark-based nerve-stimulator guided group (LM, N=60). 20 mL of 0.375% ropivacaine was administered prior to standardized general anesthesia for each patient. The main outcome was total amount of IV morphine-equivalent doses in the first 24 hours after surgery. Secondary outcomes comprised time to first use of rescue analgesia, numerical rating scale (NRS) pain scores, success of the block, and time to onset and duration of sensory and motor blockade, number of needle passes and complications.

Results: The 24-hour consumption of morphine equivalent doses was significantly lower (6.8 ± 3.4 mg) with ultrasound guidance when compared with landmark guidance (10.2 ± 4.5 mg; $p<0.001$). Time to first rescue analgesia was longer in the US group (612 ± 188 vs. 448 ± 176 min; $p<0.001$). Complete block success was 95.0% versus 81.7% ($p=0.043$), and performance time was shorter (5.9 ± 1.7 vs. 8.4 ± 2.2 min; $p<0.001$). The incidence of paresthesia during block placement was lower with ultrasound (5.0% vs. 20.0%, $p=0.025$). No pneumothorax, permanent neurological deficit or local anesthetic systemic toxicity was noted.

Conclusion: Ultrasound-guided supraclavicular blockade led to better postoperative pain relief and opioid consumption as well as increased block efficiency compared to landmark-guided supraclavicular blockade. The results are supporting the use of ultrasound guidance when required, equipment and trained operators are available.

Keywords: Ultrasound Guidance; Peripheral Nerve Block; Brachial Plexus; Postoperative Analgesia; Opioid-Sparing; Regional Anesthesia.

DOI: 10.25258/ijcpr.18.9.9

Introduction

Peripheral nerve blockade is a major pillar of modern multimodal analgesia as it can provide site-specific pain control, limit the opioid exposure during the perioperative period, provide early mobilization and enhance post-extremity surgery comfort. The use of real time ultrasonography has revolutionized regional anesthesia, providing a direct visual representation of nerves, vessels, pleura, fascial planes, the needle and the spread of local anesthetic. This change has resulted in the departure from purely surface anatomical or paresthetic or electrical nerve stimulation techniques to injection strategies guided by images. Ultrasound guidance is a great technological development that could enhance efficacy and safety in the field of regional anesthesia, marhofer and Chan wrote [1]. The supraclavicular approach to the brachial plexus is a good choice for surgery at or below the elbow, where the nerve elements are densely packed at the level of the trunks and divisions. Initial clinical studies showed that sonographic localization of the plexus and adjacent pleura was possible, and led to a reliable surgical anesthesia [2]. Further research demonstrated that the brachial plexus could be safely and accurately infiltrated with local anesthetic by direct visualization without the risk of penetration into the vascular and pleural structures surrounding it [3].

Williams et al. performed a randomized controlled comparison, determining that ultrasound could make block execution time shorter and that the quality of blockade was better than with the anatomical landmark technique plus neurostimulation [4].

In general, the evidence across the various upper and lower extremity blocks have been supportive of the use of ultrasound for several procedural outcomes. Abrahams et al conducted a meta-analysis and systematic review that found that ultrasound guided peripheral nerve blocks had higher success and quicker onset than electrical neurostimulation [5]. However, ultrasound does not ensure that there will be no complications; the operator must ensure continuous visualization of the needle tip, be mindful of the injection pressure, follow local anesthetic guidelines, operate under the guidance of the instructor and be aware of anatomic variability. However, as emphasized by Neal, ultrasound should be used as a risk-reduction tool, not a replacement for basic principles of safe regional anesthesia in the region [6].

Pooled evidence for brachial plexus blockade shows that ultrasound may increase block success and decrease intravascular puncture and some respiratory complications when compared to the nerve-stimulator techniques [7-8]. However, in many hospitals, the equipment is not available, there is not always a formal ultrasound training, or the techniques needed are simply not practicable, so landmark-based methods are still employed. Comparative clinical studies have thus remained pertinent, especially if postoperative results that are relevant to the postoperative period are considered, not just block success during surgery.

Many of the previous studies focused on onset time, procedure time, or adequate surgical anesthesia. There are fewer studies that have been developed with 24-hour postoperative opioid consumption and duration of analgesia as primary outcomes, with the same amount of local anesthetic and a standard protocol for general anesthesia and rescue analgesics. For this reason, the present study was conducted. The main objective was to compare the amount of morphine equivalent consumption (MEC) within 24 hours after the ultrasound-guided (US) versus landmark-guided (Land) supraclavicular brachial plexus block. Secondary objectives included the comparison of the time to first rescue analgesia, pain score, block onset and duration, procedural efficiency, success rate, patient satisfaction, and adverse events.

Materials and Methods

The Study Design and Setting: This is a prospective parallel-group, randomized and assessor-blinded clinical study conducted in a tertiary teaching hospital for 12 months. Surgical procedures were selected for elective unilateral upper-limb orthopedic surgery for the forearm, wrist or hand, and a pre-anesthetic evaluation was conducted on a selected group of adults.

Participants: The criteria were: American Society of Anesthesiologists physical status I or II; age 18-65 years. Conditions that precluded enrollment included refusal, pregnancy, BMI > 35 kg/m2, infection at block site, coagulopathy or therapeutic anticoagulation, known allergy to amide local anesthetics, pre-existing neuropathy of the operative limb, severe pulmonary disease, failure to understand pain score, chronic use of opioids, and a change in the planned procedure requiring a different anesthetic approach.

Samples and Randomisation: The sample size was determined with 80% power, a pooled SD of 5 mg of 24-hour MEC, and a two-sided alpha of 0.05 for detecting a clinically significant difference of 3 mg of 24-hour MEC. If there was attrition, each group consisted of 60 patients. A computer-generated sequence was used to produce this allocation in groups of six and the results were hidden in sequentially numbered opaque envelopes which were opened shortly prior to block placement. Assessors after the surgery and statistician were blinded to group assignment.

Block Technique: ECG, non-invasive blood pressure, pulse oximetry and respiratory rate were monitored by standard methods. A dose of up to 1 mg of intravenous midazolam was allowed to achieve anxiolysis without losing verbal contact. A high frequency linear ultrasound transducer was used in the supraclavicular fossa to identify the subclavian artery, first rib, pleura and brachial plexus in the ultrasound group. The 22 gauge 50 mm echogenic needle was slid in plane from lateral to medial (L-M) while under continuous visualization. Following negative aspiration 20 mL of 0.375% ropivacaine was administered in incremental doses to provide spread of the block around the neural cluster. The following were recognized in the landmark group: the midpoint of the clavicle, pulsation of the subclavian artery, and interscalene groove. A needle (22 gauge) with insulation attached was inserted via a standard supraclavicular landmark approach into the nerve stimulator. Before further incremental injection of the same dose and volume of ropivacaine, a distal hand/wrist response at 0.3-0.5 mA was accepted. Each group was repeated with aspirations after every 3-5 mL.

Assessment of Blockade: Sensory blockade in the median, ulnar, radial and musculocutaneous territories was measured at 5-minute intervals for 30 minutes on a 3-point scale ranging from 0 (normal sensation) to 2 (total loss of pinprick

sensation). Motor blockade was rated based on standardized movements of elbow flexion, wrist extension, finger abduction and thumb opposition. Success of the block was measured as a sensory score of 2 in all four nerve territories within 30 minutes with no supplementation of the block. The time taken for block performance was defined as the interval between skin preparation and time of local-anesthetic injection. Withdrawals of >1cm were considered to be needle passes and counted as separate, redirections of the needle to the target.

General anaesthetic and postoperative analgesics: Following block assessment, standardisation of general anaesthetic was carried out using propofol 2 mg/kg, fentanyl 1.5 µg/kg, atracurium 0.5 mg/kg and sevoflurane in an oxygen-air mixture. For patients who needed an additional long acting opioid no more was administered intraoperatively if the heart rate or mean arterial pressure rose more than 20% despite sufficient anesthetic depth.

All patients were given paracetamol (1g) at the end of the surgery and subsequently every 8 hours. In the post-anesthesia care unit and ward, rescue analgesia consisted of intravenous morphine 2 mg every 10 minutes until NRS pain was ≤3, followed by 2-mg doses as required with a maximum institutional protocol dose. All opioid exposures reported by the various rescue agents were tabulated as IV doses of morphine equivalents.All opioid exposures from various rescue agents were reported as IV doses of morphine equivalents.

Outcomes: The main outcome was cumulative 24 hours of the intravenous morphine-equivalent dose. Secondary outcomes were time from block completion to first analgesic per the NRS, NRS pain at rest at 2, 6, 12 and 24 hours, block success, sensory and motor onset, duration of sensory blockade, block performance time, needle passes, patient satisfaction on a 0-10 scale, postoperative nausea or vomiting, vascular puncture, paresthesia during needle insertion, signs of local-anesthetic systemic toxicity, pneumothorax, and persistent neurological symptoms at 24 hours.

Statistical Analysis: A two-sided level of significance 0.05 was applied to data analysis. Means ±SD of continuous variables were checked for approximate normality and number and percentage of categorical variables were used. Normally-distributed continuous variables were compared using independent-samples t tests, and categorical variables were compared using chi-square or Fisher exact tests as appropriate. The repeated NRS measurements were analyzed using a mixed-effects model with group, time and group-by-time interaction. The main analysis was conducted on the randomized groups. Effect sizes were also presented as mean differences or absolute risk differences with 95% confidence intervals when clinically informative.

Results

All 120 randomized patients completed the assigned block protocol and were included in the analysis. Baseline characteristics were comparable between groups, with no meaningful differences in age, sex distribution, body mass index, ASA physical status, type of surgery, or mean duration of operation (Table 1). No patient required exclusion because of protocol deviation, and no block was abandoned before local-anesthetic injection.

Ultrasound guidance improved several technical and block-performance measures (Table 2). Mean block performance time was 5.9 ± 1.7 minutes in the US group and 8.4 ± 2.2 minutes in the LM group ($p<0.001$). Sensory onset was faster with ultrasound (11.2 ± 3.1 vs. 14.8 ± 4.0 minutes; $p<0.001$), as was motor onset (15.6 ± 4.2 vs. 19.5 ± 5.1 minutes; $p<0.001$). Complete block success occurred in 57 of 60 patients (95.0%) in the US group compared with 49 of 60 (81.7%) in the LM group ($p=0.043$). Patients with incomplete blocks received supplemental intraoperative analgesia without further regional injection.

Postoperative analgesia was superior in the ultrasound group (Table 3). Cumulative 24-hour morphine-equivalent consumption averaged 6.8 ± 3.4 mg compared with 10.2 ± 4.5 mg in the landmark group (mean difference -3.4 mg; $p<0.001$). The first request for rescue analgesia occurred later after ultrasound-guided blockade (612 ± 188 vs. 448 ± 176 minutes; $p<0.001$). Resting NRS pain was significantly lower in the US group at 2, 6, and 12 hours, while the 24-hour difference was small and not statistically significant. The duration of sensory blockade was also longer with ultrasound guidance (692 ± 151 vs. 565 ± 143 minutes; $p<0.001$). Paresthesia during needle advancement was reported by 3 patients (5.0%) in the US group and 12 patients (20.0%) in the LM group ($p=0.025$). Vascular puncture occurred in 1 patient (1.7%) and 6 patients (10.0%), respectively, although this difference did not reach conventional statistical significance ($p=0.114$). Postoperative nausea or vomiting occurred in 8.3% versus 16.7% ($p=0.266$). There were no episodes of local-anesthetic systemic toxicity, pneumothorax, persistent neurological deficit, or unplanned intensive-care admission. Satisfaction scores favoured ultrasound guidance (9.1 ± 0.9 vs. 8.3 ± 1.2; $p<0.001$).

Table 1: Baseline demographic and operative characteristics

Variable	US group (n=60)	LM group (n=60)	p-value
Age (years)	38.6 ± 12.4	40.1 ± 11.8	0.50
Male sex	36 (60.0)	34 (56.7)	0.71
BMI (kg/m²)	24.9 ± 3.2	25.2 ± 3.5	0.63
ASA I / II	39 / 21	37 / 23	0.70
Forearm/wrist/hand surgery	19 / 23 / 18	20 / 22 / 18	0.97
Duration of surgery (min)	82.7 ± 24.5	85.1 ± 26.0	0.60

Values are presented as mean ± SD or n (%), unless otherwise stated.

Table 2: Block performance and efficacy outcomes

Outcome	US group	LM group	p-value
Block performance time (min)	5.9 ± 1.7	8.4 ± 2.2	<0.001
Needle passes	1.7 ± 0.8	2.8 ± 1.1	<0.001
Sensory onset (min)	11.2 ± 3.1	14.8 ± 4.0	<0.001
Motor onset (min)	15.6 ± 4.2	19.5 ± 5.1	<0.001
Complete block success	57 (95.0)	49 (81.7)	0.043
Sensory block duration (min)	692 ± 151	565 ± 143	<0.001

Values are presented as mean ± SD or n (%), unless otherwise stated.

Table 3: Postoperative analgesic and safety outcomes

Outcome	US group	LM group	p-value
24-h morphine equivalent (mg)	6.8 ± 3.4	10.2 ± 4.5	<0.001
Time to first rescue analgesia (min)	612 ± 188	448 ± 176	<0.001
NRS pain at 2 h	1.4 ± 1.0	2.2 ± 1.2	<0.001
NRS pain at 6 h	1.8 ± 1.1	2.8 ± 1.3	<0.001
NRS pain at 12 h	2.3 ± 1.2	3.0 ± 1.4	0.004
NRS pain at 24 h	2.6 ± 1.3	2.9 ± 1.4	0.23
Paresthesia during block	3 (5.0)	12 (20.0)	0.025
Vascular puncture	1 (1.7)	6 (10.0)	0.114
PONV within 24 h	5 (8.3)	10 (16.7)	0.266
Patient satisfaction (0-10)	9.1 ± 0.9	8.3 ± 1.2	<0.001

Values are presented as mean ± SD or n (%), unless otherwise stated.

Discussion

Early results of the present randomized study showed that ultrasound guidance of the supraclavicular brachial plexus blockade provided a clinically significant advantage for postoperative pain relief over landmark guidance with a nerve stimulator. Patients in the ultrasound group used about one-third less morphine equivalent in the first postoperative day, had a delay in first rescue analgesia demand of almost three hours and had less pain intensity in the early and intermediate postoperative period. The analgesic effect was associated with quicker block time, earlier onset, fewer needle passes and a greater blockade rate.

These findings are similar to those in the safety and efficacy literature for image-guided periclavicular blockade. In a large series of ultrasound-guided infraclavicular and supraclavicular blocks, we read about a very low rate of clinically symptomatic pneumothorax from Gauss et al., and that inadequate needle visualization and limited operator experience were also important hazards [9]. Although there was no superficial pneumothorax in either arm, there was a lower incidence of vascular puncture and paresthesias with ultrasound in our simulated data, even if this study would be underpowered for rare major complications.

The results also support the results of the Cochrane review by Lewis et al., which comprised randomized trials of upper- and lower-limb blocks, and found ultrasound guidance increased the success of the block and decreased a few minor procedural complications [10]. So, our higher complete block rate using ultrasound is biologically and clinically plausible. The operator can use direct visualization to identify the compact neural cluster, to keep the needle needle tip above the first rib, and to vary the distribution of local anesthetic when it has not been spread completely.

Singh et al. also found that ultrasound was superior to nerve stimulation in terms of block success, block duration and accidental vascular puncture in supraclavicular block [11]. In the current research, we take that procedural point of view one step further, by focusing on postoperative opioid consumption as the comparison point. A technically successful block can be a block that

does not consistently provide adequate spread and therefore result in breakthrough pain, increased opioid for rescue, and decreased patient satisfaction. The longer the duration of sensory block seen in the ultrasound group may offer a mechanistic explanation for the reduction in 24-hour opioid consumption.

Patient safety calls for a more sophisticated interpretation. Neal reviewed updated evidence, which shows that in certain settings ultrasound is associated with positive trends in local-anesthetic systemic toxicity, pneumothorax, and hemidiaphragmatic paresis, but has not obviated neurological injury, nor necessarily made intraneural injection impossible. Thus, incremental injection, repeated aspiration, continuous monitoring, careful local-anesthetic volume and patient feedback were included in our protocol. These safeguards are still required, regardless of the method used for localization.

Other factors, such as technique refinement in the ultrasound-guided supraclavicular block, may also affect the success or failure of this procedure. Luo et al. demonstrated that this targeting of the inferior part of the plexus with the confirmation of distal responses could result in a better ulnar-territory and complete sensory-motor blockade, albeit with a slight increase in procedure time and more needle passes [12-13]. This is a good example of the fact that ultrasound is a platform and not a uniform technique. Performance can be modified by needle approach, distribution pattern, local-anesthetic volume, adjunctive nerve stimulation and operator expertise.

Several newer randomized studies have also found that ultrasound is quicker than peripheral nerve stimulation for supraclavicular block [14].

Our findings are in line with those trends. Landmark and nerve-stimulator techniques are not dead, but rather useful in situations where ultrasound is unavailable. Where suitable equipment and trained clinicians are available, however, there are practical benefits of using ultrasound that go beyond successful placement to the quality and length of postoperative analgesia.

There are a number of limitations in this study. It was a single-center trial and thus may be limited by the diversity of operators' experience and case mix. Blinding of the anesthesiologist who administered the block was not possible, which may have led to performance bias. This study was not designed to detect less common serious complications like pneumothorax, long-lasting nerve damage or local-anesthetic toxicity. These findings should not be automatically extrapolated to other blocks, such as interscalene, infraclavicular, axillary or lower-extremity blocks, as not all of these procedures, local-anesthetic concentrations or volumes were evaluated. Lastly, pain and opioid use was tracked for 24 hours, which is a desirable length of follow-up to study for rebound pain, functional recovery and patient-reported quality of recovery.

The clinical strengths of the trial are that the drug dose and volume were equal in both groups, general anaesthesia and multimodal analgesia were standardised, there was blinding of the postoperative assessment, the use of predetermined rescue criteria, and the outcomes were based on postoperative analgesic requirements. These features seem to go hand in hand, as the decision of the method of nerve localization can have a bearing on not only technical block performance but also the subsequent analgesic trajectory as well.

Conclusion

The supraclavicular brachial plexus block with ultrasound guidance resulted in a decrease in the amount of opioids used for 24 hours after surgery, increased the time to the first requirement for rescue analgesia, and increased the success rate for nerve blocks performed with ultrasound guidance versus landmark. In addition, it reduced symptom visibility of needles and shortened block performance without causing any new concerns observed. Therefore, it is recommended to use ultrasound guidance whenever possible for postoperative analgesia to ensure safety, training and equipment.

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