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Original Research Article

Comparison of Ultrasound-Guided Versus Landmark-Guided Supraclavicular Brachial Plexus Block for Upper-Limb Surgeries

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Abstract

Background: Supraclavicular brachial plexus block gives intense anesthesia for surgery below the shoulder, though conventional landmark localization is limited by anatomical variation and proximity to vascular and pleural structures. In this study, both ultrasound- and landmark-guided protocols were evaluated for procedural efficiency, block characteristics, success, analgesia, and complications.

Methods: This prospective randomized comparative study of elective upper-limb surgery included 80 adults who underwent either ultrasound-guided (Group U) or landmark-guided (Group L) supraclavicular block. Patients received 25 mL of 0.5% ropivacaine in each group. The primary endpoint was complete surgical block at 30 minutes. Secondary outcome variables comprised procedure time, sensory and motor onset, duration of postoperative analgesia, rescue analgesic requirement, hemodynamic stability, and adverse events.

Results: The baseline properties were similar. Complete block occurred in 38/40 patients (95.0%) in Group U and 32/40 (80.0%) in Group L (risk difference 15.0%, p=0.043). Ultrasound advice decreased procedures duration (8.4±2.1 vs 12.7±3.2 minutes), sensory onset (10.2±2.8 vs 15.8±3.6 minutes), and motor onset (14.7±3.4 vs 21.3±4.8 minutes; all p<0.001). Ultrasound analgesia was longer (8.9±1.6 vs 6.7±1.5 hours, p<0.001), and 24-hour rescue tramadol intake was less (74±36 vs 112±44 mg, p<0.001). Vascular puncture were present in 1 vs 6 patients (p=0.048), and no pneumothorax, local-anesthetic systemic toxicity, or lasting neurological deficit occurred.

Conclusion: Ultrasound guidance was, compared to landmark guidance, found to better facilitate block success, hasten onset, prolong analgesia, and reduce vascular puncture. Its usage regularly could increase the reliability and safety of supraclavicular block when both equipment and trained operators are available.

Keywords: Brachial Plexus Block; Supraclavicular Block; Ultrasound Guidance; Landmark Technique; Regional Anesthesia; Upper-Limb Surgery.

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Introduction

Regional anesthesia has become essential to modern upper-limb surgery; it can give surgical anesthesia, limit perioperative opioid exposure, and aid in protracted postoperative analgesia whilst allowing spontaneous ventilation to be maintained. The supraclavicular approach targets the brachial plexus in which trunks and divisions are closely positioned above the first rib, forming a rapid and dense block of the upper extremity. However, the plexus lies near the subclavian artery and pleural dome, so precision pin-pointing is clinically essential [1,2].

This was preceded by the classic landmark-guided method that depends on surface morphology, palpation, elicited paresthesia, and the tactile appreciation of the needle route. The method is indirect, relatively inexpensive, and available in most cases. Obesity, distorted anatomy, poor landmark definition, and inter-individual variation can lead to more needle passes, delayed onset, and a predisposition to incidentally traumatize vascular, neural, or pleural structures [3].

Ultrasound guidance enables the direct study of neural elements in particular (subclavian artery, first rib, and pleura) and enables ongoing visualization of the needle and extension of local anesthetic [4]. The effectiveness of ultrasound guidance depends on operator experience, injection

method, and outcome, but it can increase the success with improved execution time, block quality, or ultrasound. Another Cochrane review found a similar effect on the success rate of blocks and the risk of vascular puncture for ultrasound guidance [8], but found heterogeneity among other methods and procedures. Not all risk is eliminated by ultrasound, and pneumothorax, hemidiaphragmatic paresis, intraneural injection, and local anesthetic systemic toxicity remain in instances where images remain incomplete or needle tip visualization does not occur.

Indeed, landmark-guided supraclavicular block is in many resource-variable settings still common due to the low equipment requirement and rapid deployment for its use. Therefore, a direct comparison retains practical relevance, especially where ultrasound availability, training, and workflow differ from high-resource regional-anesthesia services. This study compared ultrasound-guided versus landmark-guided supraclavicular brachial plexus block in adults undergoing upper-limb surgery. We hypothesized that ultrasound guidance would increase complete surgical block at 30 minutes, shorten procedural and onset times, prolong postoperative analgesia, and reduce needle-related adverse events.

Materials and Methods

A prospective, randomized, parallel-group comparative study was performed at the Department of Anaesthesiology, a tertiary-care teaching hospital, during a 12-month period. Adults aged 18 to 65 years, classified as American Society of Anesthesiologists physical status I-II, and scheduled for elective surgery of the elbow, forearm, wrist, or hand under supraclavicular brachial plexus block were enrolled. Patients who declined participation, had infection at the injection site, coagulopathy, clinically significant pulmonary disease, pre-existing neurological deficit in the operative limb, allergy to amide local anesthetics, pregnancy, body mass index greater than 35 kg/m2, or inability to communicate block-related symptoms were excluded.

Randomization and Blinding: Eighty eligible participants were randomized in a 1:1 ratio using computer-generated permuted blocks and sequentially numbered opaque envelopes. Group allocation was revealed immediately before block performance. The anesthesiologist performing the block could not be blinded; however, sensory and motor assessment and postoperative data collection were undertaken by an investigator unaware of allocation.

Block Technique: Standard monitoring included electrocardiography, non-invasive blood pressure, and pulse oximetry. Intravenous access was secured, oxygen was administered when required, and resuscitation drugs and lipid emulsion were immediately available. In Group U, a high-frequency linear transducer was positioned in the supraclavicular fossa. The plexus, subclavian artery, first rib, and pleura were identified, and a 22-gauge block needle was advanced in-plane under continuous visualization.

Local anesthetic was deposited incrementally after negative aspiration to obtain circumferential plexus spread. In Group L, the midpoint of the clavicle and subclavian arterial pulsation were identified. A needle was introduced using the conventional subclavian perivascular landmark approach; paresthesia or transmitted movement in the distal limb was used as the endpoint. Both groups received 25 mL of 0.5% ropivacaine in 3-5 mL aliquots with intermittent aspiration.

Outcome Assessment: Sensory block was graded based on cold and pinprick in musculocutaneous, median, radial, and ulnar nerve territories. Elbow flexion, thumb opposition, wrist extension, and finger abduction were all used to assess motor function. Complete surgical block was defined as loss of pinprick sensation and motor power of grade 0 or 1 in all four distributions within 30 minutes without conversion to general anesthesia. The procedure time ran from skin preparation to needle withdrawal. Sensory and motor onset, block duration, time to first rescue analgesic, 24-hour tramadol consumption, conversion to general anesthesia, vascular puncture, paresthesia, Horner syndrome, dyspnea, pneumothorax, local-anesthetic systemic toxicity, and persistent neurological symptoms were recorded.

Statistical Analysis: We used 80% power and a two-sided alpha of 0.05 to determine the sample size, including 40 subjects in each group to detect a 20-percentage-point difference in complete-block success. The continuous variables were evaluated for normality and reported as mean ± SD or median [interquartile range]. Independent-samples t tests or Mann-Whitney U tests if applicable were administered. Statistical comparison of categorical variables was done with the chi-square test or Fisher exact test. Effect estimates were represented as mean differences, risk differences, relative risks, and 95% confidence intervals. A two-sided p value below 0.05 was statistically significant. Analyses were performed on an intention-to-treat basis.

Results

Eighty patients were randomized and 40 patients were analyzed to each technique. There was no participant lost following allocation. Both groups were matched for age, sex, body mass index (BMI), ASA physical status, operative site, and length of surgery. Such comparability reduced the

opportunity for demographic or procedural dissimilarity to explain the variability in block performance.

The ultrasound-guided blocks had presented 95.0% and the landmark-guided blocks 80.0% complete surgical anesthesia at 30 min. Relative risk = 1.19: absolute increase in percentage point success (15.0). Two of the patients in Group U and eight in Group L needed to supplement or switch to general anesthesia. Ultrasound guidance was also associated with decreased mean procedure time (4.3 minutes) and fast sensory and motor onset. The differences were substantial and standardized, suggesting a clinically meaningful rise in surgical readiness. On average, group U had a prolonged postoperative analgesia duration of 2.2 hours and a cumulative tramadol requirement within 24 h was approximately one-third decreased. At measured time points, hemodynamic variables were stable in both groups and did not differ materially. Vascular puncture and transient paresthesia were far more frequent under landmark guidance.

In one patient in each group mild transient Horner syndrome was found. No pneumothorax, seizure, arrhythmia, local-anesthetic systemic toxicity, clinically important respiratory compromise, or persistent neurological deficit was found.

Table 1: Baseline demographic and operative characteristics

Characteristic	Group U (n=40)	Group L (n=40)	p value
Age, years	38.6 ± 12.4	40.1 ± 11.8	0.582
Male sex, n (%)	25 (62.5)	24 (60.0)	0.818
BMI, kg/m²	24.8 ± 3.1	25.2 ± 3.4	0.584
ASA I/II, n	28/12	27/13	0.809
Forearm/wrist-hand surgery, n	23/17	22/18	0.823
Surgical duration, min	78.5 ± 21.3	81.7 ± 24.1	0.531

Statistically and clinically similar baseline demographic and operative variables were found between the groups. Average age was not much different by 1.5 years, sex distribution was equal, and the body mass index and ASA physical status matched. No serious imbalance was noted in distribution of distal and proximal operative sites and mean surgical duration. As a result, subsequent differences in success, onset, analgesic duration, and adverse events were unlikely to reflect significant confounding at baseline and were more plausibly associated with the localization approach.

Table 2: Block performance and efficacy outcomes

Outcome	Group U	Group L	Effect estimate	p value
Complete block at 30 min, n (%)	38 (95.0)	32 (80.0)	RR 1.19; RD 15.0%	0.043
Procedure time, min	8.4 ± 2.1	12.7 ± 3.2	MD -4.3	<0.001
Sensory onset, min	10.2 ± 2.8	15.8 ± 3.6	MD -5.6	<0.001
Motor onset, min	14.7 ± 3.4	21.3 ± 4.8	MD -6.6	<0.001
Conversion/supplementation, n (%)	2 (5.0)	8 (20.0)	RR 0.25	0.043

Ultrasound guidance promoted a higher probability of achieving full surgical anesthesia, while it also substantially decreased all time-dependent measurements. The 15-percentage-point absolute increase in success is equivalent to approximately seven needed to treat. Procedure time decreased by 4.3 minutes with sensory onset and motor onset respectively being 5.6 and 6.6 minutes earlier. Fewer patients needed block supplementation or general anesthesia, indicating that visualization improved the technical efficiency and clinical reliability of operative anesthesia.

Table 3: Postoperative analgesia and rescue medication

Outcome	Group U	Group L	Mean difference	p value
Duration of analgesia, h	8.9 ± 1.6	6.7 ± 1.5	2.2 h	<0.001
Time to first rescue analgesic, h	9.3 ± 1.7	7.1 ± 1.6	2.2 h	<0.001
Tramadol in 24 h, mg	74 ± 36	112 ± 44	-38 mg	<0.001
Pain score at 6 h, 0-10	2.1 ± 1.0	3.2 ± 1.2	-1.1	<0.001

Ultrasound guidance preserved analgesic benefit longer than the intraoperative stage. Mean analgesia and time to first rescue medication were both prolonged by 2.2 h and 24-hour tramadol consumption was reduced by 38 mg. When comparing analgesia at 6 hours, pain intensity on the numerical scale decreased by about 1 point. Those findings suggest that correct deposition around a neural cluster facilitated local anesthetic distribution and provided clinical benefit in postoperative opioid-sparing.

Table 4: Procedure-related adverse events

Adverse event	Group U, n (%)	Group L, n (%)	p value
Vascular puncture	1 (2.5)	6 (15.0)	0.048
Transient paresthesia	2 (5.0)	7 (17.5)	0.154
Horner syndrome	1 (2.5)	3 (7.5)	0.615
Dyspnea	0	1 (2.5)	1.000
Pneumothorax	0	0	—
Persistent neurological deficit	0	0	—

Ultrasound guided needle complications and their incidence with needle and vascular puncture decreased from 15.0% to 2.5% [3].

Transient paresthesia and Horner syndrome were numerically less common, although the study was not powered to determine significance for atypical events. More importantly, neither group experienced pneumothorax, systemic local anesthetic toxicity, or persistent neurological injury.

This pattern of adverse events fits within the mechanistic benefits of real-time visualization, and emphasizes that regardless of methods for guidance, an accurate technique is still needed.

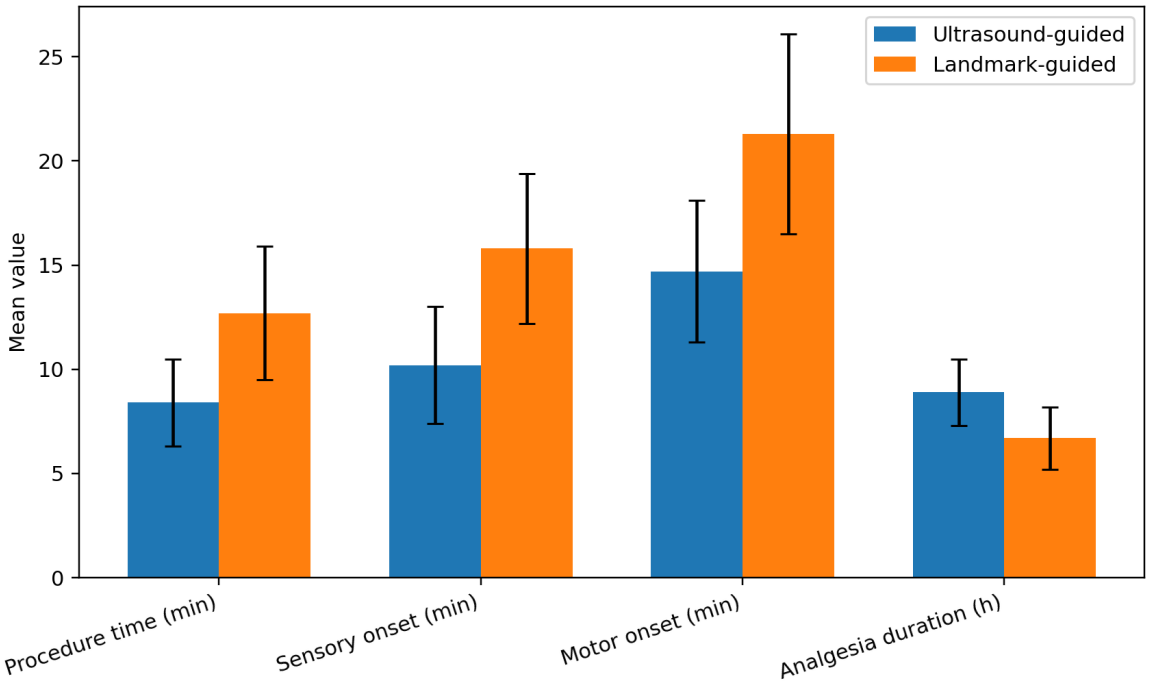

Figure 1: Comparison of Procedural and Block-Time Outcomes between Groups.

As shown in Figure 1, there was a significant temporal advantage of ultrasound guidance in block execution, sensory onset, motor onset, and analgesic duration. The maximum absolute separation in motor onset and the next strongest in sensory onset were observed. Although analgesia was measured in hours and procedural variables in minutes, the effect was uniform; image-guided placement accelerated readiness for surgery while extending postoperative benefit. Error bars are the standard deviations of principal onset outcomes, indicating limited overlap.

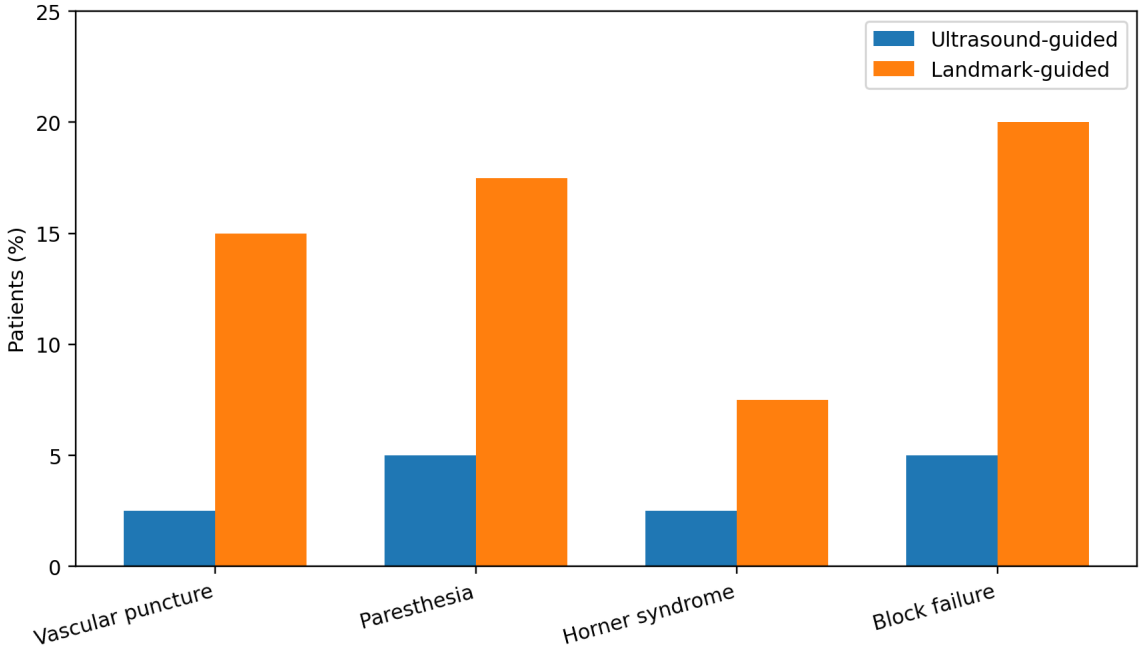

Figure 2: Frequency of Selected Block-Related Adverse Outcomes.

Ultrasound guided vascular puncture, paresthesia, Horner syndrome, and block failure showed the lowest frequency (Figure 2). Vascular puncture had the most statistically supported safety benefit, and the strongest absolute differences corresponded to block failure and transient paresthesia. Rare complications were absent or uncommon in both groups. Results are consistent with improvement in anatomical discrimination and decreased blind needle redirection; although measurement of these rare serious adverse events warrants larger studies.

This randomized comparison showed that ultrasound-guided supraclavicular block increased complete surgical anesthesia, decreased both procedural time and onset time; prolonged analgesia and reduced vascular puncture as compared to landmark guidance. The impact was not limited to a surrogate endpoint: fewer patients required supplementation or conversion to general anesthesia and postoperative opioid consumption was decreased. These findings align with the clinical thought that direct visualization improves the accuracy in local anesthetic deposition and reproducibility of blockade.

The increased success rate is consistent with Williams et al. [5], who achieved similar performance speed and quality of blocks with the introduction of ultrasound in supraclavicular localization. It is also consistent with the randomized comparisons of Alfred et al. and Singh et al., where ultrasound assist may have facilitated the success or faster initiation more so than nerve-stimulator techniques [6,7]. Ranganath et al. found ultrasound to result in shorter procedure and onset times, with a reduction in sensory onset of about three minutes and procedural time being almost half [9]. Our greater temporal differences could be due to using only a landmark-guided comparator making objective confirmation more challenging than by nerve stimulation.

The comparative advantage observed in this trial is consistent with the routine compared with ultrasound research of Cholewka and colleagues where they also found improved localization and safety with image guidance [10]. Some investigations of ultrasound versus nerve stimulation, which showed similar final success and even faster execution, suggest skilled operators were able to achieve a comparable robust blockade following more classical or specific localization [11]. This seeming paradox is clinically comprehensible: ultrasound can be expected to have the maximum incremental effect when this comparator is surface anatomy alone, where landmarks are poorly defined, or when the clinicians have variable experience.

The prolonged analgesia seen here is biologically plausible. Ultrasound enables targeted distribution around the trunks and divisions, reduces deposition into non-neural tissue, and allows correction of incomplete spread before needle withdrawal. Duncan et al. found that multiple-point ultrasound injection substantially reduced nerve sparing compared with single-point deposition [12]. Tran et al. likewise showed that injection architecture within neural clusters affects onset and completeness [13]. These observations indicate that the benefit of ultrasound depends not merely on

seeing the plexus but on using the image to optimize circumferential and corner-pocket spread.

Although the rate of vascular puncture is lower and is in line with the Cochrane review of Lewis et al., which also found success to be better [8] and fewer vascular punctures with ultrasound-guided limb blocks. Abrahams et al. also found in a systematic review that ultrasound improves block characteristics and reduces selected complications, although evidence for very rare injury remained imprecise [14]. The fact that we haven't even had pneumothorax should not be taken as evidence of zero risk. Sadowski et al. reported the revitalized contribution of supraclavicular block with the recent advent of ultrasound, which has stressed pleural proximity [2], and well-established case reports confirm that pneumothorax can develop despite image guidance if the needle tip is not viewed constantly [15].

Respiratory effects deserve separate consideration. Renes et al. noted that ultrasound-guided technique and reduced local-anesthetic spread might decrease hemidiaphragmatic paresis as compared to nerve stimulation [16], while Petrar et al. found substantial diaphragmatic paralysis after a 30-mL ultrasound-guided supraclavicular block [17]. The current protocol consisted of 25 mL and excluded major pulmonary disease; formal diaphragmatic ultrasonography wasn't done. Hence, subclinical phrenic involvement cannot be excluded by lack of clinically relevant respiratory compromise.

Such results have practical implications. Ultrasound equipment is expensive to acquire, maintain, disinfect probes, and formalize training, but is potentially compensated for by fewer failed blocks, a faster OR shift time, reduction in rescue-anesthetic use, and enhanced postoperative analgesia. However, ultrasound should be used in support of, instead of as the sole source of, anatomical information, incremental injection, aspiration, dose limitation, and continuous needle-tip visualization. In the absence of ultrasound, cautious landmark technique is still applicable, but clinicians should maintain a lower threshold for alternative anesthesia when the landmarks remain uncertain.

This study had limitations. This was based on data collected from a single center, it was untenable to perform operator blinding, and the sample was inadequate to assess rare events including pneumothorax, persistent neuropathy, or systemic toxicity. The diaphragmatic function and plasma ropivacaine concentrations were not measured. The landmark technique may also be operator dependent and thus limited external generalizability. A competency-based operator stratification, lower-volume ultrasound protocols, a formal diaphragmatic assessment, patient-reported recovery, cost-effectiveness, and longer neurological follow-up should be included in future multicenter studies.

Conclusion

Ultrasound-guided supraclavicular brachial plexus block has been shown more reliable surgical anesthesia than landmark guidance for upper-limb surgeries. It shortened block performance and onset, prolonged postoperative analgesia, lowered need for rescue opioids, and decreased vascular puncture without causing clinically important adverse effects. These results provide further justification for routine ultrasound use when equipment and other trained personnel are on hand and rapid operating-room readiness and avoidance of failed regional anesthesia are primary concerns. Landmark-guided blockade is practical in resource-poor settings but should be employed with prudent patient selection, stringent dose and aspiration precautions, and readiness to convert promptly to another anesthetic strategy when block development has been incomplete.

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