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Comparison of ultrasound-guided and neurostimulation-guided axillary brachial plexus block in patients undergoing upper extremity surgery: A prospective randomized study

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Abstract

Axillary brachial plexus block is a widely used regional anesthesia technique for upper extremity surgery. Ultrasound guidance and neurostimulation are commonly employed methods; however, their comparative effects on block performance and perioperative outcomes remain controversial. This prospective randomized study included 80 patients aged 18–75 years scheduled for upper extremity surgery under axillary brachial plexus block. Patients were randomly assigned to either the ultrasound-guided group (Group U, n = 40) or the neurostimulation-guided group (Group N, n = 40). Demographic characteristics, our primary outcomes such as block application time, time to motor block onset, and our secondary outcomes such as time to first postoperative analgesic requirement, block success rate, and block-related complications were recorded and analysed. Demographic characteristics, comorbidities, and block success rates were comparable between the groups. Block application time was significantly shorter in group U than in Group N (4.3 ± 0.7 vs. 8.7 ± 0.9 minutes, $p < 0.001$). The median time to motor block onset was also shorter in group U (10 [7–13] minutes) compared with group N (18 [14–23] minutes, $p < 0.001$). The time to first postoperative analgesic requirement was longer in group U than in Group N (11.5 [9–14] vs. 10 [1–13] hours, $p < 0.001$). The overall complication rate was 7.5% (n = 3) in group U and 12.5% (n = 5) in group N. Ultrasound-guided axillary brachial plexus block provides shorter block application and onset times with a lower complication rate compared to neurostimulation-guided techniques. In appropriately equipped centers, ultrasound guidance may be considered a more effective and potentially safer approach for axillary blocks in upper extremity surgery.

Keywords: Upper extremity surgery, axillary brachial plexus block, ultrasound guidance, nerve stimulation, regional anesthesia

Introduction

Numerous studies have demonstrated that peripheral nerve blocks, particularly brachial plexus blocks, are associated with reduced perioperative morbidity, shorter hospital stays, and lower healthcare costs, while simultaneously improving the quality of postoperative analgesia [1]. Owing to the potential complications of general anaesthesia such as postoperative nausea and vomiting, aspiration risk, difficult airway management, and malignant hyperthermia—regional anesthesia has increasingly been preferred in appropriately selected patients.

The axillary approach is a commonly utilized technique for distal upper extremity surgeries. Historically, axillary brachial plexus blocks were performed using "blind" techniques based on anatomical landmarks or paraesthesia seeking methods, which were later supplemented by the use of peripheral nerve stimulators. Nevertheless, these techniques have been associated with several limitations, including an increased risk of intravascular or intraneural injection of local anesthetics, greater procedural discomfort for patients, and incomplete or inadequate sensory blockade.

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In recent years, the widespread adoption of ultrasonography in regional anesthesia has enabled real-time visualization of neural and vascular structures, needle tip–nerve relationships, and the distribution of local anesthetic agents. This technological advancement has facilitated faster block performance, improved safety, and higher success rates in peripheral nerve block applications [2,3].

However, studies comparing ultrasound-guided and nerve stimulator–guided axillary brachial plexus block techniques have yielded conflicting results regarding block application time, onset of blockade, success rates, and complication profiles. While several investigations have reported that ultrasound guidance shortens block duration, reduces local anesthetic volume, enhances analgesic quality, and lowers complication rates, other studies have demonstrated that nerve stimulator–guided techniques can also provide clinically acceptable outcomes [2,4-6]. Given these inconsistent findings, the present study was designed to test the hypothesis that ultrasound-guided axillary brachial plexus block provides superior block performance and safety outcomes compared with nerve stimulator–guided techniques. Accordingly, the primary aim of this study was to compare block application time and block onset time between the two methods, while secondary objectives included evaluation of block success rates, time to first postoperative analgesic requirement, and block-related complications.

Material and Methods

Study Design

Designed as a prospective quasi-randomization clinical trial, this study was conducted at Malatya Training and Research Hospital between November 15, 2024, and December 15, 2024, in patients scheduled for upper extremity surgery under axillary brachial plexus block. The study was carried out in accordance with the principles of the Declaration of Helsinki and was approved by the İnönü University Clinical Research Ethics Committee (Approval number: 2024-KAEK-24, Date: 13.11.2024). Prior to enrollment, all patients and/or their legal guardians were provided with detailed information regarding the study, and written informed consent was obtained from all participants.

Randomization was performed by a staff member not involved in the study procedures. Cases were assigned quasi-randomization after the first patient's group was determined, with subsequent patients sequentially assigned to either the ultrasound-guided group (Group U) or the neurostimulation-guided group (Group N). This systematic approach was chosen to ensure equal group sizes and maintain clinical workflow efficiency.

Study Population

The study population consisted of patients aged 18–75 years who were scheduled for upper extremity surgery, had an American Society of Anesthesiologists (ASA) physical status classification of I or II, and underwent regional anesthesia using the axillary brachial plexus block technique.

Patients with a known allergy to local anesthetic agents, pregnant women, pediatric patients, those who declined the axillary block procedure, patients who required conversion to general anesthesia for any reason after axillary block application, individuals with preexisting neurological disorders affecting nerve conduction, patients with infection at the block site, and those with coagulation disorders were excluded from the study.

The sample size was determined using a power analysis based on the primary endpoint, block application time. To detect a minimum clinical difference of 4 minutes in block application time between the two groups, with a power of 90% and a significance level (alpha) of 0.05, a minimum of 38 patients per group was required. To account for potential data loss or dropouts, a total of 80 patients (40 per group) were enrolled in the study.

Anaesthesia Administration

All patients were evaluated preoperatively by an anesthesiologist with respect to anesthetic risk, physical examination findings, and relevant laboratory results. After an appropriate fasting period, patients were transferred to the preoperative preparation area, where standard monitoring—including electrocardiography, noninvasive blood pressure measurement, and pulse oximetry—was applied. To reduce procedural anxiety, intravenous midazolam at a dose of 0.05–0.1 mg/kg was administered prior to block placement.

In the ultrasound-guided group (Group U), axillary brachial plexus block was performed using an in-plane technique under real-time ultrasound guidance following identification of the relevant neural and vascular structures. A standardized local anesthetic mixture consisting of 0.5% bupivacaine, 10 mL of 2% lidocaine, and 10 mL of saline solution was administered.

In the neurostimulation-guided group (Group N), the block was performed using a peripheral nerve stimulator (Stimuplex® HNS 11; B. Braun Melsungen AG, Melsungen, Germany) with an initial stimulation current of 0.3–0.5 mA through an insulated neurostimulation needle (22 G, 50 mm; Locoplex®, Vygon, France). Appropriate motor responses were used to guide needle positioning prior to local anesthetic injection.

All blocks were performed by experienced anesthesiologists using a standardized multiple-injection technique, and the total volume of local anesthetic administered was identical in both groups.

Measurement Parameters

Demographic data, including age and sex, as well as comorbidities (hypertension, diabetes mellitus, coronary artery disease, asthma, etc.), were recorded for all patients in both groups. Our primary outcomes, perioperative parameters such as block application time, time to motor block onset, time to first postoperative analgesic requirement, and block-related

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complications (including vascular puncture and hematoma) were documented using a standardized data collection form.

Our secondary outcomes, during the postoperative period, pain intensity was assessed at regular intervals using the Visual Analog Scale (VAS), and the time to first analgesic requirement was recorded accordingly.

Block application time was defined as the interval from initial needle insertion into the skin to completion of local anesthetic injection. Motor block was evaluated using the Modified Bromage Scale (4: normal muscle strength; 3: decreased muscle strength but able to overcome resistance; 2: able to overcome gravity but not resistance; 1: minimal muscle activity; 0: no muscle strength). A Bromage score of 0 was considered indicative of complete motor block, whereas a score of ≤2 was defined as a motor block sufficient to allow surgical intervention.

Block failure was defined as the need for supplemental local anesthetic infiltration at the surgical site, conversion to general anesthesia, or the requirement for additional intraoperative analgesics.

The primary endpoints of the study were time to complete motor block onset and block success rate. Secondary endpoints included block application time and time to first postoperative analgesic requirement

Statistical Analysis

Statistical analyses were performed using SPSS software version 23.0 (IBM Corp., Chicago, IL, USA). Continuous variables were assessed for normality and are presented as mean ± standard deviation for normally distributed data or as median (minimum–maximum) for non-normally distributed data. Categorical variables are expressed as counts and percentages. For comparisons between groups, the independent samples t-test was used for normally distributed continuous variables, while the Mann–Whitney U test was applied for non-normally distributed variables. Categorical variables were compared using the Pearson chi-square test or Fisher's exact test, as appropriate. A p-value < 0.05 was considered statistically significant

Results

A total of 80 patients who met the inclusion criteria were enrolled in the study and allocated into two groups: Group U (n = 40) and Group N (n = 40). The median age was 46 (23–78) years in Group U and 44 (23–76) years in Group N, with no statistically significant difference between the groups (p = 0.627). There were also no significant differences between the groups regarding sex distribution or the presence of comorbidities, including hypertension, diabetes mellitus, coronary artery disease, and asthma (all p > 0.05) (Table 1).

Table 1. Demographic and clinical characteristics of the groups

Variable	Group U (n = 40)	Group N (n = 40)	p-Value
Age	46 (23–78)	44 (23–76)	0.627
Gender, female	18 (45.0%)	17 (42.5%)	0.822
Hypertension	11 (27.5%)	8 (20.0%)	0.431
DM	2 (5.0%)	3 (7.5 %)	0.644
CAD	0 (0.0%)	1 (2.5%)	0.314
Asthma	6 (15.0%)	2 (5.0%)	0.136

HT: hypertension, DM: Diabetes mellitus, CAD: coronary artery disease; Data are presented as n (%) or median (min-max) p < 0.05 is considered statistically significant

Block application time was significantly shorter in Group U compared with Group N (4.3 ± 0.7 vs. 8.7 ± 0.9 minutes, p < 0.001) (Figure 1). The median time to motor block onset was 10 (7–13) minutes in Group U and 18 (14–23) minutes in Group N, indicating a significantly faster onset in the ultrasound-guided group (p < 0.001) (Figure 2). The time to first postoperative analgesic requirement was longer in Group U than in Group N (11.5 (9–14) vs. 10 (1–13) hours, p < 0.001). A detailed comparison of these parameters is presented in Table 2.

Table 2. Block application time, block initiation time, and postoperative analgesic timing

Variable	Group U (n = 40)	Group N (n = 40)	p- value
Block application period (min)*	4.3 ± 0.7	8.7 ± 0.9	t = -23.865, p < 0.001
Block start time (min)**	10 (7–13)	18 (14–23)	Z = -7.746, p < 0.001
First analgesic timing postoperatively (Hours)**	11.5 (9–14)	10 (1–13)	Z = -4.565, p < 0.001

*Data are presented as mean ± SD (Independent samples t-test); **Data are presented as median (min-max) (Mann-Whitney U test)

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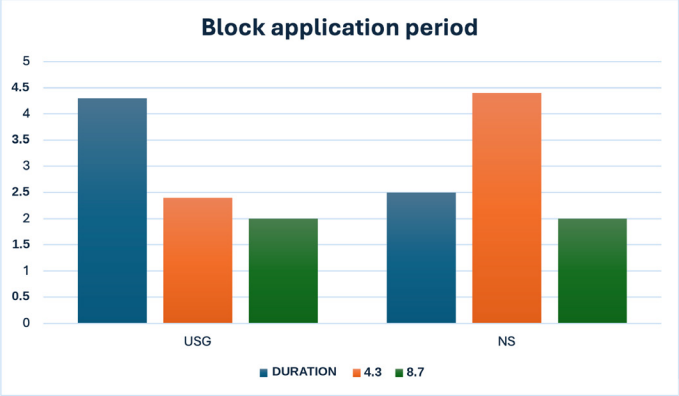

Figure 1. Block application period

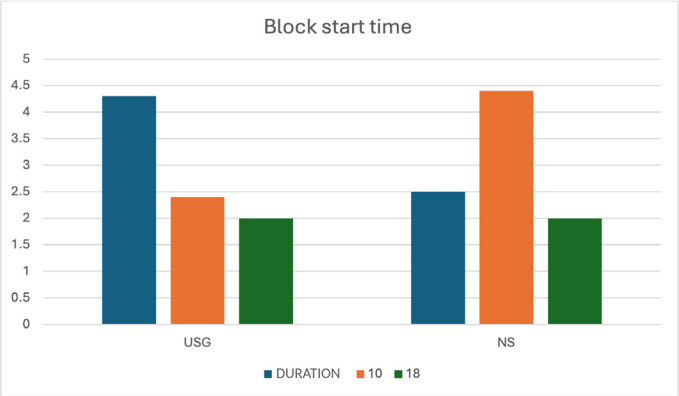

Figure 2. Block start time

Regarding block success, successful blockade was achieved in 38 of 40 patients (95%) in Group U and in 35 of 40 patients (87.5%) in Group N, with no statistically significant difference between the groups (p = 0.235) (Figure 3). When block-related complications were evaluated, 92.5% of patients in Group U and 87.5% in Group N experienced no complications. The overall complication rate was 7.5% in Group U and 12.5% in Group N**.** The distribution of complications, including the need for additional analgesics, vascular puncture, and hematoma, is summarized in Table 3. Owing to the low number of complication events, no statistical comparison was performed between the groups.

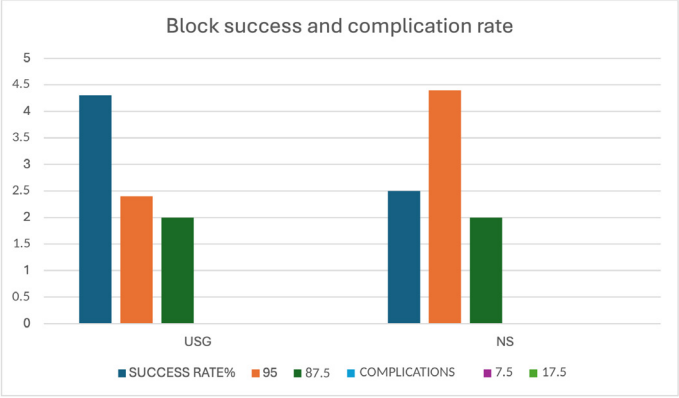

Figure 3. Block success and complication rate (as a percentage)

Table 3. Distribution of complications

Variable	Group U, n (%)	Group N, n (%)
No complications	37 (92.5)	35 (87.5)
Additional analgesic needs	1 (2.5)	3 (7.5)
Vascular puncture	2 (5.0)	1 (2.5)
Hematoma	0 (0.0)	1 (2.5)

Statistical tests for group differences were not performed due to the small number of complications. p-value < 0.05 is considered statistically significant

Discussion

In this study, the findings demonstrate that ultrasound guidance provides a significant advantage, particularly with respect to block application time and block onset time, while both techniques achieve similarly high block success rates. In the ultrasound-guided group, block application time was approximately halved (4.3 vs. 8.7 minutes), and the onset of motor block occurred nearly 8 minutes earlier compared with the neurostimulation-guided group.

Consistent with our findings, the meta-analysis by Qin et al. reported that ultrasound-guided axillary brachial plexus blocks significantly reduced both block application time and block onset time when compared with nerve stimulator–guided techniques [7]. These advantages may be attributed to the ability of ultrasonography to provide direct visualization of neural and vascular structures, enable real-time monitoring of the needle–nerve relationship, and optimize the spread of local anesthetic agents [8].

In our study, the large effect size observed in favor of ultrasound guidance for block application time (Cohen's d = −5.336) suggests a substantial difference between the two techniques. However, this finding should be interpreted with caution, as the study was conducted at a single center and blocks were performed by a limited number of experienced anesthesiologists. The visual guidance provided by ultrasonography may have facilitated faster needle positioning and more efficient local anesthetic delivery, particularly during the procedural learning curve, thereby contributing to shorter block performance times.

When evaluated in terms of block success rates, the success rates of 95% in the ultrasound-guided group and 87.5% in the neurostimulation-guided group indicate that both techniques are clinically effective. Previous randomized controlled trials have similarly reported comparable success rates between ultrasound-guided and nerve stimulator–guided axillary brachial plexus blocks, while also demonstrating that ultrasound guidance may result in more homogeneous sensory and motor blockade, shorter onset times, and improved patient comfort [9,10]. The lack of a statistically significant difference in block success rates in the present study may be explained by the relatively small sample size and the overall high success rates achieved with both techniques.

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In our study, the advantage provided by ultrasound guidance in terms of block application time and block onset time is consistent with findings from previously published randomized studies. In the randomized study conducted by Altun et al., the addition of ultrasonography to nerve stimulator–guided axillary block was shown to reduce the number of skin punctures and procedure-related pain scores, while complications were more frequent in the nerve stimulator group; however, no statistically significant difference was observed between block success rates [11]. These findings are in line with our results, in which block success rates were similar between groups, while block-related complications—such as vascular puncture and hematoma—were numerically less frequent in the ultrasound-guided group. The occurrence of vascular punctures in the ultrasound-guided group (n = 2) compared to the neurostimulation group (n = 1) in our study may be attributed to individual anatomical variations of the axillary vessels or technical challenges during needle repositioning. However, the real-time visualization provided by ultrasonography allowed for immediate recognition and prevented these punctures from progressing to clinically significant hematomas. Furthermore, our findings contribute to the existing literature by highlighting that beyond procedural safety, ultrasound guidance significantly enhances operational efficiency in high-volume surgical settings by nearly halving the block application time and accelerating the onset of motor blockade.

In a randomized controlled trial conducted by Barrington et al., ultrasound-guided and nerve stimulator–guided axillary brachial plexus block techniques were compared, and although no significant differences were observed in block performance or motor and sensory block effectiveness, ultrasound guidance was reported to have a positive impact on the learning process of block management and overall clinical performance [5]. These findings support our results, in which ultrasound guidance was associated with improved procedural efficiency, while differences in postoperative analgesic outcomes were modest and should be interpreted with caution.

In the present study, the time to first postoperative analgesic requirement was statistically significantly longer—by approximately 1.5 hours—in the ultrasound-guided group compared with the neurostimulation-guided group. However, this difference is of limited clinical relevance and should not be considered a primary determinant in clinical decision-making. Nevertheless, a more homogeneous distribution of the local anesthetic around neural structures during ultrasound-guided blocks may partially explain the relatively prolonged duration of postoperative analgesia observed in our study. Consistent with this interpretation, the existing literature reports heterogeneous findings regarding the effect of ultrasound guidance on postoperative analgesic duration, with factors such as the type and volume of local anesthetic and the use of adjuvants playing a decisive role in analgesic outcomes [12,13].

When the complication profile was evaluated, the overall complication rate was numerically lower in the ultrasound-guided group, which is consistent with findings in the literature emphasizing the potential safety advantages of ultrasound-guided peripheral nerve blocks. Direct visualization of vascular structures with ultrasonography may reduce the risk of intravascular injection and vascular puncture, while maintaining an appropriate distance between the needle tip and neural structures may help prevent intraneural injection and related neurological complications (neuronal damage, conduction disorders, prolonged motor block and sensory loss, e) and other complications such as vascular puncture, and hematoma [13,14]. In the present study, no serious neurological complications were observed, and complications such as vascular puncture and hematoma were limited in number and reversible. However, it should be acknowledged that the sample size was relatively small and therefore insufficient to reliably detect rare but serious complications.

Limitations

This study has several limitations. First, the patient allocation was performed using aquasi-randomization rather than a purely computer-generated random sequence. While this method ensured balanced group sizes and was practical for the clinical workflow of our center, it may have introduced a potential risk of selection bias. Future studies employing more concealed randomization techniques could further validate these outcomes. It was conducted at a single center with a relatively limited sample size, which may restrict the generalizability of the findings and limit the detection of rare complications. Second, long-term neurological follow-up was not performed, precluding assessment of delayed neurological outcomes. Finally, although efforts were made to standardize the block procedures, the lack of blinding and the involvement of a limited number of experienced anesthesiologists may have introduced operator-related bias.

Conclusion

In conclusion, this study demonstrates that ultrasound guidance in axillary brachial plexus block for patients undergoing upper extremity surgery is associated with shorter block application and block onset times compared with neurostimulation-guided techniques. Block success rates were comparable between the two methods, while block-related complications appeared numerically lower in the ultrasound-guided group. Taken together, these findings suggest that ultrasound-guided axillary brachial plexus block may be considered a more efficient and potentially safer technique than neurostimulation guidance in centers with appropriate equipment and clinical experience. We believe that the use of ultrasound has the potential to reduce drug dosage, minimize potential complications, and therefore reduce any additional costs that might arise.

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Ethical Approval
The study was carried out in accordance with the principles of the Declaration of Helsinki and was approved by the İnönü University Clinical Research Ethics Committee (Approval number: 2024-KAEK-24, Date: 13.11.2024).

Patient Consent
Prior to enrollment, all patients and/or their legal guardians were provided with detailed information regarding the study, and written informed consent was obtained from all participants.

Conflict of Interest
The authors confirm the absence of any conflicts associated with this work.

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