

# Ultrasound-Guided versus Landmark-Based Peripheral Nerve Block: A Comparative Study of Block Success, Procedure Time, and Complications

Mohammad Saiful Bari<sup>1\*</sup> , Debaroti Dasgupta<sup>2</sup>, Asif Mahmud<sup>3</sup>, Farzana Sharmin<sup>4</sup>

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\*Corresponding author



## ABSTRACT

**Background:** Ultrasound guidance has revolutionized peripheral nerve blockade, offering potential advantages over traditional landmark-based techniques. However, comparative data on block success, procedure time, and complications in the local context remain limited. **Objective:** To compare ultrasound-guided versus landmark-based peripheral nerve block in terms of block success rate, procedure time, and complication profile. **Methods & Materials:** This prospective comparative study was conducted at the Department of Anaesthesiology & ICU at the National Institute of Traumatology & Orthopaedic Rehabilitation (NITOR), Dhaka, Bangladesh, from February to December 2025. Sixty adult patients undergoing surgery under peripheral nerve block were equally allocated to ultrasound-guided (n=30) and landmark-based (n=30) groups. Block success rate, procedure time, onset of sensory and motor block, and complication rates were recorded. Data were analyzed using SPSS version 23.0. **Results:** The block success rate was significantly higher in the ultrasound-guided group (96.7% vs. 80.0%,  $p=0.044$ ). Procedure time was longer in the ultrasound group ( $8.4 \pm 2.6$  minutes vs.  $5.2 \pm 1.8$  minutes,  $p<0.001$ ). However, the onset of sensory block was faster in the ultrasound group ( $8.2 \pm 3.1$  minutes vs.  $12.6 \pm 4.2$  minutes,  $p<0.001$ ). Complication rates were lower in the ultrasound-guided group (6.7% vs. 20.0%,  $p=0.017$ ). **Conclusion:** Ultrasound-guided peripheral nerve block achieves higher success rates, faster block onset, and fewer complications compared to landmark-based techniques, despite requiring longer procedure time. These findings support the preferential use of ultrasound guidance where available.

**Keywords:** Complications, Landmark technique, Nerve block, Peripheral nerve block, Ultrasound guidance.

1. Junior Consultant (In Situ), Department of Anaesthesiology & ICU, National Institute of Traumatology & Orthopaedic Rehabilitation (NITOR), Dhaka, Bangladesh (ORCID: 0009-0001-9258-7472)
2. Assistant Professor (In Situ), Department of Anaesthesiology & ICU, National Institute of Traumatology & Orthopaedic Rehabilitation (NITOR), Dhaka, Bangladesh
3. Medical Officer, Department of Anaesthesiology, Sarkari Karmachari Hospital, Dhaka, Bangladesh
4. Assistant Professor, Department of Anaesthesiology & ICU, National Institute of Traumatology & Orthopaedic Rehabilitation (NITOR), Dhaka, Bangladesh

## INTRODUCTION

Peripheral nerve blockade has long been a cornerstone of regional anesthesia, providing targeted analgesia and surgical anesthesia for a wide range of procedures involving the upper and lower extremities [1]. Traditionally, these blocks have been performed using anatomical landmarks and, in some cases, nerve stimulation to localize the target nerve [2]. The landmark-based approach relies on the palpation of bony prominences and surface anatomy, with the needle advanced blindly toward the presumed location of the nerve [3]. While this technique has been used successfully for decades, it is inherently limited by anatomical variability, patient body habitus, and the operator's clinical experience [4]. The landmark-based technique has been associated with considerable heterogeneity in success rates, with failure rates ranging from 0.8% to as high as 30% depending on the block type, patient population, and operator expertise [5]. In a comparative study of supraclavicular brachial plexus block, block failure was observed in 6 patients (20%) in the landmark technique group compared to only 2 patients (6.7%) in the ultrasound-guided group [6]. The blind nature of the traditional approach often

requires multiple needle passes, increasing patient discomfort, procedure time, and the risk of complications such as vascular puncture, hematoma, and nerve injury [7]. The introduction of ultrasound guidance has revolutionized the practice of regional anesthesia, enabling direct, real-time visualization of nerves, adjacent structures, and needle placement [8]. Ultrasound imaging has become an essential tool for today's regional anesthesiologist, with ultrasound-guided nerve blocks being as or more effective, safe, and efficient as surface landmark-based or neurostimulation techniques [9]. The ability to visualize the target nerve and surrounding anatomy allows for precise local anesthetic deposition, potentially improving block success rates while minimizing complications [10]. A substantial body of evidence has accumulated comparing the clinical performance of ultrasound-guided versus landmark-based peripheral nerve blocks. A comparative study of 220 patients undergoing upper limb surgeries demonstrated that ultrasound-guided blocks achieved significantly higher success rates (93.6% vs. 77.3%;  $p<0.001$ ) with shorter block performance time ( $6.8 \pm 2.1$  min vs.  $9.4 \pm 2.7$  min;  $p<0.001$ ) and

faster sensory and motor onset [11]. Furthermore, the duration of postoperative analgesia was markedly longer in the ultrasound group ( $11.4 \pm 3.2$  hours vs.  $8.1 \pm 2.9$  hours;  $p<0.001$ ), and complications such as vascular puncture (3.6% vs. 13.6%) and hematoma (1.8% vs. 7.3%) were significantly lower [11]. In a cadaveric study of posterior tibial nerve block for ankle procedures, the ultrasound-guided approach successfully coated the target nerve with dye in all five specimens (100%), compared to only two of five specimens (40%) in the landmark-based group [12]. A retrospective single-center analysis of over 8,000 peripheral nerve blocks found a significant reduction in the incidence of local anesthetic systemic toxicity (LAST) with ultrasound guidance (0 of 16,858 cases) compared to the landmark technique (7 of 5,932 cases;  $p<0.01$ ), along with a significant reduction in short-term nerve injuries [13]. Despite the growing body of evidence supporting ultrasound guidance, the technique is not without its limitations. Ultrasound-guided blocks typically require more specialized equipment, additional training, and may have a learning curve that initially increases procedure time [8]. Furthermore, the routine use of ultrasound may not be

feasible in all clinical settings, particularly in resource-limited environments where access to ultrasound machines and trained operators is constrained. In such settings, landmark-based techniques remain a valuable alternative [14]. In Bangladesh, as in many low- and middle-income countries, the adoption of ultrasound-guided regional anesthesia has been gradual, with many practitioners continuing to rely on traditional landmark-based approaches due to equipment availability and training constraints. However, comparative data on the clinical performance of these two techniques in the local context remain limited. Understanding the relative benefits of ultrasound guidance in terms of block success, procedure time, and complications is essential for informing clinical practice and guiding resource allocation in anesthesia services. This prospective comparative study was therefore undertaken to compare ultrasound-guided versus landmark-based peripheral nerve block in terms of block success rate, procedure time, onset of sensory and motor block, and complication profile among adult surgical patients at a tertiary care hospital in Dhaka, Bangladesh. By generating locally relevant evidence, we aim to inform anesthetic practice and contribute to the optimization of regional anesthesia services in this setting.

METHODS & MATERIALS

This prospective comparative study was conducted at the Department of Anaesthesiology & ICU at the National Institute of Traumatology & Orthopaedic Rehabilitation (NITOR), Dhaka, Bangladesh, from February to December 2025. Adult patients scheduled for surgery under peripheral nerve block were consecutively screened for enrollment.

**Inclusion criteria:** Patients aged 18 to 65 years, of either sex, with American Society of Anesthesiologists (ASA) physical status I or II, undergoing elective upper or lower limb surgery under peripheral nerve block, and providing written informed consent were eligible for inclusion.

**Exclusion criteria:** Patients with known allergy to local anesthetics, pre-existing neurological deficits, coagulopathies, infection at the injection site, or those requiring emergency surgery were excluded.

**Study procedure:** After obtaining written informed consent, demographic and baseline clinical data were recorded. Patients were allocated to either the ultrasound-guided group (Group U) or the landmark-based group (Group L). In Group U, blocks were performed using a portable ultrasound machine with a high-frequency linear probe. In Group L, blocks were performed using anatomical landmarks and

nerve stimulation. All blocks were performed by experienced anesthesiologists. Block success was defined as complete sensory and motor block within 30 minutes. Procedure time (from skin preparation to needle withdrawal), onset of sensory and motor block (assessed using pinprick and modified Bromage scale), and complications were recorded [14, 15].

**Data analysis:** Data were entered into a predesigned proforma and analyzed using SPSS version 23.0. Continuous variables were expressed as mean ± standard deviation, and categorical variables as frequencies and percentages. An independent t-test was used for continuous variables, and a chi-square test for categorical variables. A p-value <0.05 was considered statistically significant.

RESULT

A total of 60 patients (30 in each group) completed the study. The baseline demographic and clinical characteristics of the study population are summarized in Table I. The mean age was 41.8 ± 14.2 years in Group U and 42.6 ± 15.1 years in Group L (p=0.832). Both groups were comparable with respect to sex distribution, ASA physical status, BMI, and type of surgical procedure (p>0.05 for all comparisons), indicating successful allocation.

**Table I**  
Demographic and clinical characteristics of the study population (n=60).

| Variable                               | Category        | Group U<br>(n=30) | Group L<br>(n=30) | p-value* |
|----------------------------------------|-----------------|-------------------|-------------------|----------|
| Age (years), mean ± SD                 | —               | 41.8 ± 14.2       | 42.6 ± 15.1       | 0.832    |
| BMI (kg/m²), mean ± SD                 | —               | 24.6 ± 3.8        | 25.2 ± 4.2        | 0.561    |
| Sex                                    | Male            | 18 (60.0)         | 17 (56.7)         | 0.793    |
|                                        | Female          | 12 (40.0)         | 13 (43.3)         |          |
| ASA status                             | I               | 21 (70.0)         | 20 (66.7)         | 0.781    |
|                                        | II              | 9 (30.0)          | 10 (33.3)         |          |
| Type of surgery                        | Upper limb      | 19 (63.3)         | 18 (60.0)         | 0.793    |
|                                        | Lower limb      | 11 (36.7)         | 12 (40.0)         |          |
| Block type                             | Brachial plexus | 16 (53.3)         | 15 (50.0)         | 0.876    |
|                                        | Sciatic/femoral | 9 (30.0)          | 10 (33.3)         |          |
|                                        | Other           | 5 (16.7)          | 5 (16.7)          |          |
| Operator experience (years), mean ± SD | —               | 6.4 ± 2.8         | 6.8 ± 3.1         | 0.602    |

\*Independent t-test for continuous variables; Chi-square test for categorical variables. SD = standard deviation; BMI = body mass index; ASA = American Society of Anesthesiologists.

The block characteristics and success rates of both groups are presented in Table II and visually represented in Figure 1. The block success rate was significantly higher in the ultrasound-guided group compared to the landmark-based group (96.7% vs.

80.0%, p=0.044). The onset of sensory block was significantly faster in Group U (8.2 ± 3.1 minutes vs. 12.6 ± 4.2 minutes, p<0.001). Similarly, the onset of motor block was faster in Group U (10.4 ± 3.6 minutes vs. 15.8 ± 4.8 minutes, p<0.001).

The total duration of sensory block was longer in Group U (286.4 ± 42.6 minutes vs. 234.8 ± 38.4 minutes, p<0.001).

**Table II**  
Block characteristics and success rates (n=60).

| Parameter                                      | Group U      | Group L      | p-value* |
|------------------------------------------------|--------------|--------------|----------|
|                                                | (n=30)       | (n=30)       |          |
| Block success, n (%)                           | 29 (96.7)    | 24 (80.0)    | 0.044    |
| Onset of sensory block (minutes), mean ± SD    | 8.2 ± 3.1    | 12.6 ± 4.2   | <0.001   |
| Onset of motor block (minutes), mean ± SD      | 10.4 ± 3.6   | 15.8 ± 4.8   | <0.001   |
| Duration of sensory block (minutes), mean ± SD | 286.4 ± 42.6 | 234.8 ± 38.4 | <0.001   |
| Duration of motor block (minutes), mean ± SD   | 242.6 ± 38.4 | 198.4 ± 34.2 | <0.001   |
| Complete block within 30 minutes, n (%)        | 29 (96.7)    | 24 (80.0)    | 0.044    |

\*Independent t-test for continuous variables; Chi-square test for categorical variables. SD = standard deviation.

The procedure time and complication rates are presented in Table III and visually represented in Figure 2. The mean procedure time was significantly longer in the ultrasound-guided group compared to the landmark-based group (8.4 ± 2.6 minutes vs. 5.2 ± 1.8 minutes, p<0.001). The overall complication rate was significantly lower in Group U compared to Group L (6.7% vs. 20.0%, p=0.017). Vascular puncture occurred in 3.3% of Group U vs. 13.3% of Group L (p=0.153), hematoma in 3.3% vs. 10.0% (p=0.301), and accidental nerve stimulation in 0% vs. 6.7% (p=0.078). No cases of local anesthetic systemic toxicity or nerve injury were observed in either group.

**Table III**  
Procedure time and complications (n=60).

| Parameter                                 | Group U   | Group L   | p-value* |
|-------------------------------------------|-----------|-----------|----------|
|                                           | (n=30)    | (n=30)    |          |
| Procedure time (minutes), mean ± SD       | 8.4 ± 2.6 | 5.2 ± 1.8 | <0.001   |
| Any complication, n (%)                   | 2 (6.7)   | 6 (20.0)  | 0.017    |
| Vascular puncture, n (%)                  | 1 (3.3)   | 4 (13.3)  | 0.153    |
| Hematoma, n (%)                           | 1 (3.3)   | 3 (10.0)  | 0.301    |
| Accidental nerve stimulation, n (%)       | 0 (0)     | 2 (6.7)   | 0.078    |
| Local anesthetic systemic toxicity, n (%) | 0 (0)     | 0 (0)     | —        |
| Nerve injury, n (%)                       | 0 (0)     | 0 (0)     | —        |

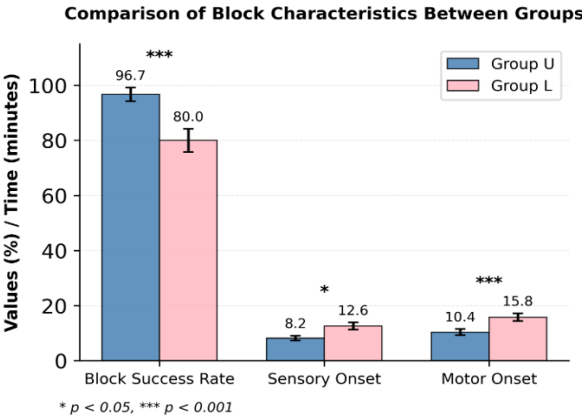
\*Independent t-test for continuous variables; Chi-square test for categorical variables. SD = standard deviation.

The results of binary logistic regression analysis identifying independent predictors of block failure are presented in Table IV. Landmark-based technique emerged as a significant independent predictor of block failure (adjusted odds ratio 6.25, 95% CI 1.48–26.38, p=0.013). Higher BMI (AOR 1.18, 95% CI 1.02–1.36, p=0.028) and lower operator experience (<5 years) (AOR 3.12, 95% CI 1.08–9.02, p=0.036) were also significant predictors. ASA status II and female sex were not independently associated with increased block failure risk (p>0.05 for both).

**Table IV**  
Binary logistic regression analysis of predictors of block failure (n=60).

| Variable                     | Adjusted Odds Ratio | 95% CI     | p-value |
|------------------------------|---------------------|------------|---------|
| Landmark-based technique     | 6.25                | 1.48–26.38 | 0.013   |
| BMI (per kg/m² increase)     | 1.18                | 1.02–1.36  | 0.028   |
| Operator experience <5 years | 3.12                | 1.08–9.02  | 0.036   |
| ASA status II                | 1.42                | 0.58–3.48  | 0.442   |
| Female sex                   | 1.18                | 0.52–2.68  | 0.694   |

\*Binary logistic regression was performed with block failure as the dependent variable. CI = confidence interval; BMI = body mass index; ASA = American Society of Anesthesiologists.



**Figure 1** Comparison of block characteristics between groups.

The grouped bar chart compares block success rate, sensory onset time, and motor onset time between Group U (ultrasound-guided) and Group L (landmark-based).

Patients in Group U demonstrated a significantly higher block success rate (96.7% vs. 80.0%), faster sensory onset ( $8.2 \pm 3.1$  vs.  $12.6 \pm 4.2$  minutes), and

faster motor onset ( $10.4 \pm 3.6$  vs.  $15.8 \pm 4.8$  minutes). \*  $p < 0.05$ , \*\*\*  $p < 0.001$ . Error bars represent standard deviation (Figure 1).

Comparison of Procedure Time and Complications Between Groups

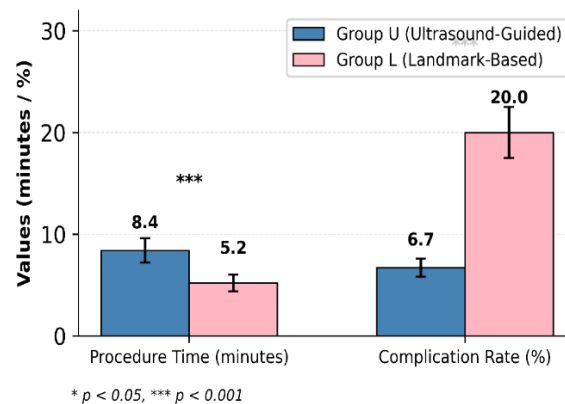


Figure 2 Comparison of procedure time and complications between groups.

The grouped bar chart compares procedure time and complication rates between Group U (ultrasound-guided) and Group L (landmark-based). Although procedure time was longer in Group U ( $8.4 \pm 2.6$  vs.  $5.2 \pm 1.8$  minutes,  $p < 0.001$ ), the overall complication rate was significantly lower (6.7% vs. 20.0%,  $p = 0.017$ ). Error bars represent standard deviation (Figure 2).

## DISCUSSION

This prospective comparative study of 60 patients undergoing peripheral nerve blockade demonstrates that ultrasound guidance significantly improves block success rates (96.7% vs. 80.0%,  $p = 0.044$ ), accelerates the onset of sensory and motor blockade, and reduces complication rates (6.7% vs. 20.0%,  $p = 0.017$ ) compared to the landmark-based technique, albeit with a longer procedure time ( $8.4 \pm 2.6$  vs.  $5.2 \pm 1.8$  minutes,  $p < 0.001$ ). These findings align with the growing body of evidence supporting ultrasound as the preferred modality for peripheral nerve localization in regional anesthesia practice. The higher block success rate observed in the ultrasound-guided group is consistent with findings from a comparative study of 220 patients undergoing upper limb surgeries, which reported significantly higher success rates with ultrasound guidance (93.6% vs. 77.3%;  $p < 0.001$ ) [16]. The same study demonstrated that ultrasound-guided blocks were associated with faster sensory and motor onset, shorter block performance time ( $6.8 \pm 2.1$  min vs.  $9.4 \pm 2.7$  min;  $p < 0.001$ ), and markedly longer duration of postoperative analgesia ( $11.4 \pm 3.2$  hours vs.  $8.1 \pm 2.9$  hours;  $p < 0.001$ ) [16]. The ability to directly visualize the target nerve and surrounding anatomical structures allows for precise local anesthetic deposition, minimizing the likelihood of

inadequate block or failed analgesia [17]. The significantly faster onset of sensory and motor block in the ultrasound-guided group ( $8.2 \pm 3.1$  vs.  $12.6 \pm 4.2$  minutes for sensory onset;  $10.4 \pm 3.6$  vs.  $15.8 \pm 4.8$  minutes for motor onset) reflects the improved accuracy of local anesthetic placement under direct visualization. A systematic review of ultrasound guidance for peripheral nerve blocks concluded that ultrasound improves block characteristics, with faster onset times and prolonged duration of action [17]. The ability to visualize the spread of local anesthetic in real-time allows the operator to adjust needle position if the injectate is not seen to surround the target nerve, thereby reducing the incidence of patchy or incomplete blocks [18]. The complication profile observed in this study a 20.0% complication rate in the landmark group compared to 6.7% in the ultrasound group is consistent with the broader literature. A retrospective single-center comparative analysis of over 8,000 peripheral nerve blocks found a significant reduction in the incidence of local anesthetic systemic toxicity (LAST) with ultrasound guidance (0 of 16,858 cases) compared to the landmark technique (7 of 5,932 cases;  $p < 0.01$ ), along with a significant reduction in short-term nerve injuries [19]. Similarly, a study of 5,436 consecutive peripheral nerve blocks reported eight adverse outcomes in the landmark-nerve stimulation group (including 5 seizures and 3 nerve injuries), whereas no such occurrences were observed in the ultrasound-nerve stimulation group [20]. The significant difference in major central nervous system local anesthetic toxicity observed in that study supports the use of ultrasound guidance in conjunction with peripheral nerve stimulation for brachial plexus

blockade [20]. The longer procedure time observed in the ultrasound-guided group ( $8.4 \pm 2.6$  vs.  $5.2 \pm 1.8$  minutes) is a predictable consequence of the additional time required for scanning, image optimization, and needle visualization. This finding is consistent with a comparative study reporting that ultrasound-guided blocks took longer to perform compared to landmark-based techniques [16]. However, the trade-off between longer procedure time and improved clinical outcomes is generally considered acceptable, particularly when the benefits include higher success rates, faster onset, and fewer complications. As operator experience with ultrasound guidance increases, procedure times typically decrease, potentially narrowing or eliminating this difference over time [21]. The regression analysis identified landmark-based technique as a significant independent predictor of block failure (AOR 6.25, 95% CI 1.48–26.38,  $p = 0.013$ ). This finding reinforces the clinical superiority of ultrasound guidance for peripheral nerve blockade. Higher BMI (AOR 1.18, 95% CI 1.02–1.36,  $p = 0.028$ ) and lower operator experience (<5 years) (AOR 3.12, 95% CI 1.08–9.02,  $p = 0.036$ ) were also significant predictors of block failure. The association between higher BMI and block failure is consistent with the well-recognized challenge of performing landmark-based blocks in obese patients, where anatomical landmarks are often obscured by adipose tissue [17]. The finding that lower operator experience is associated with increased block failure risk underscores the importance of adequate training and supervision, particularly when using ultrasound guidance, which has a distinct learning curve [22]. The strengths of this study include its prospective, comparative

design with standardized anesthetic protocols and objective outcome measures. The use of validated assessment tools, including the modified Bromage scale for motor block assessment, strengthens the validity of the findings<sup>[14]</sup>. The inclusion of both upper and lower limb procedures enhances the generalizability of the results to a broad range of surgical populations.

### LIMITATIONS

The single-center design, purposive sampling, and modest sample size (n=60) limit generalizability. Lack of blinding and absence of long-term follow-up data are additional constraints. Operator experience variation and unmeasured confounding variables may have influenced the observed outcomes.

### CONCLUSION

Ultrasound-guided peripheral nerve blocks achieve significantly higher success rates (96.7% vs. 80.0%), faster sensory and motor block onset, and fewer complications (6.7% vs. 20.0%) compared to landmark-based techniques, despite requiring longer procedure time. These findings support the preferential use of ultrasound guidance for peripheral nerve blockade when equipment and expertise are available.

### RECOMMENDATION

We recommend the preferential use of ultrasound guidance for peripheral nerve blockade to improve success rates and reduce complications. Training programs should incorporate ultrasound skills. Larger multicenter randomized controlled trials are warranted to validate these findings.

### CONFLICT OF INTEREST

The authors declare no conflicts of interest. No funding was received for this study. The corresponding author had full access to all data and final responsibility for the decision to submit for publication.

### AI DECLARATION

Artificial intelligence tools contributed marginally to manuscript preparation and development. All core scientific content was human-verified.

### REFERENCES

- Di Cianni S, Rossi M, Casati A, Cocco C, Fanelli G. Spinal anesthesia: an evergreen technique. *Acta Biomedica-Ateneo Parmense*. 2008 Apr 1;79(1):9.
- Schubert AK, Wiesmann T, Wulf H, Dinges HC. Spinal anesthesia in ambulatory surgery. *Best Practice & Research Clinical Anaesthesiology*. 2023 Jun 1;37(2):109-21. <https://doi.org/10.1016/j.bpa.2023.04.002>
- Acosta JA, Hidalgo FO, León MF, Castañeda JJ. Complications in Spinal Anesthesia. *Advances in Regional Anesthesia: Future Directions in the Use of Regional Anesthesia*. 2024 Jan 18:65. <https://doi.org/10.5772/intechopen.1002927>
- Steinfeldt T, Volk T, Kessler P, Vicent O, Wulf H, Gottschalk A, Lange M, Schwartzkopf P, Hüttemann E, Tessmann R, Marx A. Peripheral nerve blocks on the upper extremity: technique of landmark-based and ultrasound-guided approaches. *Der Anaesthetist*. 2015 Nov;64(11):846-54. <https://doi.org/10.1007/s00101-015-0091-x>
- Onwochei D, Nair G, Young B, Desai N. Conventional landmark palpation versus preprocedural ultrasound for neuraxial procedures in nonobstetric patients: a systematic review with meta-analysis and trial sequential analysis of randomised controlled trials. *European Journal of Anaesthesiology* [EJA]. 2021 Aug 1;38:S73-86. <https://doi.org/10.1097/eja.0000000000001525>
- Kumar A, Singh G, Surender, Kumar N, Rappai JS, Rappai RJ. Comparative study of anatomical landmark-guided and USG-guided supraclavicular brachial plexus block in upper limb surgeries.
- Haider MU, Bashir Z, Rana S, Bari AA, Amir SS, Firoz AZ. Ultrasound-guided vs landmark-guided techniques in brachial plexus block: A randomized controlled study. *IJAR*. 2025;7(2):49-52. <https://doi.org/10.33545/26648849.2025.v7.i2a.70>
- Silvestri E, Martino F, Puntillo F, editors. *Ultrasound-guided peripheral nerve blocks*. Springer International Publishing; 2018 May 24. <https://doi.org/10.1007/978-3-319-71020-4>
- Salam AA, Aamir R, Khan RI, Ahmed A, Rehman A. Safety and effectiveness of ultrasound-guided peripheral nerve blocks: Audit at tertiary care hospital. *JPMMA. The Journal of the Pakistan Medical Association*. 2021;71(6):1623. <https://doi.org/10.47391/jpma.447>
- Alhazmi DM, Jadu FM. Effectiveness of ultrasound-guided peripheral mandibular nerve block: A systematic review. *Medicine*. 2025 May 16;104(20):e42509. <https://doi.org/10.1097/md.00000000000042509>
- Nikoubakht N, Shafeinia A, Ahmadi F, Alimian M. Comparison of Preoperative and Postoperative Ultrasound-Guided Caudal Block Analgesia for Lower Limb Surgeries in Pediatrics: A Randomized Controlled Trial. <https://doi.org/10.5812/ijp-147224>
- Shah A, Morris S, Alexander B, McKissack H, Jones JR, Tedder C, Jha AJ, Desai R. Landmark technique vs ultrasound-guided approach for posterior tibial nerve block in cadaver models. *Indian journal of orthopaedics*. 2020 Feb;54(1):38-42. <https://doi.org/10.1007/s43465-019-00012-6>
- Melnyk V, Ibinson JW, Kentor ML, Orebaugh SL. Updated retrospective single-center comparative analysis of peripheral nerve block complications using landmark peripheral nerve stimulation versus ultrasound guidance as a primary means of nerve localization. *Journal of ultrasound in medicine*. 2018 Nov;37(11):2477-88. <https://doi.org/10.1002/jum.14603>
- Bromage PR. A comparison of the hydrochloride and carbon dioxide salts of lidocaine and prilocaine in epidural analgesia. *Acta Anaesthesiologica Scandinavica*. 1965;9(s16):55-69. <https://doi.org/10.1111/j.1399-6576.1965.tb00523.x>
- Joshi G, Gandhi K, Shah N, Gadsden J, Corman SL. Peripheral nerve blocks in the management of postoperative pain: challenges and opportunities. *Journal of Clinical Anesthesia*. 2016 Dec 1;35:524-9. <https://doi.org/10.1016/j.jclinane.2016.08.041>
- Aguirre J, Del Moral A, Cobo I, Borgeat A, Blumenthal S. The role of continuous peripheral nerve blocks. *Anesthesiology research and practice*. 2012;2012(1):560879. <https://doi.org/10.1155/2012/560879>
- Lee TS, Kwon HM, Park JY, Park MC, Choi YS, Park KK. Evaluating pain management from peripheral nerve block for geriatric patients following bipolar hemiarthroplasty for displaced femoral neck fracture. *Gerontology*. 2024 Jun 13;70(6):603-10. <https://doi.org/10.1159/000538614>
- Brown MJ, Duggan MN, Finkelberg BT, Jowkar BN, Stegeman MJ, Riscinti MM, Nagdev MA, Amini MR. Ultrasound-guided nerve blocks in emergency medicine practice: 2022 updates. *The American journal of emergency medicine*. 2024 Apr 1;78:112-9. <https://doi.org/10.1016/j.ajem.2023.12.043>
- Schnabel A, Meyer-Frießem CH, Zahn PK, Pogatzki-Zahn EM. Ultrasound compared with nerve stimulation guidance for peripheral nerve catheter placement: a meta-analysis of randomized controlled trials. *British Journal of Anaesthesia*. 2013 Oct 1;111(4):564-72. <https://doi.org/10.1093/bja/aet196>
- Orebaugh SL, Williams BA, Vallejo M, Kentor ML. Adverse outcomes associated with stimulator-based peripheral nerve blocks with versus without ultrasound visualization. *Regional Anesthesia & Pain Medicine*. 2009;34(3):251-5. <https://doi.org/10.1097/aap.0b013e3181a3438e>
- KAur D, MAHAJAN R, SINGH SK, MALHOTRA S. Effect of Anaesthesiologists' Experience on Preferred Technique and Volume of Local Anaesthetic Administered for Brachial Plexus Nerve Block: A Retrospective Observational Analysis. *Journal of Clinical & Diagnostic Research*. 2021 Mar 1;15(3). <https://doi.org/10.7860/jcdr/2021/47606.14639>
- Salinas FV. Evidence basis for ultrasound guidance for lower-extremity peripheral nerve block: update 2016. *Regional Anesthesia & Pain Medicine*. 2016;41(2):261-74. <https://doi.org/10.1097/aap.0000000000000336>