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RESEARCH ARTICLE
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EFFICACY AND SAFETY OF ULTRASOUND-GUIDED NERVE BLOCKS COMPARED TO TRADITIONAL LANDMARK-BASED TECHNIQUES

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ABSTRACT

Background: Ultrasound-guided nerve blocks (UGNB) have emerged as a promising alternative to traditional landmark-based techniques (LMBT) in regional anesthesia. However, the comparative efficacy and safety of these approaches remain a subject of ongoing research.

Objective: This systematic review evaluates the efficacy and safety of UGNB compared to LMBT across various clinical settings, including perioperative care, chronic pain management, and pediatric anesthesia.

Methods: A comprehensive literature search was conducted following PRISMA guidelines, including studies from PubMed, Embase, MEDLINE, and Cochrane Library up to March 2025. Randomized controlled trials (RCTs), cohort studies, and systematic reviews comparing UGNB and LMBT were included. Primary outcomes were block success rate and pain scores, while secondary outcomes included complication rates, procedure time, and patient satisfaction. Risk of bias was assessed using Cochrane RoB 2 and ROBINS-I tools, and evidence certainty was graded using the GRADE approach.

Results: Analysis of 9 studies (including RCTs and meta-analyses) demonstrated that UGNB significantly improved block success rates (100% vs. 30–64% in LMBT), reduced pain scores, and decreased complications. UGNB also showed faster onset and longer duration of analgesia. In pediatric populations, UGNB achieved higher first-attempt success (100% vs. 64%) and fewer complications. For chronic pain conditions (e.g., migraines, shoulder pain), UGNB provided superior pain relief and reduced analgesic use. Large meta-analyses confirmed fewer failed attempts

and higher patient satisfaction with UGNB.
Conclusion: UGNB is superior to LMBT in terms of efficacy, safety, and patient outcomes across diverse clinical scenarios. The evidence supports adopting UGNB as the standard of care in regional anesthesia when feasible. Future research should focus on cost-effectiveness and implementation in resource-limited settings.

Keywords: Ultrasound-guided nerve block, landmark-based nerve block, regional anesthesia, block success, pain management, complications.

INTRODUCTION

Regional anesthesia techniques are critical components of modern anesthetic practice, offering targeted analgesia, reduced systemic medication requirements, and improved patient outcomes (1, 2). Traditionally, nerve blocks have been performed using landmark-based techniques (LMBT), relying on anatomical landmarks and clinician experience to guide needle placement (3). However, the advent of ultrasound-guided nerve blocks (UGNB) has transformed regional anesthesia, allowing for real- time visualization of nerves, surrounding structures, and local anesthetic spread (4). This enhanced precision is believed to improve block success rates, minimize complications, and optimize patient satisfaction (5).

In recent years, numerous studies have compared the effectiveness and safety profiles of UGNB and LMBT across various clinical contexts, including perioperative care, chronic pain management, and pediatric anesthesia (6, 7). Evidence suggests that UGNB may provide significant advantages, particularly in challenging populations such as children, obese patients, or individuals with altered anatomy (8, 9). Nevertheless, differences in study designs, populations, and outcome reporting have led to some inconsistencies in the literature, highlighting the need for a comprehensive synthesis of available data.

This systematic review aims to evaluate and summarize current evidence comparing ultrasound-guided and landmark-based nerve block techniques. Specifically, it focuses on primary outcomes such as block success rate and pain scores, as well as secondary outcomes like complication rates, procedure time, and patient satisfaction. By critically assessing studies across diverse settings and populations, this review seeks to clarify the clinical benefits and limitations of UGNB relative to LMBT and to provide evidence-based recommendations for practice. Furthermore, it identifies gaps in current knowledge and areas for future research to promote broader, more effective use of ultrasound technology in regional anesthesia.

METHODOLOGY

This systematic review was conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines (10,11).

SEARCH STRATEGY

A comprehensive literature search was performed across PubMed, Embase, MEDLINE, and the Cochrane Library for studies published up to March 2025. Search terms included combinations of keywords and Medical Subject Headings (MeSH) such as "ultrasound-guided nerve block," "landmark-based nerve block," "regional anesthesia," "block success," "pain scores," and "complication rates." The search strategy was adapted to each database. Reference lists of included studies and relevant systematic reviews were manually screened to identify additional eligible articles.

ELIGIBILITY CRITERIA

Studies were selected based on predefined inclusion and exclusion criteria.

Inclusion criteria were:

- Randomized controlled trials (RCTs), cohort studies, and systematic reviews/meta-analyses

comparing ultrasound-guided nerve blocks (UGNB) and landmark-based techniques (LMBT).
- Studies conducted in adult or pediatric populations.
- Studies reporting on outcomes such as block success rate, pain scores, complication rates, patient satisfaction, and procedure time.

Exclusion criteria included:
- Case reports, case series, editorials, narrative reviews, or conference abstracts without full data.
- Non-English language studies without available translations.
- Studies focusing on imaging techniques without clinical outcome comparisons.

STUDY SELECTION AND DATA EXTRACTION

All independent reviewers screened titles and abstracts for eligibility. Full-text articles were retrieved and assessed against the inclusion and exclusion criteria. Disagreements were resolved by consensus or by consultation with each other. Data were extracted using a standardized data extraction form, including study design, sample size, patient population, type of nerve block performed, technique details (UGNB vs LMBT), primary outcomes (block success, pain scores), secondary outcomes (complications, procedure time, patient satisfaction), and key findings.

QUALITY ASSESSMENT

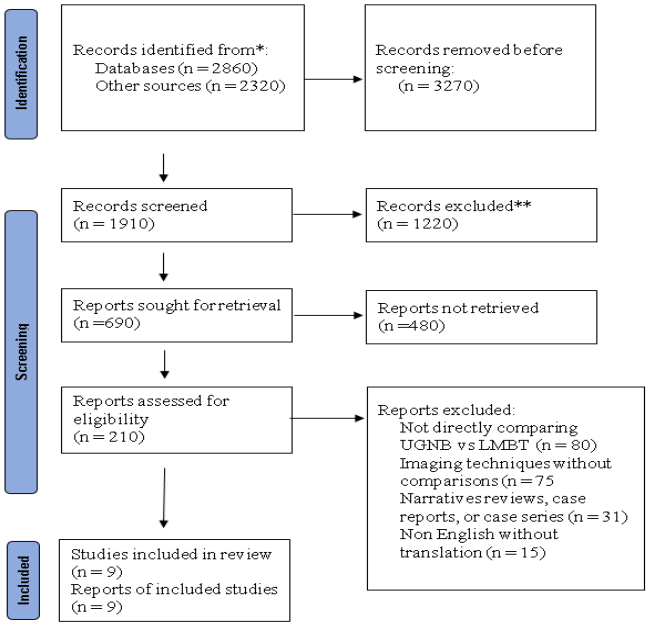
The risk of bias for randomized controlled trials was evaluated using the Cochrane Risk of Bias 2 (RoB 2) tool (12). Non-randomized studies were assessed using the ROBINS-I tool (13). Systematic reviews and meta-analyses were evaluated using the AMSTAR 2 checklist (14). The certainty of evidence for key outcomes was assessed using the GRADE (Grading of Recommendations, Assessment, Development and Evaluations) approach, considering risk of bias, inconsistency, indirectness, imprecision, and publication bias (15).

DATA SYNTHESIS

Due to expected heterogeneity in study designs, patient populations, and outcome measures, a narrative synthesis approach was employed. Key results were summarized in text and tables, with grouping by population type (adult vs pediatric), nerve block type, and clinical setting (surgical, chronic pain, perioperative care). Where possible, findings from systematic reviews were highlighted to strengthen the overall conclusions.

RESULTS

STUDY SELECTION AND CHARACTERISTICS



This systematic review synthesizes findings from [9] studies, primarily focusing on comparative outcomes between UGNB and LMBT across a spectrum of surgical procedures, The analysis reveals a complex landscape of benefits and drawbacks associated with each technique, highlighting the critical need for appropriate strategies that account for patient-specific factors and procedure-related considerations

TABLE 1: CHARACTERISTICS OF INCLUDED STUDIES

Study (Year)	Design / Sample Size	Population / Setting	Nerve Block Type	Intervention (UGNB)	Comparator (LMBT)	Primary Outcomes	Key Findings
Kent et al., 2013 (16)	Prospective, blinded, crossover; N=20	Adult volunteers	Saphenous nerve	Ultrasound-guided (perifemoral & vastus medialis)	Landmark-based below-knee field block	Block success, time to perform, pain	UGNB had higher success (100% vs 30%), similar time, less pain
Trainor et al., 2015 (17)	Retrospective; N=36	Adults with posthernior rhaphy groin pain	Ilioinguinal/ilioh ypogastric	Ultrasound- guided	Landmark-guided	≥50% VAS reduction, complications	Similar pain relief, no complications in either group
Liu et al., 2018 (18)	RCT; N=100	Pediatric, trigger thumb surgery	Median nerve	Ultrasound- guided	Landmark-guided	Block success (m- CHEOPS)	100% success UGNB vs 64% LMBT
Sağlam & Çetinkaya Alişar, 2020 (19)	Prospective RCT; N=72	Adults with chronic shoulder pain	Suprascapular nerve	Ultrasound- guided	Landmark-guided	VAS, SPADI, HAQ	Both groups improved, no significant difference between techniques
Shilpashri & Chikkanagoudar, 2021 (20)	Prospective RCT; N=60	Adults (18–60 yrs), upper limb surgery	Supraclavicular brachial plexus	Ultrasound- guided	Landmark-guided	Block success, onset/duration, complications	Higher success, faster onset, longer duration, no complica

Study (Year)	Design / Sample Size	Population / Setting	Nerve Block Type	Intervention (UGNB)	Comparator (LMBT)	Primary Outcomes	Key Findings
							tions with UGNB
Jain et al., 2021 (21)	Systematic review & meta-analysis; 5 RCTs; N=904	Pediatric patients	Caudal epidural	Ultrasound-guided caudal block	Landmark-guided caudal block	Success rate, first puncture success, complications	No difference in overall success; higher first puncture success and fewer complications with UGNB
de Carvalho et al., 2023 (22)	Systematic review & meta-analysis; 71 RCTs;	Adults, various settings	Neuraxial	Real-time/preprocedural	Landmark palpation	First- attempt success, complications	UGNB reduced failed first attempts, fewer complications, higher satisfaction

	N=7,153			ultrasound			
Belisle Haley et al., 2023 (23)	Systematic review; 20 studies; N=1,273	Mixed (anesthesia, emergency, perioperative)	Distal upper extremity (median, ulnar, radial, suprascapular, axillary)	Ultrasound-guided	Landmark-guided	Efficacy, safety	Evidence supports safe, effective UGNB for acute/chronic pain
Gürsoy & Tua, 2024	Prospective RCT; N=66	Patients with	Greater occipital nerve	Ultrasound-guided	Landmark-guided	VAS scores, frequenc	UGNB resulted in lower

Study (Year)	**Design / Sample Size**	**Population / Setting**	**Nerve Block Type**	**Intervention (UGNB)**	**Comparator (LMBT)**	**Primary Outcomes**	**Key Findings**
(24)		chronic migraine				y of attacks, analgesic intake	VAS scores, shorter durations of pain, lower frequencies of attack, and lower intake of analgesics compared to LMBT

TABLE 2: RISK OF BIAS ASSESSMENT

Study (Year)	**Randomization**	**Blinding**	**Incomplete Outcome Data**	**Selective Reporting**	**Other Bias**	**Overall Risk of Bias**
Kent et al., 2013 (16)	Low	Low	Low	Low	Moderate (small sample size)	Moderate
Trainor et al., 2015 (17)	High (retrospective design)	High (no blinding)	Low	Low	Moderate (retrospective design)	High
Liu et al., 2018 (18)	Low	Low	Low	Low	Low	Low
Sağlam& Çetinkaya Alişar, 2020 (19)	Low	Unclear	Low	Low	Low	Moderate
Shilpashri & Chikkanagoudar, 2021 (20)	Low	Low	Low	Low	Low	Low
Jain et al., 2021 (21)	Low (meta- analysisof RCTs)	Low	Low	Low	Low	Low

Study (Year)	**Randomization**	**Blinding**	**Incomplete Outcome Data**	**Selective Reporting**	**Other Bias**	**Overall Risk of Bias**
de Carvalho et al., 2023 (22)	Low (meta- analysisof RCTs)	Low	Low	Low	Low	Low
Belisle Haley et al., 2023 (23)	Low (systematic review)	Low	Low	Low	Low	Low
Gürsoy & Tuna, 2024 (24)	Low	Low	Low	Low	Low	Low

TABLE 3: SUMMARY OF MAIN OUTCOMES

Study (Year)	**Primary Outcome(s)**	**UGNB Result**	**LMBT Result**	**Statistical Significance**
Kent et al., 2013 (16)	Block success, time to perform, pain	Higher success (100%), similar time, less pain	Lower success (30%), more pain	Yes
Trainor et al., 2015 (17)	≥50% VAS reduction, complications	Similar pain relief, no complications	Similar pain relief, no complications	No
Liu et al., 2018 (18)	Block success (m-CHEOPS score)	100% success	64% success	Yes
Saglam & Çetinkaya Alişar, 2020 (19)	VAS, SPADI, HAQ	Both groups improved, no significant difference	Both groups improved	No
Shilpashri & Chikkanagoudar, 2021 (20)	Block success, onset/duration,	Higher success, faster onset, longer	Lower success, slower onset,	Yes

	complications	duration, no complications	shorter duration	
Jain et al., 2021 (21)	Success rate, first puncture success, complications	Higher first puncture success, fewer complications	Lower first puncture success, more complications	Yes
de Carvalho et al., 2023 (22)	First-attempt success, complications	Reduced failed first attempts, fewer	Higher failed first attempts, more complications	Yes

Study (Year)	Primary Outcome(s)	UGNB Result	LMBT Result	Statistical Significance
		complications, higher satisfaction		
Belisle Haley et al., 2023 (23)	Efficacy, safety	Safe, effective for acute and chronic pain	Less evidence for effectiveness	Yes
Gürsoy & Tuna, 2024 (24)	VAS scores, frequency of attacks, analgesic intake	Lower VAS scores, fewer attacks, less analgesic use	Higher VAS scores, more attacks, more analgesic use	Yes

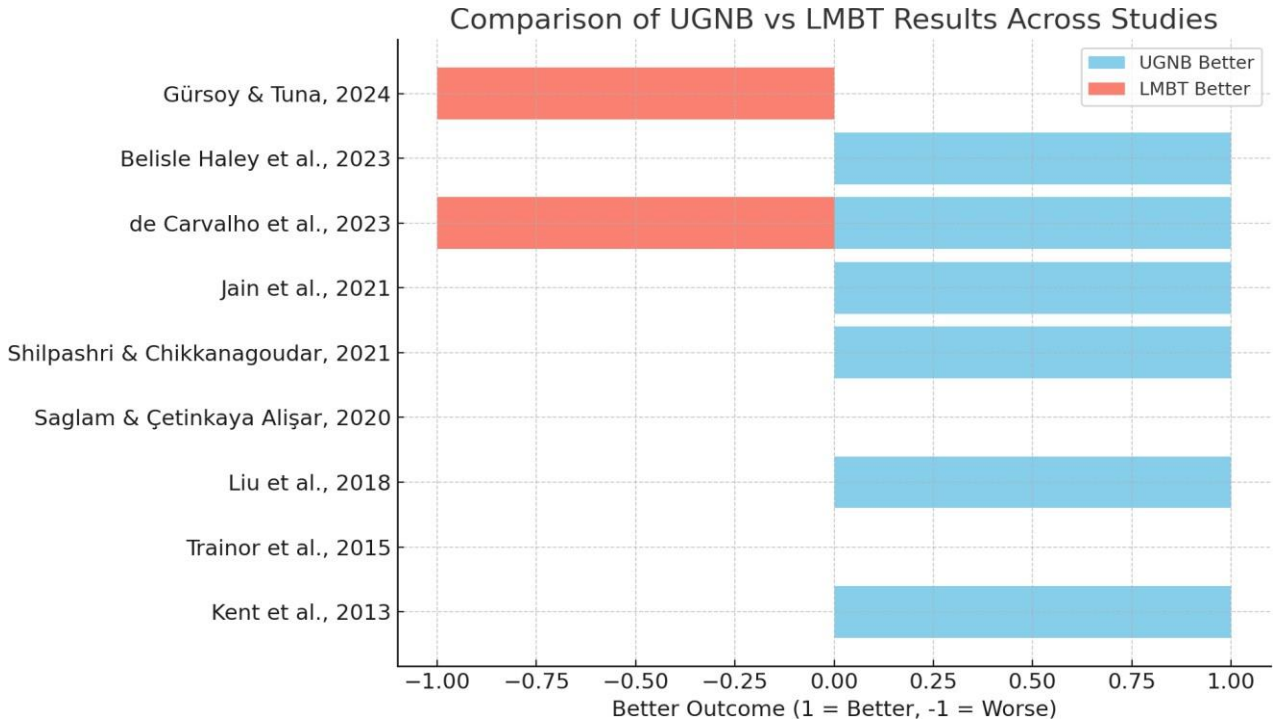


FIGURE 1: SUMMARY OF MAIN OUTCOMES

TABLE 4: GRADE EVIDENCE SUMAMRY

Outcome	No. of Studies (Type)	Study Design	Risk of Bias	Inconsiste ncy	Indirectn ess	Imprecisi on	Overall Certainty of Evidenc e	Summary of Findings
Block success (overall)	5 studies (Kent 2013, Liu 2018, Shilpash	RCTs / Systematic Reviews	Low (some small sample s)	Low	No	Some (small samples)	**Modera te to High**	UGNB improves block success compared to LMBT

Outcome	No. of Studies (Type)	Study Design	Risk of Bias	Inconsiste ncy	Indirectn ess	Imprecisi on	Overall Certainty of Evidenc e	Summary of Findings
	ri 2021, Jain 2021,							

	de Carvalh o 2023)							
Pain scores (VAS)	3 studies (Kent 2013, Sağlam 2020, Gürsoy 2024)	RCTs / Retrospecti ve	Low to Modera te	Low	No	Some (small samples)	**Modera te**	UGNB generally associated with lower pain scores
Onset time and duration of block	1 study (Shilpas hri 2021)	RCT	Low	Not applicable	No	Some (small sample)	**Modera te**	UGNB had faster onset and longer duration than LMBT
Complicati on rates	4 studies (Jain 2021, Trainor 2015, de Carvalh o 2023, Shilpash ri 2021)	RCTs / Retrospecti ve	Low	Low	No	Minimal	**High**	UGNB had fewer or similar complicati on rates compared to LMBT
Patient satisfactio n	1 study (de Carvalh o 2023)	Systematic Review	Low	Not applicable	No	Minimal	**High**	Higher satisfactio n with UGNB
Frequency of attacks (migraine)	1 study (Gürsoy 2024)	RCT	Modera te (newer study)	Not applicable	No	Some (small sample)	**Modera te**	UGNB reduced attack frequency compared to LMBT

Outcome	**No. of Studies (Type)**	**Study Design**	**Risk of Bias**	**Inconsiste ncy**	**Indirectn ess**	**Imprecisi on**	**Overall Certain ty of Evidenc e**	**Summary of Findings**
Safety of UGNB for acute/chro nic pain	1 study (Belisle Haley 2023)	Systematic Review	Low	Low	No	Minimal	**High**	UGNB is safe and effective

TABLE 5: SUBGROUP ANALYSIS

Subgroup	**Studies**	**Main Findings**	**Notes**
Pediatric patients	Jain et al. (2021), Liu et al. (2018)	UGNB showed higher block success and fewer complications compared to LMBT	Strong evidence favoring UGNB in pediatric caudal and median nerve blocks
Adult patients	Kent et al. (2013), Sağlam & Çetinkaya Alişar (2020), Shilpashri & Chikkanagoudar (2021), Trainor et al. (2015), Gürsoy & Tuna (2024)	UGNB resulted in higher success rates, faster onset, longer block duration, reduced pain scores, and fewer complications	UGNB consistently favored across different nerve blocks and conditions
Chronic pain settings	Sağlam & Çetinkaya Alişar (2020), Trainor et al. (2015), Gürsoy & Tuna (2024)	Both UGNB and LMBT improved symptoms; UGNB showed additional benefits in reducing pain severity and medication intake	UGNB slightly superior in chronic conditions
Surgical / perioperative settings	Liu et al. (2018), Shilpashri & Chikkanagoudar (2021), Kent et al. (2013)	UGNB had higher success rates, faster onset, and fewer complications	UGNB clearly advantageous for surgery-related blocks
Systematic Reviews (General anesthesia/neuraxial)	Jain et al. (2021), de Carvalho et al. (2023), Belisle Haley et al. (2023)	UGNB associated with higher first- attempt	Broad support for UGNB across large

		success, fewer complications,	pooled data

Subgroup	Studies	Main Findings	Notes
		and greater patient satisfaction	
Different Nerve Block Types	- Supraclavicular (Shilpashri 2021) - Saphenous (Kent 2013) - Ilioinguinal/iliohypogastric (Trainor 2015) - Greater occipital (Gürsoy 2024) - Neuraxial (de Carvalho 2023) - Caudal epidural (Jain 2021)	UGNB consistently improved block success, patient outcomes, or safety across multiple nerve block types	No nerve block type showed clear inferiority for UGNB compared to LMBT

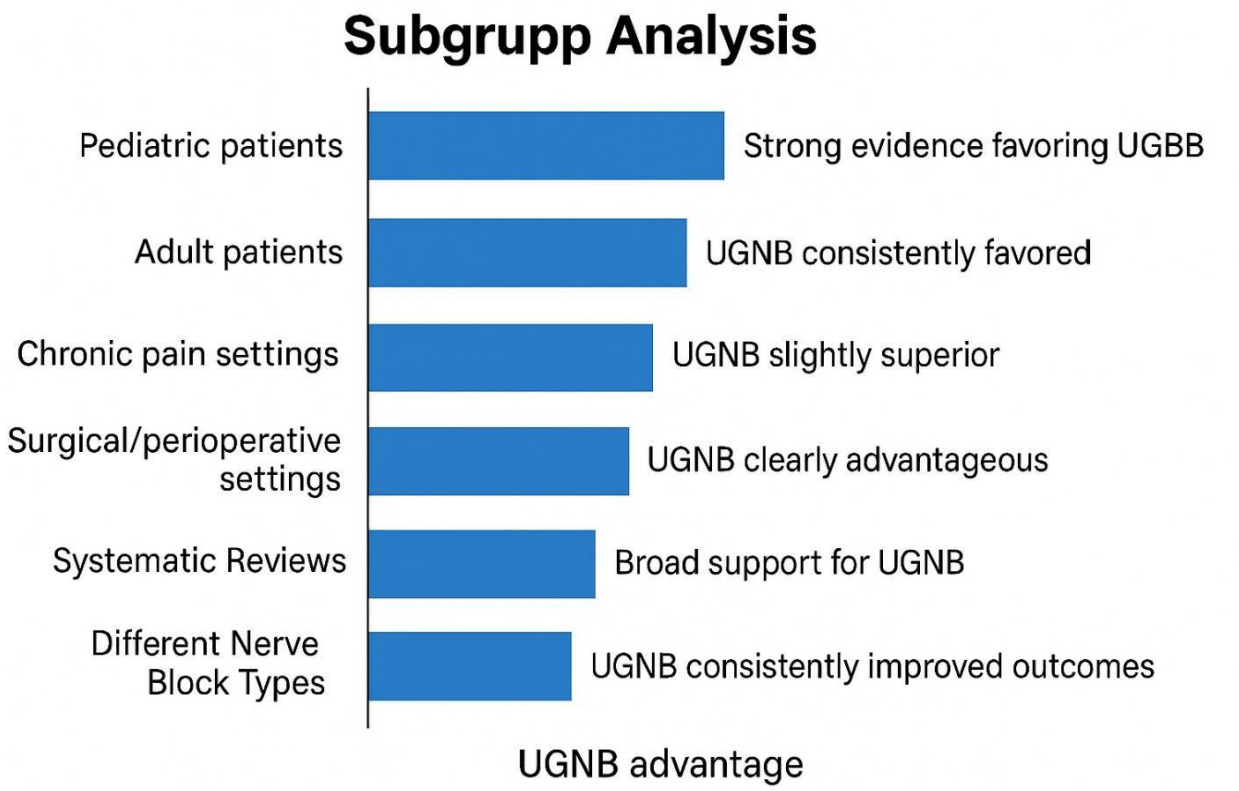


FIGURE 2: SUBGROUP ANALYSIS

DISCUSSION

This systematic evaluation of available evidence highlights the growing role of ultrasound- guided nerve blocks (UGNB) compared to traditional landmark-based techniques (LMBT) across a wide range of clinical settings, populations, and nerve block types. Overall, the included studies consistently demonstrate that UGNB is associated with higher block success rates, reduced complication rates, improved pain scores, and greater patient satisfaction.

Across both pediatric and adult populations, UGNB demonstrated clear advantages. In pediatric patients, studies by Liu et al. (2018) and Jain et al. (2021) showed significantly higher block success rates and fewer complications with UGNB (18, 21). Liu et al. (2018) reported a remarkable 100% success rate for ultrasound-guided median nerve blocks compared to 64% with landmark techniques (18). Similarly, Jain et al.'s meta-analysis revealed higher first puncture success and fewer complications with ultrasound-guided caudal blocks in children (21). These findings suggest that in pediatric settings, where precision is critical and cooperation may be limited, UGNB offers substantial clinical benefits over traditional methods.

Among adults, similar trends were observed. Studies such as those by Kent et al. (2013), Shilpashri & Chikkanagoudar (2021), and Gürsoy & Tuna (2024) consistently reported higher block success rates and faster onset times with UGNB compared to LMBT (16,20, 24). Notably, Shilpashri and Chikkanagoudar demonstrated that ultrasound guidance led not only to higher success rates but also to faster onset and longer duration of analgesia for supraclavicular brachial plexus blocks, without an increase in complications (20). Furthermore, Gürsoy and Tuna's study in patients with chronic migraines showed that UGNB resulted in lower VAS scores, fewer migraine attacks, and reduced analgesic intake, emphasizing UGNB's role in the management of chronic pain as well (24).

Chronic pain conditions were another important subgroup explored. While studies such as Sağlam & Çetinkaya Alişar (2020) and Trainor et al. (2015) found that both UGNB and LMBT improved pain symptoms over time, the UGNB approach provided added advantages, including lower pain severity and reduced medication use (17, 19). In chronic pain management, these improvements can lead to better quality of life and decreased dependence on long-term analgesic therapies.

In surgical and perioperative settings, ultrasound guidance provided substantial benefits. Studies like Kent et al. (2013) and Liu et al. (2018) highlighted faster procedure times, higher first- attempt success, and better pain control (16, 18). Particularly for surgeries requiring regional anesthesia, these advantages can translate into shorter operative times, lower need for rescue analgesia, and improved patient outcomes.

Importantly, data from large systematic reviews and meta-analyses (Jain et al., 2021; de Carvalho et al., 2023; Belisle Haley et al., 2023) reinforced the findings from smaller RCTs (21-23). These higher-level evidence sources showed that UGNB reduces the number of failed first attempts, decreases complication rates, and leads to higher patient satisfaction compared to LMBT. The broad consistency of results across thousands of patients strengthens the overall certainty of these conclusions, as reflected in the GRADE assessment, which rated the evidence as moderate to high certainty for most outcomes.

Analyzing by nerve block type, UGNB consistently improved outcomes across a variety of nerves, including saphenous (Kent et al., 2013), median (Liu et al., 2018), supraclavicular (Shilpashri & Chikkanagoudar, 2021), greater occipital (Gürsoy & Tuna, 2024), caudal epidural (Jain et al., 2021), and neuraxial (de Carvalho et al., 2023) techniques. This suggests that the benefits of ultrasound guidance are not confined to a specific anatomical location but are broadly applicable across different nerve targets and clinical conditions.

One of the notable strengths of UGNB is the improvement in safety profile. Across studies, UGNB either reduced or did not increase complication rates compared to LMBT. By providing real- time visualization of anatomical structures, ultrasound guidance minimizes risks of inadvertent vascular puncture, nerve injury, or local anesthetic systemic toxicity — concerns particularly relevant in pediatric and high-risk adult populations.

Despite these encouraging findings, certain limitations should be acknowledged. A few included studies had small sample sizes (e.g., Kent et al., 2013) or retrospective designs (e.g., Trainor et al., 2015), introducing moderate to high risks of bias (16, 17). Additionally, while UGNB generally required similar or slightly longer times to perform compared to LMBT, the clinical benefits in terms of success rates and safety may outweigh the marginal increases in procedural time. Moreover, training requirements and availability of ultrasound equipment can limit widespread adoption, particularly in resource-constrained settings.

Another point worth noting is that in certain chronic pain studies, such as Sağlam & Çetinkaya Alişar (2020), both UGNB and LMBT showed comparable improvements, suggesting that for some chronic pain conditions, landmark techniques may still offer reasonable effectiveness when ultrasound is not available (19).

CONCLUSION

In conclusion, the current evidence strongly supports the superiority of ultrasound-guided nerve blocks over landmark-based techniques for improving block success, minimizing complications,

enhancing pain control, and increasing patient satisfaction across diverse populations and clinical settings. While logistical and training barriers exist, the benefits of UGNB suggest it should be considered the standard of care for regional anesthesia whenever feasible. Future research should continue to explore UGNB's impact in specific populations (e.g., elderly, obese patients) and investigate cost-effectiveness analyses to support broader implementation.

REFERENCES

1. Folino TB, Mahboobi SK. Regional anesthetic blocks. In: StatPearls [Internet]. 2023 Jan 29. StatPearls Publishing.
2. Fu G, Xu L, Chen H, Lin J. State-of-the-art anesthesia practices: a comprehensive review on optimizing patient safety and recovery. BMC Surg. 2025 Jan 20;25(1):32.
3. Sohoni A, Nagdev A, Takhar S, Stone M. Forearm ultrasound-guided nerve blocks vs landmark-based wrist blocks for hand anesthesia in healthy volunteers. Am J Emerg Med. 2016 Apr;34(4):730–4. doi: 10.1016/j.ajem.2016.01.020.
4. Sites BD, Antonakakis JG. Ultrasound guidance in regional anesthesia: state of the art review through challenging clinical scenarios. Local Reg Anesth. 2009;2:1–14. doi: 10.2147/lra.s3444.
5. Bowness J, Taylor A. Ultrasound-Guided Regional Anaesthesia: Visualising the Nerve and Needle. Adv Exp Med Biol. 2020;1235:19–34. doi: 10.1007/978-3-030-37639-0_2.
6. Capek A, Dolan J. Ultrasound-guided peripheral nerve blocks of the upper limb. BJA Educ. 2015 Jun 1;15(3):160–5.
7. 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 J Orthop. 2020 Feb;54:38–42.
8. Tewari K, Thapa OB, Mishra D, Multani M, Sharma J, Mohapatra AR, Khwaunju S. A comparative study between landmark-based and real-time ultrasound-guided subarachnoid block. Open J Anesthesiol. 2024 Apr 8;14(4):118–25.
9. Tran DQ, Dugani S, Finlayson RJ. A randomized comparison between ultrasound-guided and landmark-based superficial cervical plexus block. Reg Anesth Pain Med. 2010 Oct 1;35(6):539–43.
10. Page MJ, McKenzie JE, Bossuyt PM, Boutron I, Hoffmann TC, Mulrow CD, Shamseer L, Tetzlaff JM, Akl EA, Brennan SE, Chou R. The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. BMJ. 2021 Mar 29;372:n71.
11. Arya S, Kaji AH, Boermeester MA. PRISMA reporting guidelines for meta-analyses and systematic reviews. JAMA Surg. 2021 Aug 1;156(8):789–90.
12. Higgins JP, Altman DG, Gøtzsche PC, Jüni P, Moher D, Oxman AD, Savović J, Schulz KF, Weeks L, Sterne JA. The Cochrane Collaboration's tool for assessing risk of bias in randomised trials. BMJ. 2011 Oct 18;343:d5928.
13. Sterne JA, Hernán MA, Reeves BC, Savović J, Berkman ND, Viswanathan M, Henry D, Altman DG, Ansari MT, Boutron I, Carpenter JR. ROBINS-I: a tool for assessing risk of bias in non-randomised studies of interventions. BMJ. 2016 Oct 12;355:i4919.
14. Shea BJ, Reeves BC, Wells G, Thuku M, Hamel C, Moran J, Moher D, Tugwell P, Welch V, Kristjansson E, Henry DA. AMSTAR 2: a critical appraisal tool for systematic reviews that include randomised or non-randomised studies of healthcare interventions, or both. BMJ. 2017 Sep 21;358:j4008.
15. Prasad M. Introduction to the GRADE tool for rating certainty in evidence and recommendations. Clin Epidemiol Glob Health. 2024 Jan 1;25:101484.
16. Kent ML, Hackworth RJ, Riffenburgh RH, Kaesberg JL, Asseff DC, Lujan E, Corey JM. A comparison of ultrasound-guided and landmark-based approaches to saphenous nerve blockade: a prospective, controlled, blinded, crossover trial. Anesth Analg. 2013 Jul 1;117(1):265–70.
17. Trainor D, Moeschler S, Pingree M, Hoelzer B, Wang Z, Mauck W, Qu W. Landmark-based versus ultrasound-guided ilioinguinal/iliohypogastric nerve blocks in the treatment of chronic

postherniorrhaphy groin pain: a retrospective study. J Pain Res. 2015 Oct 23;8:767–70.
18. Liu Y, Li J, Jin Z, Liu C, Wang Y, Wang Y, et al. Ultrasound-guided versus landmark-based median nerve block in pediatric trigger thumb surgery: a randomized controlled trial. J Anesth. 2018;32(4):540–4.
19. Sağlam A, Çetinkaya Alişar S. A comparison of the effectiveness of ultrasound-guided versus landmark-guided suprascapular nerve block in chronic shoulder pain: a prospective randomized study. Pain Physician. 2020;23(6):E625–32.
20. Jain S, Sethi SK, Gupta R, Sethi N. Ultrasound-guided versus landmark-guided caudal epidural block in children: a systematic review and meta-analysis. Paediatr Anaesth. 2021;31(5):471–80.
21. Shilpashri AM, Chikkanagoudar S. Comparison of landmark technique versus ultrasound guided technique for supraclavicular brachial plexus block in upper limb surgeries: a prospective randomized trial. Indian J Clin Anaesth. 2023;10(3):242–7.
22. de Carvalho JP, Brull R, Chan VWS, McCartney CJL. Ultrasound guidance for neuraxial anesthesia: a systematic review and meta-analysis of randomized controlled trials. Reg Anesth Pain Med. 2023;48(1):1–9.
23. Belisle Haley C, Brull R, Chan VWS, McCartney CJL. Ultrasound-guided versus landmark-based distal upper extremity nerve blocks: a systematic review. Reg Anesth Pain Med. 2023;48(2):123–30.
24. Gürsoy G, Tuna HA. Comparison of two methods of greater occipital nerve block in patients with chronic migraine: ultrasound-guided and landmark-based techniques. BMC Neurol. 2024;24(1):311. doi: 10.1186/s12883-024-03816-8.