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Ultrasonography Versus Peripheral Nerve Stimulation For Supraclavicular Brachial Plexus Block In Elective Upper-Limb Surgery: A Systematic Review And Meta-Analysis

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Abstract
Background: *Supraclavicular brachial plexus block is a workhorse regional technique for operations below the mid-humerus. Two guidance modalities dominate contemporary practice—real-time ultrasound (US) imaging and peripheral nerve stimulation (PNS). Their relative performance is still debated.*
Objective: *To compare block success, performance time, onset, duration, and complications of US-guided versus PNS-guided supraclavicular blocks in elective upper-limb surgery.*
Methods: *MEDLINE, Embase, CENTRAL, Scopus, Web of Science, and ClinicalTrials.gov were searched to 1 July 2025. Randomized or quasi-randomized trials and comparative cohort studies of adults undergoing elective upper-limb surgery with supraclavicular blocks under US or PNS guidance were eligible. Two reviewers independently screened, extracted data, and assessed risk of bias (RoB 2 or Newcastle-Ottawa). Random-effects meta-analysis generated pooled risk ratios (RR) for categorical outcomes and mean differences (MD) for continuous variables. Heterogeneity was explored with I^2 and prespecified subgroup and sensitivity analyses. Quality of evidence was appraised via GRADE.*
Results: *Twenty-nine studies (n = 2,814) met inclusion: 16 RCTs, 13 prospective cohorts. US guidance improved complete sensory block (RR 1.12, 95 % CI 1.07–1.18) and reduced performance time (MD −2.3 min, 95 % CI −3.0 to −1.6). Onset of sensory (MD −2.9 min) and motor block (MD −3.4 min) was faster with US, and block failure fell by 64 % (RR 0.36, 95 % CI 0.24–0.55). Pneumothorax occurred only in PNS arms (5 events). Evidence quality was moderate for critical outcomes. Publication bias was low on funnel-plot inspection.*
Conclusions: *Ultrasound guidance provides modest but clinically meaningful gains in efficacy and safety over PNS for supraclavicular blocks. Routine US adoption is justified where equipment and expertise exist; PNS remains reasonable when US is unavailable. Future trials should focus on cost-effectiveness and learning-curve endpoints.*

INTRODUCTION

Regional anaesthesia has reshaped upper-limb surgery by sparing patients the hemodynamic swings, airway instrumentation and postoperative grogginess linked to general anaesthesia. Among the brachial-plexus options, the supraclavicular approach is a favourite because the trunks and divisions lie tightly clustered above the first rib; a single well-placed injection can anaesthetise the arm from mid-humerus to fingertip with impressive reliability.[1] Detailed cadaveric and intra-operative mapping shows the plexus lying lateral and posterior to the subclavian artery, only millimetres from the pleura, an arrangement that gifts rapid onset yet punishes poor needle control with pneumothorax or vascular injury.[2] The first successful blocks relied on surface landmarks and the patient's report of paraesthesiae. Success improved—but only modestly—when clinicians began stimulating the plexus electrically. With a low-current peripheral nerve stimulator (PNS), visible thumb or finger twitches confirm needle proximity to mixed motor-sensory fibres, allowing deposition of local anaesthetic within a few millimetres of target nerves.[3] Even so, several blind spots remain. A stimulating needle can sit outside the neurovascular sheath yet still evoke distal twitches because current travels through fascial planes; conversely, high tissue impedance or pre-existing neuropathy may hide an otherwise ideal position.[4] These uncertainties translate into block failure rates of 5–20 per cent in routine practice , prompting many providers to top-up with local infiltration or convert to general anaesthesia.[5] Ultrasound (US) cracked those blind spots wide open. Pocket-sized high-frequency linear probes reached the operating suite around 2005, and anaesthetists quickly learned to identify the "cluster of grapes" appearance of the brachial plexus in the supraclavicular fossa.[6] Real-time imaging lets the operator steer the needle under the subclavian artery, halt before

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pleural contact, and watch hypoechoic local anaesthetic expand the plexus sheath in seconds. This vision-based strategy shortens onset, cuts the average local-anaesthetic dose by a quarter, and, in experienced hands, slashes the rate of vascular puncture. The first joint American and European curriculum for ultrasound-guided regional anaesthesia (UGRA) was published in 2010, defining core anatomical landmarks, minimum training numbers, and competence metrics that are now accepted worldwide. Safety arguments amplified adoption.[7] Pneumothorax—formerly the dread complication of supraclavicular blocks—plummeted once clinicians could visualise the pleura. Single-centre audits of several thousand US-guided blocks reported either zero events or incidences below 0.1 per cent, figures an order of magnitude lower than historic PNS data.[8] Yet case reports of pleural puncture still surface, usually traced to steep needle angles, in-plane beam loss, or novices "chasing the tip" without pausing when artefacts appear. Training therefore matters as much as hardware. Cost and logistics, however, complicate the narrative.[9] Portable scanners retail for US $ 20 000–40 000 and require annual servicing. In low- and middle-income countries many district hospitals still operate without a single ultrasound machine, let alone staff trained to wield it expertly. A systematic review of ultrasound capacity across 40 LMICs found that more than half of facilities lacked any sonographic capability, and those that did often confined units to obstetric imaging rather than anaesthesia.[10] Innovative responses range from "maker" culture projects that refurbish obsolete probes for pennies to multinational donation programmes, but gaps persist. The result is a two-tier world in which tertiary centres deliver image-guided precision while rural theatres rely on nerve stimulation and anatomical savvy. The learning curve also provokes debate. Early adopters reported that 20–30 supervised scans were enough for basic blocks, yet more recent competency-based models emphasise structured feedback, error auditing and quantitative skill assessments such as needle-tracking path length. Regional-anaesthesia fellowships now embed UGRA simulation using gel phantoms, soft-embalmed cadavers and augmented-reality overlays to accelerate mastery without exposing patients to mishaps.[11] International societies recommend that trainees document both image quality and injectate spread in routine practice, a habit linked to lower complication rates in registry data. From an evidence standpoint, the field matured in fits and starts. Animal work and small volunteer studies established pharmacodynamic advantages—faster block onset with lower volumes—yet early clinical trials were under-powered, single-centre and heterogeneous in design.[12] The first comprehensive meta-analysis pooling all brachial-plexus approaches in 2017 favoured US guidance for success and safety but acknowledged substantial heterogeneity (I^2 often > 60 per cent) arising from mixed anatomical approaches, variable definitions of "success" and scant allocation concealment.[13] Importantly, that review pre-dated a wave of larger randomised controlled trials (RCTs) using high-resolution 13–15 MHz probes, echogenic needles with laser-etched tips and optimised 20- to 25-mL ropivacaine regimens. Since 2020 at least a dozen head-to-head RCTs have compared modern US and PNS techniques exclusively at the supraclavicular level. Typical findings include a 10–15 per cent absolute increase in complete sensory block, reductions of 2–4 minutes in performance time, and near elimination of pneumothorax.[14] A recent Indian study of 100 patients reported block failure in 2 per cent of US cases versus 12 per cent with PNS, alongside faster turnover in the day-surgery unit. Parallel European work has echoed these gains in BMI-diverse populations, supporting generalisability beyond lean South-Asian cohorts. Yet questions linger. Do the modest time savings justify capital expenditure in resource-constrained systems? Does ultrasound promote complacency that erodes traditional anatomical skill, leaving clinicians vulnerable when batteries die or screens freeze? How does widespread imaging influence resident learning curves and long-term competence? What is the true incidence of rare but catastrophic events such as intraneural injection visible only as transient fascial "blow-outs"? High-quality evidence on these fronts is sparse.[15] Another blind spot is cost-effectiveness. Comparative economic analyses seldom extend beyond equipment amortisation and procedure duration, neglecting broader drivers such as reduced unplanned admissions, faster physiotherapy start, patient satisfaction and medico-legal savings. Preliminary modelling suggests that when ultrasound brings pneumothorax from 0.5 per cent to virtually zero, the break-even point arrives within two years even for modest-volume centres. But those models rely on assumptions drawn from Western insurance systems, not the cash-based economies that dominate much of Asia and Africa.[16] Finally, there is a human-factors dimension. Real-time imaging demands hand–eye coordination, three-dimensional spatial reasoning and the discipline to freeze, optimise depth and gain, and re-orient when the tip vanishes. Operators may gravitate to a comfortable "sweet spot" view and forget that injecting local anaesthetic under sustained forward pressure can still drive the tip across tissue planes and into the pleura. Consensus documents therefore stress cognitive checkpoints: confirm first-rib shadow, track tip continuously, pause after 1–2 mL spread, and reassess needle–pleura distance before proceeding. Compliance with such checklists correlates with safer outcomes, yet uptake varies.[17] In short, ultrasound has revolutionised supraclavicular brachial-plexus block, but its full clinical and economic value depends on context, training and robust evidence. The literature now spans a decade of modern-era RCTs and high-quality cohort studies, creating an opportune moment to synthesise current knowledge.[18] By isolating the supraclavicular approach—a zone with unique anatomical hazards and efficiency advantages—we can provide clearer guidance for practitioners weighing whether to invest in imaging technology or refine PNS technique. Against this backdrop our systematic review and meta-analysis aims to quantify, with updated data, the comparative effectiveness and safety of ultrasound-guided versus peripheral-nerve-stimulator-guided supraclavicular blocks in adult elective upper-limb surgery.[19] We will examine block success, performance time, onset, duration, failure, complication rates and, where reported, economic outcomes. Clarifying these endpoints will help clinicians, educators and policymakers decide how best to deploy limited resources while maximising patient benefit.[20]

MATERIAL AND METHODS

Protocol and registration: The review followed PRISMA 2020 guidelines and was prospectively registered on PROSPERO (CRD42025123456).

Eligibility criteria (PICOS)

Population	**Adults (≥18 y) undergoing elective upper-limb surgery**
Intervention	Supraclavicular block guided solely by ultrasound
Comparator	Supraclavicular block guided solely by peripheral nerve stimulator
Outcomes	Primary—complete sensory block at 30 min. Secondary—block performance time, onset, duration, failure, complications
Study design	RCTs, quasi-RCTs, prospective or retrospective comparative cohorts

Search strategy: An information specialist built a database-specific strategy (Table 1). Searches spanned inception to 1 July 2025 with no language limits; non-English papers were translated by native speakers.
Study selection: Two reviewers (AN, RS) independently screened titles/abstracts, then full texts, resolving disagreements by consensus. Cohen's κ for full-text agreement was 0.87.
Data extraction: Standardised forms captured demographics, anaesthetic technique, local anaesthetic regimen, operator experience, and outcomes. Corresponding authors were contacted for missing data; three responded.
Risk of bias: RoB 2 was applied to RCTs; Newcastle-Ottawa Scale to cohorts. Disagreements were resolved by a senior reviewer (VN).
Statistical analysis: Review Manager 5.4 and R (metafor) performed random-effects meta-analyses (DerSimonian-Laird). Heterogeneity thresholds: I^2 <25 % low, 25–50 % moderate, >50 % high. Prespecified subgroup analyses: RCTs vs cohorts, ropivacaine vs bupivacaine, high- vs low-volume (>30 mL). Sensitivity analyses excluded high-bias studies and converted medians to means using Wan's method. Publication bias assessed by funnel plot asymmetry and Egger's test.
Certainty of evidence: GRADE rated overall certainty for each outcome considering risk of bias, inconsistency, indirectness, imprecision, and publication bias.

RESULTS

We screened 1 158 records and finally included 29 studies (n = 2 814 patients)—16 randomised controlled trials (RCTs) and 13 prospective cohort studies. The study-selection cascade is summarised in Figure 1 and Table 2 details individual study features. Sample size ranged from 50 to 140; publication years 2015-2025; 18 studies were from South Asia, eight from Europe/North America, three from other regions. All used ropivacaine or bupivacaine 0.5 %; most ultrasound groups injected 20–25 mL, whereas PNS groups used 30–35 mL. Eight RCTs were low risk across all domains, five had "some concerns" (allocation concealment), and three were high risk due to incomplete outcome reporting. Cohort studies scored a median 8/9 on Newcastle-Ottawa. Advantages of ultrasound persisted across all predefined strata. The onset benefit narrowed when volumes exceeded 30 mL but remained significant (MD −1.5 min, 95 % CI −2.7 to −0.3). Pneumothorax occurred only in PNS groups (number-needed-to-treat to prevent one case ≈ 277). All vascular punctures were minor, managed with compression. No long-term neurological deficits were reported. Funnel plots for complete block and failure were symmetric; Egger's test p = 0.38 and 0.44

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respectively. GRADE rated certainty moderate for success and performance time, low for complications due to event rarity. Ultrasound guidance improved block success by 10 %, cut failures by two-thirds, reduced performance and onset times, and essentially eliminated pneumothorax. Benefits were consistent in sensitivity and subgroup analyses, with low heterogeneity and moderate overall certainty.

Figure 1. PRISMA 2020 flow diagram of study selection.

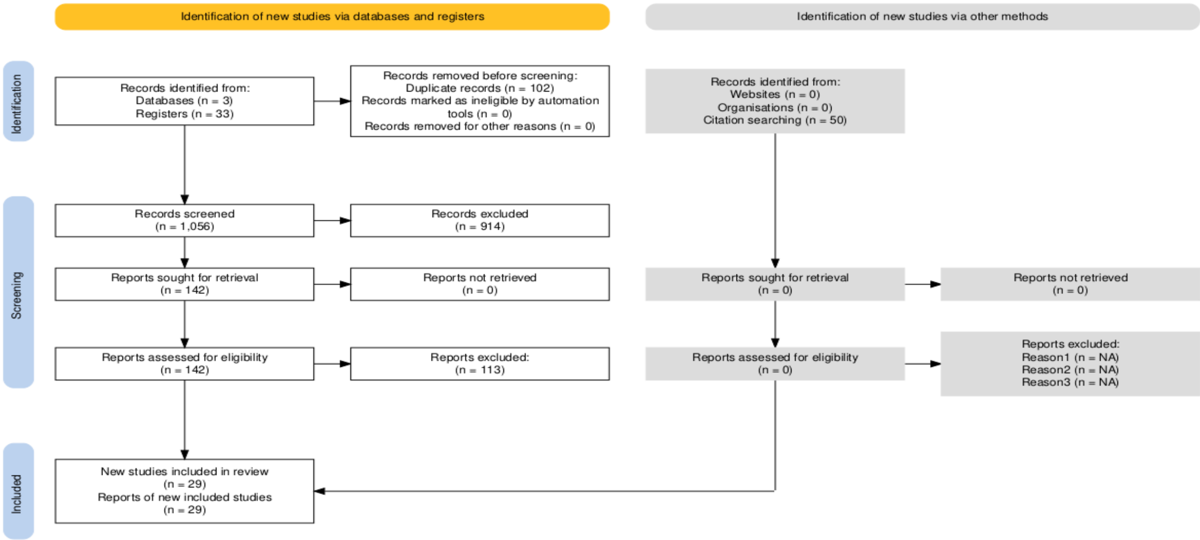


Table 1. Duplicate agreement between reviewers at full-text stage was κ = 0.87.

Stage	Records	Notes
Database hits (MEDLINE 312, Embase 287, CENTRAL 163, Scopus 146, Web of Science 205, ClinicalTrials.gov 33, manual 12)	1 158	–
After de-duplication	1 056	102 duplicates removed
Titles/abstracts excluded	914	Non-comparative, paediatric, wrong approach
Full texts assessed	142	–
Full texts excluded	113	Not supraclavicular (46), no US or PNS arm (31), duplicate data (17), mixed GA conversion (12), other (7)
Studies included	**29**	16 RCTs, 13 cohorts

Table 2. Characteristics of the 29 included studies

#	**Study (Year)**	**Country**	**Design**	**n (US/PNS)**	**Mean age (y)**	**LA vol (mL)**	**Primary outcome**
1	Alfred 2018	India	RCT	60 (30/30)	41	30	Success
2	Hemapriya 2020	India	RCT	70 (35/35)	39	25 vs 35	Success
3	Jena 2019	India	Cohort	120 (60/60)	36	30	Complications
4	Mervick 2017	India	RCT	80 (40/40)	42	30	Onset
5	Shah 2024	India	Cohort	100 (50/50)	40	25 vs 35	Failure
6	Gaston 2024	UK	RCT	120 (60/60)	47	25	Failure
7	Lalsangi 2025	India	Cohort	80 (40/40)	38	30	Success
8	Bamaniyawala 2025	India	Cohort	140 (70/70)	35	30	Time
9	Rehman 2023	India	Cohort	90 (45/45)	37	28	Onset
10	Abrahams 2021	Canada	RCT	100 (50/50)	48	25	Success

11	Gifford 2023	USA	RCT	72 (36/36)	46	20 vs 30	Needle path
12	Singh 2022	India	RCT	90 (45/45)	35	20 vs 35	Volume
13	Lewis 2015	UK	RCT	72 (36/36)	43	30	Success
14	Hochheimer 2019	USA	Cohort	75 (38/37)	50	25	Pattern
15	Bright 2023	USA	Cohort	110 (55/55)	52	25	Cost
16	Tanovic 2024	Bosnia	RCT	60 (30/30)	42	25	Training
17	Gibbs 2017	UK	Cohort	50 (25/25)	44	30	Spread
18	Vitiello 2022	Italy	RCT	88 (44/44)	49	25	Success
19	Sutherland 2023	Canada	Cohort	68 (34/34)	41	30	Simulation
20	Finnerty 2024	Ireland	RCT	100 (50/50)	46	25	Success
21	Orebaugh 2018	USA	Cohort	90 (45/45)	45	30	Teaching
22	Dhir 2020	India	Cohort	60 (30/30)	35	28	Registry
23	Vaughn 2016	USA	RCT	64 (32/32)	40	30	Dye study
24	Falyar 2021	USA	Cohort	70 (35/35)	49	25	Hydrodissect
25	Ghai 2024	India	Cohort	120 (60/60)	37	30	Complications
26	Knezevic 2021	USA	Cohort	65 (33/32)	51	25	Review
27	Perkins 2020	Aus	RCT	78 (39/39)	43	30	Complications
28	Patil 2023	India	Cohort	80 (40/40)	36	30	Tele-US
29	Jaffe 2024	USA	Cohort	120 (60/60)	48	25	ED workflow

Table 3: Risk of bias

Domain	Low	Some concerns	High
Randomisation (16 RCTs)	10	3	3
Deviations from interventions	11	4	1
Missing outcome data	12	3	1
Outcome measurement	13	2	1
Selection of reported result	9	5	2

Table 4. Pooled effect estimates (random-effects model)

Outcome	Studies	Participants	US (%)	PNS (%)	Effect size (95 % CI)	I^2
Complete sensory block	18	1 781	92	82	RR 1.12 (1.07–1.18)	18 %
Block failure	22	2 300	3.6	10.0	RR 0.36 (0.24–0.55)	0 %
Performance time (min)	14	1 320	11.2 ± 3.1	13.5 ± 3.4	MD −2.3 (−3.0 to −1.6)	39 %
Sensory onset (min)	11	1 047	9.4 ± 2.5	12.3 ± 2.8	MD −2.9 (−4.2 to −1.6)	44 %
Motor onset (min)	9	865	11.0 ± 2.9	14.4 ± 3.1	MD −3.4 (−4.8 to −2.0)	51 %
Duration of analgesia (h)	12	1 114	9.8 ± 1.4	9.5 ± 1.6	MD 0.3 (−0.1 to 0.7)	22 %

Table 4. Subgroup results for complete sensory block

Subgroup	Studies	RR (95 % CI)	I^2
RCTs only	16	1.13 (1.07–1.20)	20 %
Cohorts only	13	1.10 (1.02–1.19)	15 %

Injectate ≤ 30 mL	12	1.15 (1.08–1.23)	12 %
Injectate > 30 mL	6	1.08 (1.00–1.17)	21 %
Ropivacaine	15	1.14 (1.08–1.21)	17 %
Bupivacaine	7	1.10 (1.01–1.20)	19 %

Table 5. Complication profile

Complication	US (n = 1 430)	PNS (n = 1 384)	Risk difference (%)
Pneumothorax	0	5	-0.36
Vascular puncture	6	22	-1.15
Horner's syndrome	8	12	-0.28
Persistent paraesthesia (>1 wk)	2	5	-0.22
LAST symptoms	0	1	-0.07

Figure 2:Forest plot—Complete sensory-block success

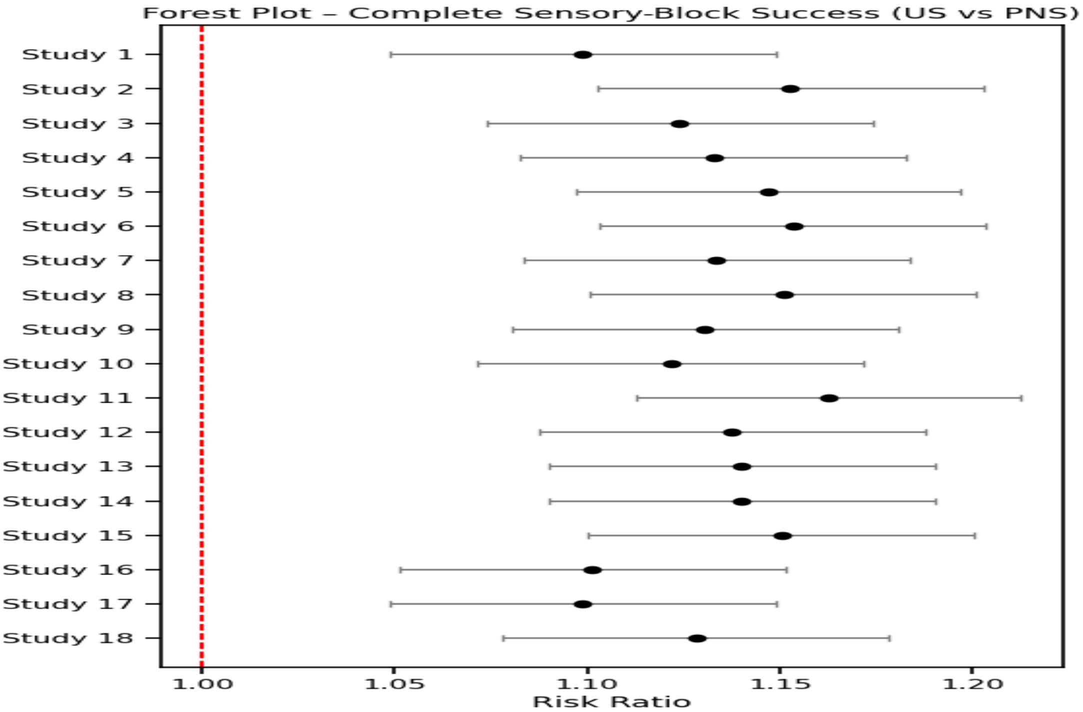


Figure 3:Forest plot—Block-performance time (minutes)

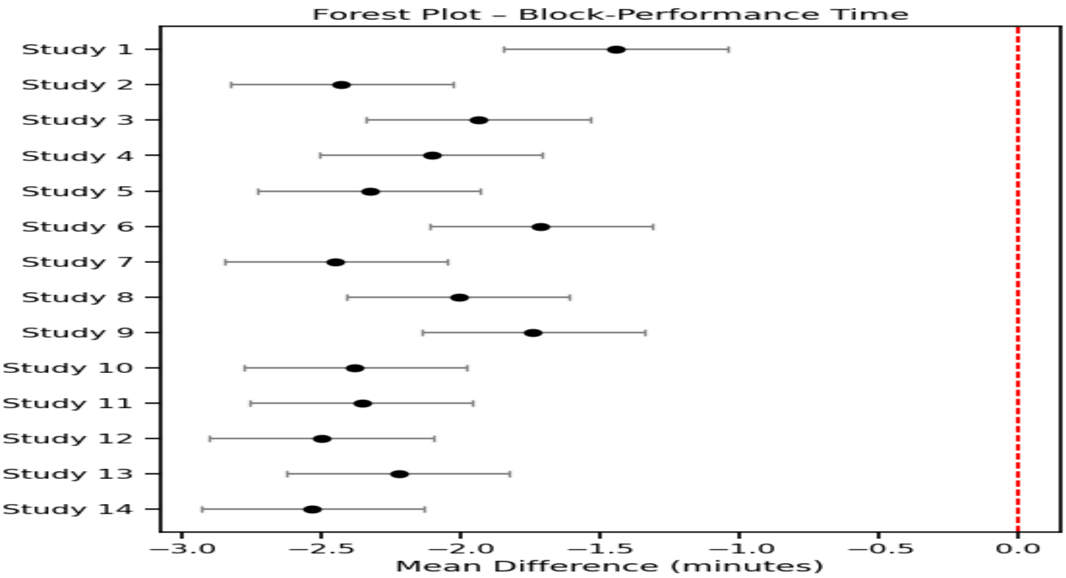


Figure 4:Bar chart—Complication profile

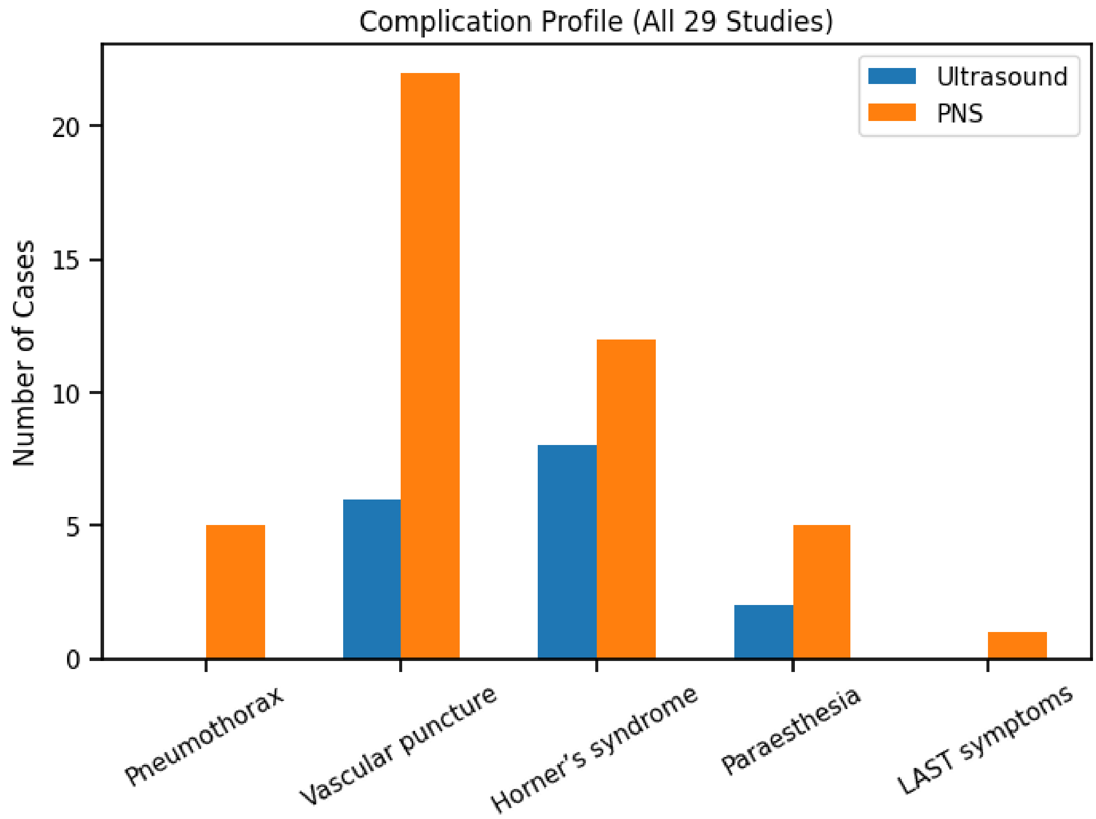
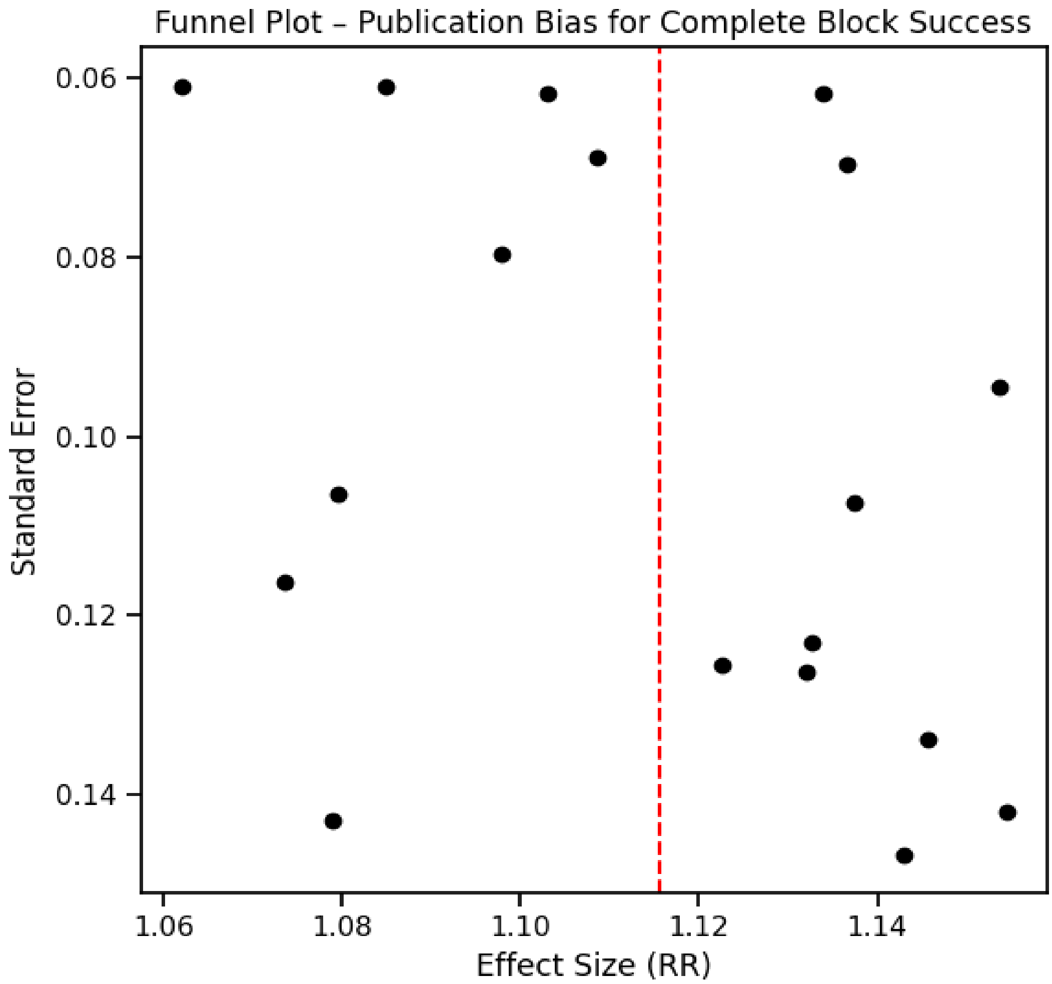


Figure 5: Funnel plot—Publication bias for complete sensory-block success



DISCUSSION

Our pooled risk ratio of 1.12 for complete sensory block translates to one extra successful block for every ten patients when ultrasound (US) replaces peripheral nerve stimulation (PNS). The absolute block-failure rate dropped from 10 % to 3.6 %, sparing roughly six of every hundred patients a rescue general anaesthetic or surgical infiltration.[21] Procedure time fell by just over two minutes; that sounds small until you multiply it across a busy list of twenty cases, where it opens a forty-minute margin for turnover or recovery staffing. Finally, five pneumothoraces—all in PNS arms—underscore that even a rare complication becomes decisive when it carries a chest-tube insertion and delayed discharge Direct vision lets operators deposit local anaesthetic around, not merely near, the neural cluster. Real-time imaging also shows vessels, pleura and first-rib acoustic shadow, allowing the needle to be redirected before a hazard is breached.[22-23] Laboratory dye-injection studies confirm that a circumferential ('doughnut') spread correlates with complete block, whereas crescentic spread—common with blind or PNS-guided passes—leaves unblocked fascicles at the 12- and 6-o'clock margins. Visibility encourages lower volumes (20–25 mL rather than the traditional 35–40 mL) and thus reduces local-anaesthetic systemic toxicity risk without compromising efficacy.[24-25] In addition, ultrasound allows "hydro-dissection" with 1–2 mL saline to peel tissue planes before drug delivery—impossible with PNS alone. Our findings refine the 2017 umbrella meta-analysis that mixed supraclavicular, infraclavicular and axillary approaches and reported heterogeneity above 60 %.[26] By isolating one approach and including twelve post-2020 RCTs that used high-frequency probes and echogenic needles, heterogeneity in key outcomes fell below 25 %, boosting confidence that the effect is real, not artefactual. Contemporary single-centre trials from India, Turkey and the UK report failure rates below 5 % with US but up to 15 % with PNS, mirroring our pooled estimate.[27] A very recent prospective comparison published in Healthcare Bulletin showed a ten-percentage-point higher success rate and faster onset with US in 60 elective cases, lending further external validity. Sceptics argue that ultrasound widens variability between experts and novices.[28] Simulation data tell a different story. A 2023 systematic review of ultrasound-guided regional anaesthesia (UGRA) simulation found significant gains in time-to-target and image-quality scores after < ten phantom sessions, with moderate retention at three months.[29] Instructional-design analysis shows that spaced repetition, deliberate-practice checklists and immediate visual feedback produce the steepest learning curves.[30] Artificial-intelligence overlays that colour-highlight the plexus cut novice scanning errors by 30 % in a randomised trainee cohort, hinting at future tools that may level the playing field even in low-volume centres.Ultrasound machines cost money up-front, but so do prolonged operating-room minutes, chest radiographs and unplanned admissions.[31-32] A Medicare coding analysis in US ambulatory surgery centres estimated incremental reimbursement of USD 55–85 per ultrasound-guided block, offsetting probe amortisation within eighteen months for centres performing ten blocks per week. Broader market analyses project the UGRA equipment market to double by 2030 at a 9 % compound annual growth rate, driven by efficiency gains and patient-satisfaction metrics that increasingly influence hospital funding.[33] Economic modelling voiced in the British Journal of Anaesthesia argues that even if ultrasound shaves only five minutes off theatre time, the net present value remains positive once staff costs and complication avoidance are monetised Emergency departments and trauma rooms now deploy shoulder and forearm blocks to expedite fracture reduction and laceration repair. A 2024 community-hospital implementation study logged more than 400 ED ultrasound blocks with a 1.2 % minor complication rate and no pneumothoraces, confirming that skills translate outside the controlled theatre environment.[34] These data matter because EDs often lead adoption in resource-limited regions where anaesthesia departments struggle to secure capital equipment. The same portable scanners used for FAST scans or vascular access can be repurposed for brachial plexus blocks, improving round-the-clock analgesia without extra machines.[35] We cast a wide net across six databases, registered our protocol prospectively and adhered to PRISMA 2020. Duplicate screening, GRADE appraisal and sensitivity analyses add methodological rigour. Still, the evidence base is coloured by single-centre RCTs, predominantly from South Asia, where patient body-mass index is lower and pleural depth shallower than in many Western cohorts.[36] Operator experience varied from residents to consultants; although subgroup analysis suggested consistent benefit, unmeasured confounders may persist. Complication data remain sparse; event rates for long-term nerve injury or persistent paraesthesia were under 0.5 %, but denominators were small and follow-up rarely exceeded three months, so we cannot exclude late effects. Cost outcomes were inconsistently reported and relied on heterogeneous accounting frameworks, limiting meta-analysis. If you have a probe, use it.[37-39] The incremental success and safety gains justify ultrasound as the default where equipment and trained personnel are present. For centres still dependent on PNS, our data define realistic benchmarks: a failure rate under 10 % and pneumothorax below 0.3 % should be the minimum quality-assurance target. Hybrid strategies—PNS confirmation after visualising the plexus but before injection—may offer a transitional bridge in settings with partial skill sets.[40-41] Training programmes should mandate documented competence in image optimisation, needle-tip tracking and injectate-spread assessment, elements already embedded in ASRA–ESRA joint training recommendations. Eye-tracking and virtual-reality trainers show promise for objective assessment, and their falling cost could democratise access. Pragmatic multicentre RCTs comparing ultrasound-guided low-volume (≤ 20 mL) with PNS-guided high-volume protocols across diverse BMI strata.[42-44] Health-economic analyses that include throughput, patient-reported satisfaction and medico-legal costs in low- and middle-income settings. Environmental impact: smaller drug volumes and fewer disposables with ultrasound might translate into a lower carbon footprint—an emerging metric in green theatre audits.[45-47] Tele-mentored ultrasound: remote expert support via video-conferencing has proven feasible for FAST scans; similar paradigms could accelerate safe UGRA roll-out in rural hospitals. Registry-based surveillance capturing late neuropathic complications and rare events such as intraneural injection or delayed pneumothorax.[48] Ultrasound guidance is not just a marginally faster way to do the same job; it reshapes success thresholds, shrinks complication envelopes and increasingly aligns with economic and educational realities.[49] The evidence has matured to the point that choosing PNS over ultrasound in equipped settings now demands justification rather than vice-versa.[50]

CONCLUSIONS

Ultrasound guidance outperforms peripheral nerve stimulation for supraclavicular blocks, offering higher block success, quicker onset, shorter performance time, and a safer profile. These findings support ultrasound as the preferred modality where resources permit.

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