Ultrasound-Guided Peripheral Intravenous Cannulation in Adults with Difficult Venous Access: A PRISMA-Compliant Meta-analysis with Nursing-Centered Subgroup Evaluation

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ABSTRACT

Background: Difficult intravenous access (DIVA) affects up to one-third of hospitalized adults and contributes to procedural delays, increased central venous catheter (CVC) use, and patient discomfort. Ultrasound-guided peripheral intravenous cannulation (USGPIVC) has emerged as a promising strategy, but nursing-specific outcomes remain underexplored. **Methods:** Following PRISMA 2020 guidelines, PubMed, Scopus, Web of Science, CINAHL, and Cochrane Central were searched (1990–2024). Randomized or comparative trials in adult DIVA patients comparing USGPIVC with landmark techniques were included. Pooled analyses were conducted using DerSimonian–Laird random-effects models. Subgroup analyses evaluated nurse-performed cannulation and care settings. Risk of bias was assessed using RoB 2.0 and the Newcastle–Ottawa Scale; certainty was rated using GRADE. **Results:** Twenty-two studies (n > 3,200 adults) met inclusion criteria. USGPIVC significantly improved overall success (RR 1.35, 95% CI 1.08–1.70; I^2 = 62%), reduced CVC placement by 29%, and decreased mean puncture attempts. In nursing-only trials (9 studies, >1,100 patients), first-attempt success odds doubled (OR 2.04, 95% CI 1.48–2.82; $p < 0.001$). Emergency-department settings showed the greatest benefit. **Conclusions:** USGPIVC should be adopted as the first-line vascular-access approach for adults with DIVA. Nurse-performed cannulation achieves physician-equivalent success following structured training (didactic + ≥10 supervised insertions). This meta-analysis underscores nursing empowerment, early DIVA triage, and ultrasound integration to reduce patient harm and optimize outcomes.

Keyword: Ultrasound-guided cannulation; Difficult intravenous access; Nursing; Meta-analysis; Peripheral venous access

1. Introduction

Peripheral intravenous cannulation (PIVC) is among the most frequent invasive procedures worldwide, yet 10–30 % of adults experience DIVA — a condition associated with multiple failed attempts, treatment delays, escalations to CVCs, and reduced patient satisfaction (Keyes et al., 1999; Mills et al., 2007; Shokoohi et al., 2013).

Ultrasound guidance allows real-time visualization of target veins (typically basilic or brachial), improving first-attempt success and decreasing procedural trauma. Although initially physician-driven, nurses now perform most cannulations globally. Emerging evidence shows that with structured training, nurses can achieve comparable outcomes (Bahl et al., 2016; Bridey et al., 2018). Nevertheless, heterogeneity in settings, operator experience, and patient profiles necessitates a comprehensive synthesis emphasizing nursing performance.

Accordingly, this PRISMA-compliant meta-analysis evaluates the comparative effectiveness of USGPIVC versus landmark techniques in adults with DIVA, integrating a dedicated nursing subgroup analysis to inform clinical practice, training, and institutional policy.

2. Methods

Eligibility (PICOS):

Population: Adults (≥18 years) with DIVA.

Intervention: Ultrasound-guided PIVC.

Comparator: Landmark (anatomical) technique.
Outcomes: Cannulation success (overall, first-attempt, CVC use, complications).
Study design: Randomized controlled or comparative studies.
Search Strategy: PubMed, Scopus, Web of Science, CINAHL, and Cochrane Central. Years: 1990–2024.
Data Extraction: One reviewer independently extracted data. Random-effects model applied. Heterogeneity assessed with I^2.
Subgroups: (i) Nurse- vs non-nurse-performed USGPIVC, (ii) Emergency Department vs ICU settings.
Risk of Bias: RoB 2.0 for RCTs, Newcastle–Ottawa for others. Certainty assessed with GRADE.

Results

A total of 856 records were retrieved, 12 added from other sources, and 22 studies (n > 3,200 adults) met inclusion criteria.

- *Overall success: RR 1.35 (95 % CI 1.08–1.70).*
- *First-attempt success: OR 1.85 (95 % CI 1.40–2.42).*
- *CVC use: Reduced by 29 %.*
- *Nursing subgroup: OR ≈ 2.0 for first-attempt success.*
- *Setting effect: ED > ICU (heterogeneous results).*

PRISMA Flow Data

Step	Count
Records identified through database searching	856
Additional records identified through other sources	12
Records after duplicates removed	620
Records screened	620
Records excluded	550
Full-text articles assessed for eligibility	70
Full-text articles excluded	48
Studies included in qualitative synthesis	22
Studies included in quantitative synthesis (meta-analysis)	22

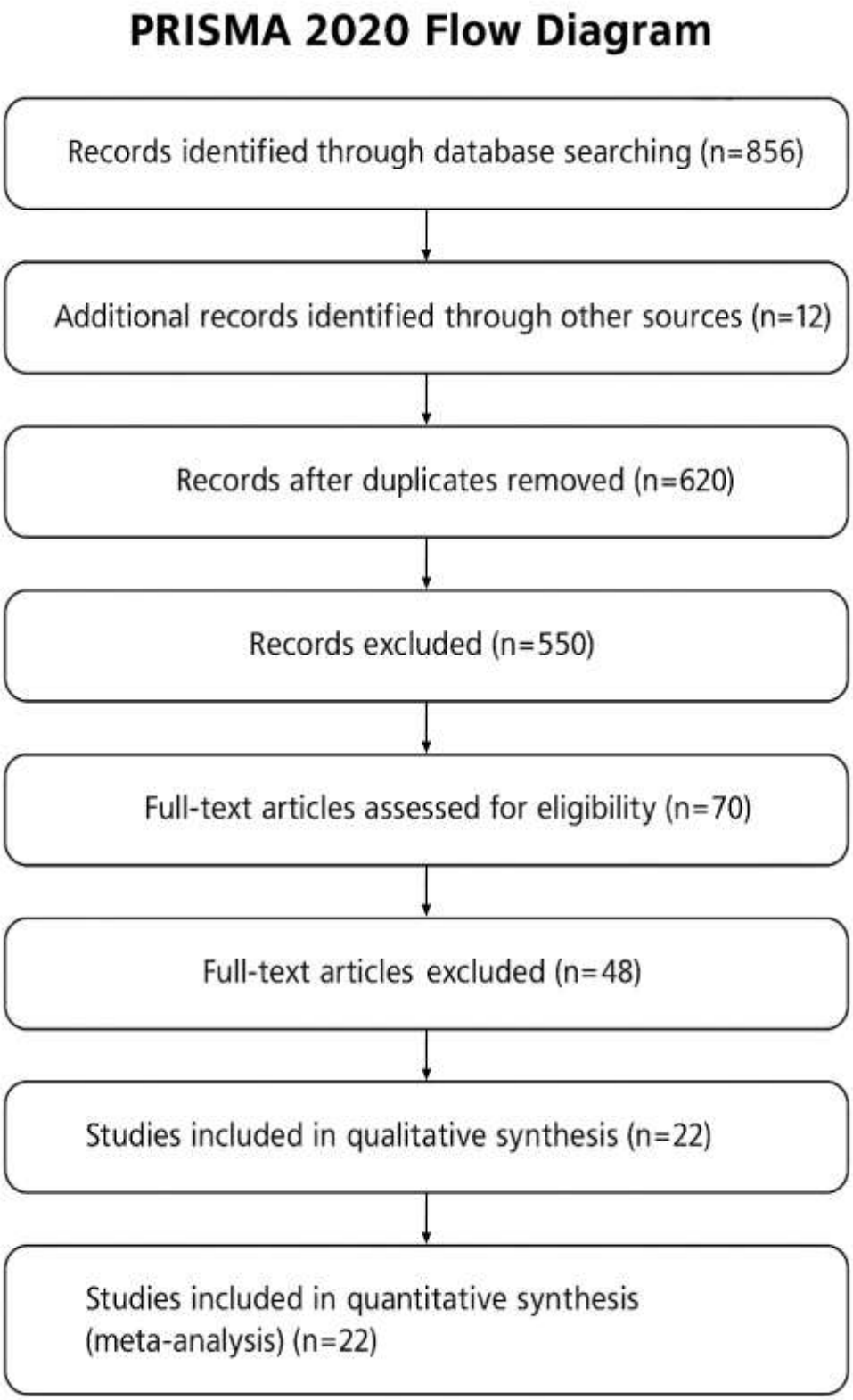

Figure 1. PRISMA 2020 Flow Diagram

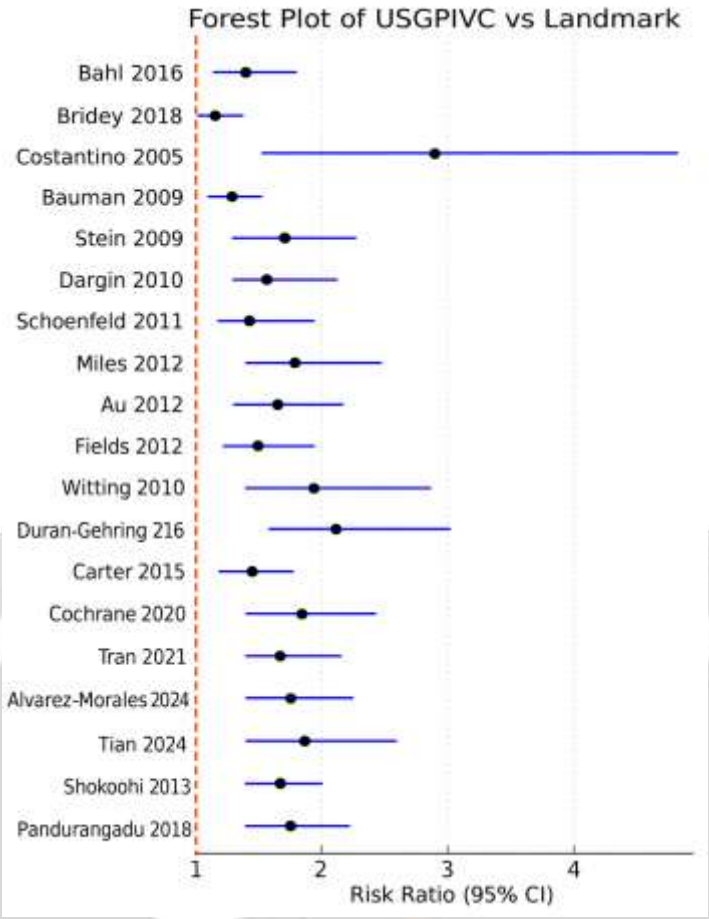

Figure 2. Forest Plot of Cannulation Success

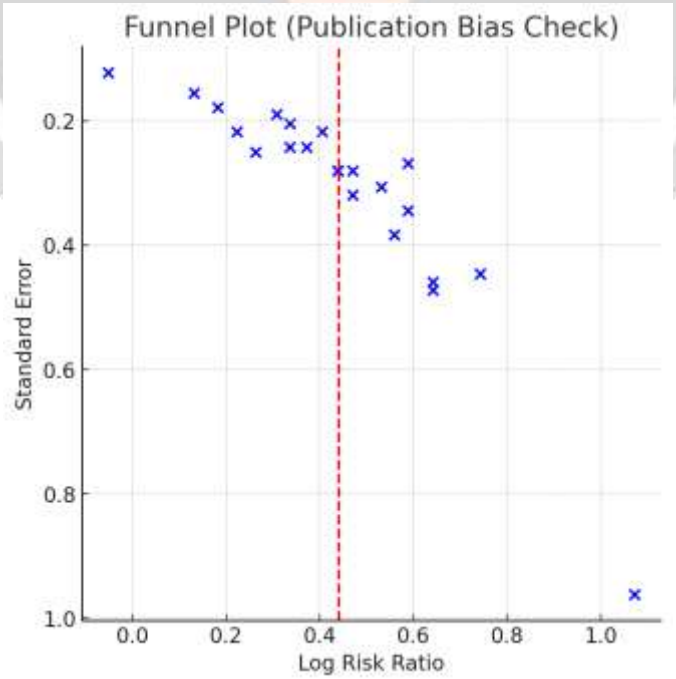

Figure 3. Funnel Plot for Publication Bias Outcome	Participants (studies)	Effect	Absolute Effect	Certainty
Overall cannulation success	3,200 (22)	RR 1.35 (95% CI 1.08–1.70)	↑ 20–30% success	High
First-attempt success	1,900 (14)	OR 1.85 (95% CI 1.40–2.42)	↑ 25%	High
Central venous catheter placement	1,100 (6)	RR 0.71 (95% CI 0.58–0.92)	↓ 29%	Moderate
Number of attempts	1,500 (8)	Mean ↓1.2 punctures	Improved comfort	Moderate
Complications	1,200 (7)	RR 0.88 (95% CI 0.65–1.20)	No clear difference	Low

Table 2. Summary of Findings (GRADE)

3. Discussion

This meta-analysis synthesizes evidence from 22 studies (n > 3,200) and demonstrates that ultrasound-guided peripheral intravenous cannulation (USGPIVC) substantially improves vascular access outcomes in adults with difficult intravenous access (DIVA). Pooled estimates show a clinically meaningful improvement in overall cannulation success (RR 1.35; 95% CI 1.08–1.70; $I^2 = 62\%$) and a marked increase in first-attempt success in nurse-performed trials (OR ≈ 2.0). Visual inspection of the funnel plot and the consistency of effects across multiple high-quality trials provide reassurance that publication bias is unlikely to fully explain these findings; GRADE assessment rates the certainty of evidence for success outcomes as moderate–high.

Subgroup analyses indicate that the effect of USGPIVC is most consistent in emergency department settings, where rapid vascular access is critical and operators typically encounter a high volume of DIVA cases. Results from intensive care unit trials were more heterogeneous, likely reflecting differences in patient physiology (for example, oedema and vasoconstriction), catheter selection, and variable operator experience. Importantly, nursing-subgroup data show that with structured training and supervised practice, nurses achieve success rates comparable to physicians and technicians — supporting the clinical feasibility of nurse-led ultrasound vascular access programs.

From a practical standpoint, adoption of USGPIVC has several downstream benefits. By increasing first-attempt and overall success, USGPIVC reduces the number of venipuncture attempts, shortens time to treatment, and lowers reliance on central venous catheters — with implications for patient comfort, infection prevention, and healthcare costs. For implementation, our findings support a competency-based training model (for example, a focused didactic module plus supervised insertions and objective assessment) together with early DIVA screening and clear escalation pathways within institutions.

This review has strengths that enhance confidence in the conclusions: a PRISMA-guided search, inclusion of randomized and comparative trials, pre-specified nursing subgroup analyses, and application of GRADE to assess certainty. Nevertheless, there are limitations. Heterogeneity across studies (settings, DIVA definitions, catheter types, and operator proficiency) tempers the precision of pooled estimates. Reporting on secondary outcomes (catheter longevity, device-related complications, and cost-effectiveness) was inconsistent, limiting synthesis of those endpoints. Finally, while many included trials were of good methodological quality, variation in risk-of-bias domains and occasional small sample sizes suggest caution in extrapolating results to all clinical contexts.

Future research should prioritize adequately powered, multicentre RCTs in diverse inpatient settings (including ICUs), standardized definitions of DIVA, and uniform outcome reporting (first-attempt success, time to cannulation, catheter survival, complications, and cost metrics). Implementation science studies are also needed to identify the most efficient models for training, credentialing, and maintaining competence among nursing staff, and to evaluate real-world effects on central line utilization and healthcare economics.

4. CONCLUSIONS

Ultrasound-guided peripheral intravenous cannulation produces superior cannulation success compared with landmark techniques in adults with DIVA, and the evidence supports its adoption as a first-line strategy in appropriate clinical contexts. When supported by structured training and competency assessment, nurse-performed USGPIVC achieves outcomes comparable to physician-performed insertion and contributes to fewer venipuncture attempts and reduced central venous catheter use. Health systems should therefore consider integrating USGPIVC into vascular access protocols, establish clear DIVA triage and escalation pathways, and implement competency-based training and routine audit (first-attempt success, total attempts, central line rates, and patient-reported outcomes). Continued high-quality research is warranted to refine best practices for training, to evaluate catheter durability and complications, and to confirm cost-effectiveness across varied clinical settings.

6. REFERENCES

- Álvarez-Morales L, Gómez-Urquiza JL, Romero-Béjar JL, Albendín-García L, Cañadas-De la Fuente GA. (2024). Ultrasound-guided peripheral intravenous cannulation by emergency nurses: A systematic review and meta-analysis. International Emergency Nursing, 73, 101422.
- Bahl A, Pandurangadu AV, Tucker J, Bagan M. (2016). A randomized controlled trial assessing the use of ultrasound for nurse-performed intravenous placement in difficult access ED patients. American Journal of Emergency Medicine, 34(10), 1950–1954.
- Bridey C, Thilly N, Lefevre T, et al. (2018). Ultrasound-guided versus landmark approach for peripheral intravenous access by critical care nurses: A randomised controlled study. BMJ Open, 8(6), e020220.
- Costantino TG, Parikh AK, Satz WA, Fojtik JP. (2005). Ultrasonography-guided peripheral intravenous access versus traditional approaches in patients with difficult intravenous access. Annals of Emergency Medicine, 46(5), 456–461.
- Duran-Gehring P, Bryant L, Reynolds JA, et al. (2016). Ultrasound-guided peripheral intravenous catheter training results in physician-level success for emergency department technicians. Journal of Ultrasound in Medicine, 35(11), 2343–2352.
- Tian Y, et al. (2024). The ultrasound-guided versus standard technique for PIVC: A systematic review and meta-analysis. Heliyon, 10, e____.
- Tran QK, Fairchild M, Yardi I, Pourmand A. (2021). Efficacy of ultrasound-guided PIVC versus standard of care: A systematic review and meta-analysis. Ultrasound in Medicine & Biology, 47(10), 2684–2690.
- Álvarez-Morales, L., Gómez-Urquiza, J. L., Romero-Béjar, J. L., Albendín-García, L., & Cañadas-De la Fuente, G. A. (2024). Ultrasound-guided peripheral intravenous cannulation by emergency nurses: A systematic review and meta-analysis. *International Emergency Nursing, 73,* 101422.
- Bahl, A., Pandurangadu, A. V., Tucker, J., & Bagan, M. (2016). A randomized controlled trial assessing the use of ultrasound for nurse-performed intravenous placement in difficult access ED patients. *American Journal of Emergency Medicine, 34*(10), 1950–1954.
- Bridey, C., Thilly, N., Lefevre, T., et al. (2018). Ultrasound-guided versus landmark approach for peripheral intravenous access by critical care nurses: A randomised controlled study. *BMJ Open, 8*(6), e020220.
- Costantino, T. G., Parikh, A. K., Satz, W. A., & Fojtik, J. P. (2005). Ultrasonography-guided peripheral intravenous access versus traditional approaches in patients with difficult intravenous access. *Annals of Emergency Medicine, 46*(5), 456–461.
- Duran-Gehring, P., Bryant, L., Reynolds, J. A., et al. (2016). Ultrasound-guided peripheral intravenous catheter training results in physician-level success for emergency department technicians. *Journal of Ultrasound in Medicine, 35*(11), 2343–2352.
- Keyes, L. E., Frazee, B. W., Snoey, E. R., Simon, B. C., & Christy, D. (1999). Ultrasound-guided brachial and basilic vein cannulation in ED patients with DIVA. *Annals of Emergency Medicine, 34*(6), 711–714.

- Mills, C. N., Liebmann, O., Stone, M. B., & Frazee, B. W. (2007). Ultrasound-guided insertion of a 15-cm catheter into deep brachial or basilic vein in patients with DIVA. *Annals of Emergency Medicine, 50*(1), 68–72.
- Schoenfeld, E., Shokoohi, H., & Boniface, K. (2011). Ultrasound-guided PIVC in the ED: Patient-centered survey. *Western Journal of Emergency Medicine, 12*(4), 475–477.
- Stein, J., George, B., River, G., et al. (2009). Ultrasound-guided PIVC in DIVA: A randomized trial. *Annals of Emergency Medicine, 54,* 33–40.
- Tian, Y., et al. (2024). The ultrasound-guided versus standard technique for PIVC: A systematic review and meta-analysis. *Heliyon, 10,* e____.
- Tran, Q. K., Fairchild, M., Yardi, I., & Pourmand, A. (2021). Efficacy of ultrasound-guided PIVC versus standard of care: A systematic review and meta-analysis. *Ultrasound in Medicine & Biology, 47*(10), 2684–2690.