Angulated Versus Traditional Peripheral Intravenous Cannulas: A Systematic Review and Meta-Analysis of Ease of Insertion, Flow Characteristics, and Catheter Longevity

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Abstract

Background: Peripheral intravenous (IV) cannulation represents one of the most frequently performed invasive medical procedures worldwide, undertaken in 60–80% of all hospitalised patients. Despite its ubiquity, the procedure is associated with significant challenges, including first-attempt failure rates of 20–40%, patient discomfort, and premature catheter failure occurring in up to 40–50% of cases prior to therapy completion. The 5° angulated (preformed) venflon has emerged as a device innovation designed to improve anatomical alignment with peripheral veins, potentially enhancing procedural success and clinical performance.

Objectives: To systematically evaluate and synthesise all available comparative evidence on the clinical performance of angulated (preformed) peripheral IV cannulas versus traditional straight venflons, with respect to ease of insertion, cannulation time, catheter longevity, patient-reported pain, and haemodynamic stability.

Methods: This systematic review and meta-analysis was conducted in strict adherence with PRISMA 2020 (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines. Six electronic databases were searched (PubMed/MEDLINE, Cochrane CENTRAL, Embase, CINAHL, Scopus, and Google Scholar) from inception to December 2025. Eligible study designs included randomised controlled trials (RCTs) and prospective comparative cohort studies enrolling adult hospitalised patients requiring peripheral IV cannulation. Two independent reviewers performed screening, data extraction, and quality assessment. Risk of bias was evaluated using the Cochrane RoB 2 tool for RCTs. Pooled effect estimates were computed using the Mantel-Haenszel method for dichotomous outcomes (odds ratio, OR) and the inverse variance method for continuous outcomes (weighted mean difference, WMD). Heterogeneity was quantified using the I^2 statistic and Cochran's Q test. Subgroup analyses and sensitivity analyses were pre-specified.

Results: Four studies met the eligibility criteria for qualitative synthesis; one RCT (n = 100; 50 per group) contributed to quantitative meta-analysis. Angulated venflons demonstrated a statistically significant and clinically meaningful advantage in ease of insertion (68.0% vs. 2.0% classified as easy; OR = 120.4; 95% CI: 15.2–953.1; $p < 0.001$) and reduced cannulation time (WMD = −3.52 min; 95% CI: −3.88, −3.16; $p < 0.001$). Conversely, traditional venflons exhibited significantly superior catheter longevity (WMD = −15.68 h; 95% CI: −19.15, −12.21; $p < 0.001$), favouring conventional devices by approximately 15.7 hours of additional functional dwell time. Post-procedural Visual Analogue Scale (VAS) pain scores at 5, 15, and 30 minutes showed statistically significant but clinically marginal differences, with both groups remaining in the mild-discomfort range. Haemodynamic parameters (mean arterial pressure [MAP] and heart rate) were stable and comparable across all time points in both groups.

Conclusions: The 5° angulated venflon provides clinically significant advantages in procedural ease and efficiency but is associated with reduced catheter longevity compared with traditional straight venflons. A context-sensitive approach to cannula selection is recommended: angulated devices are preferred in emergency, perioperative, and high-turnover settings, while traditional venflons remain advantageous where prolonged IV therapy is anticipated. Large-scale, multicentre RCTs are urgently needed to consolidate the evidence base, inform device selection guidelines, and investigate design modifications that could combine the insertion benefits of angulated geometry with the durability of conventional straight cannulas.

Keywords: Environment, Sustainability, Ethics, Intrinsic Value, Environmental Issues.

1. Introduction

Peripheral intravenous (IV) cannulation is the cornerstone of modern inpatient medical care. Across emergency,

perioperative, and general ward settings, it is estimated that 60–80% of hospitalised patients require at least one peripheral intravenous catheter (PIVC) insertion during their hospital admission, primarily for administration of fluids, medications, blood products, electrolyte replacement, and parenteral nutrition [1,2]. Globally, over one billion peripheral IV cannulations are performed annually, making it one of the most commonly executed invasive clinical procedures in medicine [3].

Despite its perceived simplicity, peripheral IV cannulation carries a substantial clinical burden. First-attempt failure rates vary between 20% and 40% in the general adult population, escalating to over 50% in patients with difficult intravenous access (DIVA) — a group that includes the elderly, obese individuals, those with chronic illnesses or veins compromised by repeated cannulations, oncology patients receiving vesicant drugs, and intravenous substance users [4,5,6]. Each failed attempt extends procedure time, increases patient pain and anxiety, amplifies infection risk, and erodes patient confidence in clinical staff. From a healthcare systems perspective, repeated cannulation attempts are associated with increased nursing workload, consumable costs, and delayed treatment initiation [7].

Beyond insertion success, the functional performance of an indwelling peripheral IV cannula is a critical determinant of treatment continuity. Premature catheter failure — defined as the non-elective removal of a peripheral IV catheter prior to completion of the prescribed therapy — has been reported in 40–50% of cases across diverse clinical settings [8,9]. The predominant causes of premature failure include infiltration, thrombophlebitis, catheter occlusion, accidental dislodgement, and local infection. Each episode of failure necessitates repeated cannulation, exposing patients to cumulative procedural pain, vein damage, and iatrogenic infection risk. The economic and human cost of peripheral IV catheter failure thus represents a significant and underaddressed burden in hospital care.

Traditional straight peripheral IV cannulas (venflons) have served as the clinical standard for decades, valued for their simplicity, low manufacturing cost, and broad availability. However, a recognised limitation of these devices lies in their rigid, straight geometry, which does not conform to the natural curvature of peripheral veins. The dorsal hand veins, cephalic vein at the wrist, and antecubital forearm veins — common targets for IV cannulation — exhibit tortuosity and natural angulation that a straight cannula may traverse at a suboptimal angle, creating increased insertion resistance, endothelial trauma during advancement, and mechanical stress on the vessel wall during the dwell period [10,11].

In response to these anatomical limitations, modified cannula designs have been developed and introduced into clinical practice. The 5° angulated (preformed) venflon represents one such innovation: a peripheral IV catheter with a fixed 5-degree angulation engineered into the cannula shaft, designed to more closely conform to the natural course of superficial peripheral veins. The theoretical basis for this design is well-founded: improved alignment between the cannula geometry and the vein trajectory should reduce insertion resistance, facilitate smoother advancement through the vein lumen, decrease endothelial contact during dwell, and potentially prolong catheter functional life [12,13].

Despite these promising theoretical advantages, the comparative evidence base for angulated versus traditional peripheral IV cannulas remains sparse. Few high-quality randomised controlled trials have specifically addressed this comparison, and no systematic review with meta-analysis has been published to date consolidating available evidence. Existing literature has predominantly evaluated procedural adjuncts — such as ultrasound guidance [14], vein visualisation devices [15], and insertion technique training [16] — rather than device design innovations. This represents a meaningful evidence gap, as device selection is a modifiable determinant of cannulation outcomes that clinicians encounter in every IV insertion episode.

The present systematic review and meta-analysis was designed to address this gap by synthesising all available comparative evidence on angulated versus traditional peripheral IV cannulas. We evaluated five pre-specified outcomes: (1) ease of insertion, (2) time to successful cannulation, (3) catheter longevity (dwell time), (4) patient-reported procedural pain using the Visual Analogue Scale (VAS), and (5) haemodynamic stability (MAP and heart rate) during and after cannulation. The findings of this review are intended to provide evidence-based guidance for clinicians, healthcare systems, and device manufacturers on the optimal selection of peripheral IV cannulation devices across diverse clinical contexts.

2. Materials And Methods

2.1 Protocol and Registration

This systematic review and meta-analysis was designed, conducted, and reported in accordance with the 2020 Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA 2020) guidelines [17]. The review protocol was pre-registered with the International Prospective Register of Systematic Reviews (PROSPERO). The PICOS (Population, Intervention, Comparator, Outcomes, Study design) framework guided the development of eligibility criteria and the literature search strategy.

2.2 Eligibility Criteria

Studies were included in this review if they satisfied all of the following PICOS criteria:

- Population: Adult hospitalised patients (age ≥18 years) requiring peripheral intravenous cannulation in any clinical setting, including emergency departments, pre-operative areas, intensive care units (ICU), and general wards.
- Intervention: Any angulated or preformed peripheral IV cannula with a fixed angulation, including 5° preformed venflons and other fixed-angle peripheral catheter designs.
- Comparator: Traditional straight peripheral IV cannulas (0° angulation; conventional design) used as the active comparator.

• Outcomes (primary): Ease of insertion assessed by validated scale or operator classification. Outcomes (secondary): cannulation time (minutes), catheter longevity/dwell time (hours), patient pain scores (VAS 0–10), heart rate (beats per minute), and mean arterial pressure (mmHg) at specified time points.
• Study design: Randomised controlled trials (RCTs) and prospective comparative cohort studies with concurrent control groups.

Studies were excluded if they met any of the following criteria: exclusively paediatric or neonatal populations (age <18 years); evaluated central venous, arterial, or midline catheters rather than peripheral IV cannulas; did not include a concurrent comparator group of traditional straight cannulas; were retrospective or cross-sectional in design without prospective data collection; were published as conference abstracts only without full-text data; or were not published in English.

2.3 Literature Search Strategy

A comprehensive systematic literature search was conducted across six electronic databases: PubMed/MEDLINE, Cochrane Central Register of Controlled Trials (CENTRAL), Embase, Cumulative Index to Nursing and Allied Health Literature (CINAHL), Scopus, and Google Scholar. The search encompassed all records from database inception through 31 December 2025. No restrictions were imposed on publication year, geographic region, or study setting.

The search strategy incorporated controlled vocabulary (MeSH terms) and free-text keywords combined using Boolean operators (AND, OR, NOT). The core search string applied across databases was:

("peripheral intravenous catheter" OR "peripheral IV cannula" OR "venflon" OR "PIVC" OR "intravenous access") AND ("angulated" OR "preformed" OR "angled" OR "5-degree" OR "5°" OR "bent cannula" OR "contoured catheter") AND ("ease of insertion" OR "first-attempt success" OR "catheter longevity" OR "dwell time" OR "cannulation time" OR "insertion success")

Database-specific adaptations were applied where required (e.g., CINAHL headings, Emtree terms in Embase). The reference lists of all included studies and eligible systematic reviews identified during screening were additionally hand-searched to identify any relevant publications not captured by the electronic search. Grey literature, including clinical trial registry entries (WHO ICTRP, ClinicalTrials.gov, CTRI) and relevant conference proceedings, was also reviewed.

2.4 Study Selection

All identified records were imported into Rayyan (Qatar Computing Research Institute) for systematic management of the screening process. Duplicates were identified and removed algorithmically. Two independent reviewers (MDD, AS) performed title and abstract screening against the pre-specified eligibility criteria. Full-text articles of all potentially eligible records were retrieved and assessed independently by the same reviewers. Disagreements at each stage were resolved through structured discussion and, where necessary, adjudication by a third reviewer (AKB). The study selection process is reported in a PRISMA 2020 flow diagram (Figure 1).

2.5 Data Extraction

Data were extracted into a standardised, piloted extraction form by one reviewer (MDD) and independently verified by a second reviewer (MD-2). Extracted data elements included: study identifier (author, year, country); study design and setting; patient population characteristics (mean age, gender distribution, BMI, inclusion/exclusion criteria); intervention details (cannula type, gauge, angulation, insertion site, operator experience); comparator details; sample size; primary and secondary outcome data (proportions, means, standard deviations, confidence intervals, p-values); follow-up duration; statistical methods; and risk of bias indicators. Where essential data were not reported in the publication, corresponding authors were contacted by email.

2.6 Quality Assessment and Risk of Bias

The methodological quality of each included RCT was assessed independently by two reviewers using the Cochrane Risk of Bias 2 (RoB 2) tool [18], which evaluates five domains:

• D1: Bias arising from the randomisation process (sequence generation; allocation concealment).
• D2: Bias due to deviations from intended interventions (blinding of participants and personnel).
• D3: Bias due to missing outcome data (completeness of follow-up; intention-to-treat analysis).
• D4: Bias in measurement of the outcome (blinding of outcome assessors; outcome measurement methods).
• D5: Bias in selection of the reported result (pre-specified analysis; selective outcome reporting).

Each domain was rated as low risk, some concerns, or high risk of bias. An overall risk of bias judgement was made for each study. Discrepancies between reviewers were resolved by consensus. The overall evidence certainty was graded using the GRADE (Grading of Recommendations Assessment, Development and Evaluation) approach, categorising evidence as high, moderate, low, or very low certainty.

2.7 Statistical Analysis and Meta-Analytic Methods

All meta-analyses were performed using Review Manager (RevMan) version 5.4.1 (Cochrane Collaboration, Copenhagen, Denmark) with STATA 17.0 (StataCorp, Texas, USA) used for supplementary analyses and plot generation.

2.7.1 Effect Measure Selection

For dichotomous outcomes (ease of insertion classified as easy vs. not easy; first-attempt success), pooled odds ratios (OR) with 95% confidence intervals (CI) were computed using the Mantel-Haenszel method. For continuous outcomes (cannulation time in minutes; catheter longevity in hours; VAS pain scores; heart rate in bpm; MAP in mmHg), the weighted mean difference (WMD) with 95% CI was calculated using the inverse variance (IV) method, provided outcomes were measured on the same scale across studies. Where outcomes were measured on heterogeneous scales, the standardised mean difference (SMD) was employed. The primary effect

measure was pre-specified in the protocol.

2.7.2 Heterogeneity Assessment

Statistical heterogeneity across studies was assessed using Cochran's Q test and quantified using the I^2 statistic. Following established conventions, I^2 values were interpreted as follows: 0–25% = low heterogeneity; 25–50% = moderate heterogeneity; 50–75% = substantial heterogeneity; >75% = considerable heterogeneity [17]. The τ^2 (tau-squared) statistic was calculated to quantify between-study variance in random-effects models. A p-value of <0.10 for Cochran's Q was used to indicate statistically significant heterogeneity.

2.7.3 Pooling Model Selection

A fixed-effects (Mantel-Haenszel or inverse variance) model was applied in the absence of significant heterogeneity (I^2 ≤25%, Q test p ≥0.10). Where heterogeneity was moderate or substantial (I^2 >25%), a DerSimonian-Laird random-effects model was employed to account for between-study variability. The choice of model for each outcome is explicitly reported in the Results section. Pooled estimates are presented as forest plots with individual study estimates, 95% CIs, and statistical weights.

2.7.4 Subgroup and Sensitivity Analyses

Pre-specified subgroup analyses were planned to explore potential sources of heterogeneity, including: (1) operator experience level (novice [PG Year 1] vs. experienced [PG Year 2+]); (2) cannulation site (upper limb vs. other); (3) cannula gauge (16G/18G vs. 20G/22G); and (4) clinical setting (emergency vs. elective). Sensitivity analyses were conducted by: (a) excluding studies at high overall risk of bias; (b) applying an alternative pooling model (fixed vs. random effects); and (c) using imputed standard deviations where only medians and ranges were reported. Results of sensitivity analyses are reported alongside main analyses.

2.7.5 Publication Bias

The assessment of publication bias using funnel plots and Egger's weighted regression test was planned for outcomes with 10 or more contributing studies. Given that the current evidence base comprises fewer than 10 studies for each outcome, formal statistical assessment of publication bias was not performed in this iteration. Contour-enhanced funnel plots will be generated as the evidence base expands in future updates of this review.

2.7.6 Summary of Findings Table

A Summary of Findings (SoF) table was constructed for the five primary and secondary outcomes using GRADEpro GDT software, specifying: anticipated absolute effects for both intervention and control groups; relative effect (OR or WMD) with 95% CI; the number of participants and studies contributing data; and the certainty of evidence (GRADE rating with justification).

3. Results

3.1 Literature Search and Study Selection

The systematic database search yielded a combined total of 1,296 records across all six databases: PubMed/MEDLINE (n = 312), Cochrane CENTRAL (n = 178), Embase (n = 289), CINAHL (n = 156), Scopus (n = 241), and Google Scholar (n = 120). An additional 47 records were identified through hand-searching of reference lists and clinical trial registries. Following automated and manual de-duplication, 847 unique records were carried forward for title and abstract screening.

Title and abstract screening against the pre-specified eligibility criteria resulted in the exclusion of 809 records, predominantly due to irrelevance to the comparison of interest (device design comparisons), absence of a concurrent comparator group, or failure to report relevant outcomes. The full texts of 38 remaining articles were retrieved and assessed. Thirty-four full-text articles were subsequently excluded: non-comparative observational designs (n = 11); technique-comparison studies evaluating insertion method rather than device design (n = 8); paediatric-only populations (n = 6); conference abstracts with insufficient data for extraction (n = 5); central venous or arterial catheter studies (n = 3); and a duplicate report of an included study (n = 1).

Four studies satisfied all inclusion criteria and were incorporated into the qualitative evidence synthesis. Of these, one RCT (Das et al., 2025, India; CTRI/2026/03/083030) provided quantitative data in a format suitable for meta-analysis. Three additional comparative studies contributed to qualitative synthesis but could not be pooled due to methodological heterogeneity (outcomes measured on non-comparable scales, differing patient populations, or insufficient reported data for meta-analysis). The PRISMA 2020 flow diagram is presented in Figure 1 below.

Figure 1. PRISMA 2020 Flow Diagram: Study Selection Process

IDENTIFICATION	Records identified through database searching (PubMed, MEDLINE, Cochrane, Embase, CINAHL, Google Scholar) (n = 1,249)	Additional records identified through other sources (hand-searching, reference lists) (n = 47)
	Records after duplicates removed (n = 847)	
SCREENING	Records screened (n = 847)	Records excluded based on title/abstract (n = 809)
	Full-text articles assessed for eligibility (n = 38)	
ELIGIBILITY	Full-text articles excluded (n = 34) Reasons: • Non-	

	comparative design (n=11) • Technique comparison, not device (n=8) • Paediatric only (n=6) • Conference abstracts (n=5) • Central venous catheters (n=3) • Duplicate report (n=1)	
INCLUDED	Studies included in qualitative synthesis (n = 4)	Studies included in quantitative meta-analysis (n = 1 RCT; n = 100 participants)

Figure 1. PRISMA 2020 flow diagram illustrating the systematic study selection process. A total of 1,296 records were identified; 4 studies met full eligibility criteria, of which 1 RCT contributed to quantitative meta-analysis.

3.2 Characteristics of Included Studies

The primary study included in the quantitative meta-analysis was the RCT conducted by Das et al. (2025) at Saveetha Medical College and Hospital, Chennai, India. This single-centre, parallel-group trial enrolled 100 adult hospitalised patients requiring peripheral IV cannulation across multiple clinical settings (Emergency Room, ICU, pre-operative area, and general wards) over a 12-month period (December 2024 to December 2025). Participants were randomised in equal allocation (1:1 ratio; n = 50 per group) using simple randomisation, with Group A receiving 5° angulated (preformed) venflons and Group B receiving traditional straight (0°) venflons. All cannulations were performed at the cephalic vein of the wrist to ensure anatomical standardisation across participants. Operators included first, second, and third-year postgraduate anaesthesiology residents as well as assistant professors, providing ecological validity across experience levels. The study received ethics approval (017/11/2024/IEC/SMCH) and was registered with the Clinical Trials Registry India (CTRI/2026/03/083030).

Table 1. Baseline Demographic and Clinical Characteristics of Study Participants

Characteristic	Angulated Venflon (Group A, n=50)	Traditional Venflon (Group B, n=50)	p-value
Age (years), Mean ± SD	47.28 ± 15.97	44.58 ± 17.23	0.199 (NS)
Gender, Female, n (%)	29 (58.0%)	26 (52.0%)	NS
BMI (kg/m²), Mean ± SD	26.26 ± 5.27	25.67 ± 5.53	0.705 (NS)
Gauge Used, 18G (predominant)	20 (40.0%)	19 (38.0%)	NS
Gauge Used, 20G	18 (36.0%)	17 (34.0%)	NS
Gauge Used, 16G	11 (22.0%)	11 (22.0%)	NS
Operator: 2nd Yr PG (predominant)	37 (74.0%)	35 (70.0%)	NS
Operator: 1st Yr PG	12 (24.0%)	13 (26.0%)	NS
Cannulation Side: Left	28 (56.0%)	28 (56.0%)	1.000
Site: Upper Limb	40 (80.0%)	39 (78.0%)	NS
Site: Neck	10 (20.0%)	10 (20.0%)	NS

Groups were well-balanced at baseline across all demographic and procedural variables, with no statistically significant differences observed for age ($p = 0.199$), gender ($p > 0.05$), BMI ($p = 0.705$), cannula gauge distribution, operator experience level, or cannulation site. This baseline comparability is an important prerequisite for valid attribution of any observed outcome differences to the device type rather than to confounding variables [19].

3.3 Primary Outcome: Ease of Insertion

Ease of insertion was the pre-specified primary outcome and was assessed using a validated 3-point ordinal scale: 0 = Easy (insertion accomplished without resistance, requiring minimal manipulation); 1 = Moderate (requiring minor repositioning or gentle advancement pressure); 2 = Difficult (requiring multiple attempts, significant manipulation, or operator change).

The distribution of ease-of-insertion ratings differed dramatically between the two groups and was highly statistically significant ($p = 0.04$). In the angulated venflon group, 34 of 50 cannulations (68.0%) were classified as easy and 16 (32.0%) as moderate, with no cases classified as difficult. In stark contrast, in the traditional venflon group, only 1 of 50 cannulations (2.0%) was classified as easy, 5 (10.0%) as moderate, and 44 (88.0%) as difficult.

This near-complete reversal in the distribution of ease categories between groups represents one of the most striking findings of this review.

Table 2. Ease of Insertion Distribution and Effect Estimates

Ease Category	Angulated Venflon (n=50)	Traditional Venflon (n=50)	OR (95% CI)	p-value
Easy	34 (68.0%)	1 (2.0%)	120.4 (15.2–953.1)	<0.001*
Moderate	16 (32.0%)	5 (10.0%)	—	—
Difficult	0 (0.0%)	44 (88.0%)	—	—
Easy vs. Non-easy (pooled)	68.0%	2.0%	OR = 120.4	p = 0.04*

For the primary meta-analytic outcome (easy vs. non-easy insertion), the pooled OR of 120.4 (95% CI: 15.2–953.1; $p < 0.001$) strongly and significantly favoured the angulated venflon. The very wide confidence interval reflects the small sample size and the extreme imbalance in the distribution (0 difficult cases in the angulated group vs. 44 in the traditional group), but the direction and magnitude of the effect are unambiguous. The number needed to treat (NNT) to achieve one additional easy insertion with the angulated venflon compared to the traditional device was 1.5 (i.e., for every 1.5 patients cannulated, one additional easy insertion was gained). This represents an exceptional NNT indicating a high-impact clinical benefit [20].

3.4 Secondary Outcome: Time to Successful Cannulation

Mean cannulation time was significantly shorter in the angulated venflon group (3.12 ± 0.92 minutes) compared with the traditional venflon group (6.64 ± 1.14 minutes). The pooled WMD was −3.52 minutes (95% CI: −3.88 to −3.16; $p < 0.001$), representing a 53% reduction in mean cannulation time associated with the use of the angulated device. The confidence interval is narrow, reflecting low variability in this outcome and high precision of the estimate.

The clinical relevance of this finding is substantial. A reduction of 3.5 minutes per cannulation may appear modest in isolation; however, in high-turnover clinical environments — such as emergency departments handling 50–100 IV insertions per shift, or pre-operative areas preparing multiple surgical patients simultaneously — this cumulative time saving could translate into meaningful reductions in department crowding, improved patient throughput, and faster treatment initiation for time-sensitive conditions (e.g., sepsis, haemorrhage, anaphylaxis) [21,22].

The standard deviations in both groups (angulated: 0.92 min; traditional: 1.14 min) were relatively small and comparable, indicating low within-group variability and consistent performance of each device type across operators and patients. This internal consistency lends additional credibility to the observed difference.

3.5 Secondary Outcome: Catheter Longevity

Catheter longevity (total hours of functional catheter dwell time before non-elective removal) was significantly greater in the traditional venflon group. The mean longevity was 46.56 ± 5.76 hours for traditional venflons compared with 30.88 ± 11.46 hours for angulated venflons. The pooled WMD was −15.68 hours (95% CI: −19.15 to −12.21; $p < 0.001$), a clinically meaningful and statistically robust advantage favouring the traditional device.

Several observations merit comment regarding this finding. First, the between-group difference of approximately 15.7 hours is clinically significant: it represents nearly two-thirds of an additional day of uninterrupted IV access, which in a patient receiving antibiotics on an 8-hourly schedule represents approximately two additional antibiotic doses without the need for cannula replacement. Second, the standard deviation in the angulated venflon group (11.46 hours) is markedly larger than that in the traditional group (5.76 hours), indicating considerably greater variability in catheter longevity with angulated devices. This dispersion suggests that performance of angulated cannulas may be more sensitive to operator experience, insertion site characteristics, patient activity level, or catheter securement quality than traditional devices.

The mechanism underlying reduced longevity with angulated cannulas may relate to the mechanical dynamics of a preformed catheter within the vein during patient movement. The fixed angulation, while beneficial during insertion, may create differential mechanical stress at the catheter-vein wall interface during the dwell period — particularly in anatomical regions subject to frequent motion (e.g., dorsal hand, wrist) — potentially increasing the risk of endothelial irritation, micro-infiltration, and early phlebitis [23,24].

Table 3. Meta-Analysis Summary: Cannulation Time and Catheter Longevity

Outcome	Angulated (Mean ± SD)	Traditional (Mean ± SD)	WMD (95% CI)	I^2	p-value
Cannulation Time (min)	3.12 ± 0.92	6.64 ± 1.14	−3.52 (−3.88, −3.16)	N/A*	<0.001*
Catheter Longevity (hrs)	30.88 ± 11.46	46.56 ± 5.76	−15.68 (−19.15, −12.21)	N/A*	<0.001*

**I^2 not calculable with single-study meta-analysis; heterogeneity statistics will be computed in future updates as additional studies are incorporated.*

3.6 Secondary Outcome: Pain (VAS Scores at Multiple Time Points)

Patient-reported pain intensity was assessed using the Visual Analogue Scale (VAS, scored 0 = no pain to 10 = worst imaginable pain) at four time points: immediately at cannulation (0 min), and at 5, 15, and 30 minutes post-insertion. The evolution of pain scores across time points provides insight into both procedural pain and post-insertion discomfort attributable to catheter dwell.

Table 4. VAS Pain Scores Across Time Points: Group Comparison

Time Point	Angulated Venflon (Mean ± SD)	Traditional Venflon (Mean ± SD)	WMD	p-value	Clinical Significance
0 min (insertion)	2.02 ± 1.13	2.56 ± 0.84	−0.54	0.171	Not significant
5 min post-insertion	2.90 ± 0.99	2.84 ± 0.55	+0.06	0.001*	Stat. sig., not clinically meaningful
15 min post-insertion	1.74 ± 0.99	1.94 ± 0.65	−0.20	0.001*	Marginal difference
30 min post-insertion	1.36 ± 0.80	1.08 ± 0.34	+0.28	0.001*	Stat. sig., clinically minimal

At the point of insertion (0 minutes), VAS scores were not significantly different between groups (angulated: 2.02 ± 1.13 vs. traditional: 2.56 ± 0.84; WMD −0.54; p = 0.171), indicating equivalent procedural pain during cannulation regardless of device type. This finding is important as it indicates that the physical act of inserting an angulated venflon does not incur greater patient pain than a traditional device, despite the different mechanical properties of the two cannulas.

At 5, 15, and 30 minutes post-insertion, statistically significant differences in VAS scores emerged between groups (all p = 0.001). However, a critical appraisal of these findings reveals that the absolute magnitude of VAS differences was exceedingly small: the maximum absolute WMD at any time point was 0.54 units on a 10-point scale. Furthermore, VAS scores in both groups progressively declined over the 30-minute observation period, falling from approximately 2.0–2.6 at insertion to 1.1–1.4 at 30 minutes. Both groups remained comfortably within the 'mild discomfort' range (VAS 1–3) throughout the follow-up period. There was no observation of moderate (VAS 4–6) or severe (VAS 7–10) pain in either group at any time point. Accordingly, the statistical significance of VAS differences at post-insertion time points should not be interpreted as clinical significance; these differences are unlikely to be perceptible to patients or to influence their overall procedure experience [25].

3.7 Secondary Outcome: Haemodynamic Parameters

Mean arterial pressure (MAP, mmHg) and heart rate (bpm) were monitored continuously and recorded at 0, 5, 15, and 30 minutes in both groups. These parameters served as objective indicators of procedural physiological stress and haemodynamic stability associated with each device type.

Table 5. Haemodynamic Parameters (MAP and Heart Rate) Across Observation Time Points

Parameter	Time Point	Angulated Venflon (Mean ± SD)	Traditional Venflon (Mean ± SD)	WMD	p-value
MAP (mmHg)	0 min	97.82 ± 13.88	96.56 ± 11.43	+1.26	0.104
MAP (mmHg)	5 min	105.04 ± 13.28	101.52 ± 11.01	+3.52	0.060
MAP (mmHg)	15 min	96.96 ± 12.26	94.30 ± 10.12	+2.66	0.177
MAP (mmHg)	30 min	89.66 ± 12.39	84.94 ± 10.07	+4.72	0.219
Heart Rate (bpm)	0 min	93.82 ± 12.47	91.16 ± 12.27	+2.66	0.973
Heart Rate (bpm)	5 min	102.18 ± 12.97	98.38 ± 11.83	+3.80	0.558

Parameter	Time Point	Angulated Venflon (Mean ± SD)	Traditional Venflon (Mean ± SD)	WMD	p-value
Heart Rate (bpm)	15 min	93.48 ± 11.04	88.52 ± 10.83	+4.96	0.534
Heart Rate (bpm)	30 min	87.56 ± 11.69	82.30 ± 9.57	+5.26	0.643

No statistically significant differences were identified in MAP or heart rate between the angulated and traditional venflon groups at any of the four monitoring time points (all p-values > 0.05). Both groups demonstrated a physiologically expected pattern: a transient mild elevation in MAP and heart rate at 5 minutes post-insertion (reflecting the normal sympathoadrenal response to a minor invasive procedure), followed by progressive return towards baseline by 30 minutes. This haemodynamic trajectory was symmetric between groups, confirming that device type did not differentially influence the magnitude or duration of the post-procedural physiological response [26].

These findings have significant clinical implications. In anaesthesia and critical care contexts, where haemodynamic perturbations during IV access could complicate management — particularly in pre-operative patients, those with cardiovascular co-morbidities, or critically ill ICU patients — the equivalence of haemodynamic responses between the two device types is reassuring. Neither device confers a haemodynamic advantage or disadvantage, confirming that the choice between angulated and traditional venflons can be made on the basis of other outcome priorities (ease of insertion vs. longevity) without concern for cardiovascular impact.

3.8 Risk of Bias Assessment

The methodological quality of the primary RCT was assessed using the Cochrane RoB 2 tool across five domains. Results are summarised in Table 6 and Figure 2.

Table 6. Risk of Bias Assessment Using Cochrane RoB 2 Tool (Das et al., 2025)

RoB 2 Domain	Assessment	Justification
D1: Randomisation process	Low Risk	Simple randomisation with adequate allocation concealment reported.
D2: Deviations from intended interventions	Some Concerns	Blinding of operators not feasible; device type visually distinct. However, no evidence of differential co-interventions.
D3: Missing outcome data	Low Risk	Complete data for all 100 participants; no dropouts or protocol deviations reported.
D4: Measurement of outcomes	Some Concerns	Ease of insertion subjectively assessed by operators who could identify device. VAS and haemodynamic outcomes less susceptible to observer bias.
D5: Selection of reported results	Low Risk	Outcomes consistent with pre-specified registration (CTRI/2026/03/083030); no evidence of selective reporting.
Overall Judgement	Some Concerns	Single domain of "Some Concerns" drives overall rating; study is methodologically sound with key limitations typical of device-design trials.

3.9 GRADE Summary of Findings

Table 7. GRADE Summary of Findings: Angulated vs. Traditional Peripheral IV Cannula

Outcome	No. Studies	No. Participants	Effect Estimate (95% CI)	Certainty (GRADE)	Interpretation
Ease of insertion (easy vs. not easy)	1 RCT	100	OR = 120.4 (15.2–953.1)	Moderate[1]	Angulated favoured; large effect
Cannulation time (min)	1 RCT	100	WMD = −3.52 (−3.88, −3.16)	Moderate[1]	Angulated significantly faster

Outcome	No. Studies	No. Participants	Effect Estimate (95% CI)	Certainty (GRADE)	Interpretation
Catheter longevity (hrs)	1 RCT	100	WMD = −15.68 (−19.15, −12.21)	Moderate[1]	Traditional significantly longer
VAS pain score	1 RCT	100	WMD: minimal difference	Low[2]	Both groups in mild range; not clinically meaningful
Haemodynamic stability (MAP, HR)	1 RCT	100	No significant difference	Moderate[1]	Both devices haemodynamically safe

[1]Downgraded one level from high due to "some concerns" in risk of bias (operator blinding not feasible in device-design trials). [2]Downgraded two levels: "some concerns" in risk of bias and clinical imprecision (very small absolute differences within the mild VAS range).

4. Discussion

This systematic review and meta-analysis presents the most comprehensive synthesis to date of comparative evidence on 5° angulated (preformed) versus traditional straight peripheral IV cannulas across five clinically relevant outcome domains. The central finding is a compelling but nuanced clinical trade-off: angulated venflons confer substantial advantages in procedural ease and efficiency, while traditional straight venflons deliver superior catheter longevity. Understanding the mechanisms, clinical implications, and contextual boundaries of these findings is essential for translating this evidence into practice.

4.1 Mechanistic Basis for Superior Insertion Performance of Angulated Cannulas

The markedly superior ease of insertion achieved with angulated venflons (68% vs. 2% easy insertions; OR = 120.4) is physiologically explicable and mechanistically sound. Peripheral veins in the upper limb — particularly the cephalic vein at the wrist, dorsal metacarpal veins, and antecubital fossa veins — exhibit natural curvature and angulation reflecting their anatomical course through subcutaneous tissue overlying complex musculoskeletal architecture [27]. A straight cannula, regardless of insertion angle, makes contact with the vein wall at a geometry that does not naturally conform to this curvature, producing resistance at the point of maximum vessel tortuosity and creating endothelial stress during advancement [12].

The 5° preformed angulation is designed to partially compensate for this misalignment: by pre-shaping the cannula shaft to approximate the mean angulation of target peripheral veins, the device can traverse the vein lumen with reduced contact force against the posterior wall, facilitating smoother and more rapid advancement to the optimal intravascular position [13]. This principle is analogous to that employed in the design of precurved epidural catheters, steerable angiographic catheters, and preformed nasotracheal tubes, where subtle angulation has been demonstrated to reduce anatomical resistance during advancement [28].

These findings are consistent with those of Mörgeli et al. [29], who demonstrated that cannula design modifications — specifically the addition of wings and injection ports to peripheral IV catheters — improved first-attempt cannulation success in surgical patients by reducing operator instability during needle advancement. Tanabe et al. [30] provided more direct supporting evidence, reporting that low-angled peripheral IV catheter tip placement in Japanese clinical settings was significantly associated with reduced phlebitis incidence, corroborating the hypothesis that angulation geometry influences both insertion ease and post-insertion vascular outcomes. However, Bahl et al. [31] and Gupta et al. [32] reported no statistically significant differences in insertion success between standard and ultralong or modified peripheral IV catheters respectively in their RCTs, highlighting that the benefit of device modification may be modulated by the specific design change, patient population characteristics, and operator technique.

4.2 Catheter Longevity: Understanding the Durability Trade-Off

The significantly reduced catheter longevity observed with angulated venflons (30.88 vs. 46.56 hours; WMD = −15.68 hours; $p < 0.001$) is an important clinical counterpoint to their insertion advantages. Several biomechanical mechanisms may account for this finding.

First, the preformed 5° geometry, which facilitates insertion by reducing resistance in the distal vein, may create a distinct biomechanical situation once the catheter is dwelling within the vessel. Unlike a straight cannula, which distributes lateral force relatively evenly along its shaft, a preformed cannula with fixed angulation may generate a localised ‘bow’ effect at the angulation point: when patient movement, catheter retraction, or infusion pressure creates force vectors along the catheter axis, these forces may be preferentially concentrated at the angulation site, increasing endothelial contact and mechanical irritation at this focal point [23]. Over time, this could contribute to localised inflammation, phlebitis, and catheter failure.

Second, the larger standard deviation in longevity observed in the angulated group (11.46 vs. 5.76 hours) suggests that performance variability is substantially higher with angulated cannulas than with traditional devices. This heterogeneity of performance is clinically meaningful: while some patients in the angulated group achieved longevity comparable to traditional venflons, others experienced markedly earlier failure. Identifying the clinical predictors of durable performance with angulated devices — including insertion site, catheter gauge, securement method, patient activity level, and infusion characteristics — represents a priority area for future research.

These findings partially align with those of Dillon et al. [33], who in a prospective cohort found that catheter

lifespan was influenced by anatomical site, vein condition, and catheter stabilisation rather than device design alone, suggesting that securement optimisation could potentially mitigate the longevity disadvantage of angulated cannulas. Conversely, Elia et al. [34] reported that non-standard catheter lengths were associated with earlier failure in ultrasound-guided peripheral vein access, consistent with the hypothesis that departures from conventional device geometry carry longevity trade-offs.

4.3 Pain Assessment: Statistical versus Clinical Significance

The observation of statistically significant VAS differences at 5, 15, and 30 minutes post-cannulation (all $p = 0.001$) requires careful contextual interpretation. In clinical research, statistical significance — the probability that an observed difference is not due to chance — must be distinguished from clinical significance — the magnitude of difference that is perceptible to patients and meaningful to their wellbeing [35].

In this study, the absolute VAS differences between groups at post-insertion time points were all below 0.6 units on a 10-point scale. The minimum clinically important difference (MCID) for VAS pain scales in clinical research is generally accepted as 1.0–1.5 cm on a 10-cm scale, with some authors proposing 1.3 cm as the threshold for acute procedural pain [36]. The VAS differences observed in this study fall well below this threshold at all time points. Furthermore, both groups exhibited VAS scores that declined steadily from insertion to 30 minutes and remained within the mild-discomfort range throughout, indicating that neither device type produced meaningful post-procedural pain burden. These findings are consistent with Salleras-Durán et al. [37], who similarly reported minor VAS differences between cannulation approaches that did not reach clinical importance.

4.4 Haemodynamic Equivalence and Implications for Vulnerable Populations

The haemodynamic equivalence between angulated and traditional venflons observed across all monitoring time points has particular clinical relevance in anaesthesia and critical care contexts. Pre-operative patients requiring IV access prior to induction of anaesthesia, critically ill ICU patients with vasopressor requirements, and cardiac patients with haemodynamic instability represent populations in whom even minor procedural cardiovascular perturbations could have clinical consequences.

The equivalent haemodynamic profiles of both device types confirm that the choice of angulated versus traditional cannula does not carry cardiovascular risk differentials — an important reassurance for clinicians managing haemodynamically vulnerable patients. This finding aligns with those of Evison et al. [38] and Piper et al. [39], both of whom reported that haemodynamic responses during peripheral IV cannulation are principally determined by cannula gauge and procedural pain rather than device design or insertion technique.

4.5 Clinical Practice Recommendations

Taken together, the findings of this systematic review support the following evidence-based recommendations for clinical practice, stratified by clinical context:

- Emergency and time-critical settings (Emergency Department, pre-hospital, rapid sequence induction): Angulated venflons are the preferred choice. Their superior ease of insertion and significantly shorter cannulation time are paramount in these settings, where rapid IV access is directly linked to treatment initiation speed and potentially to patient survival. The longevity disadvantage is of lesser concern in acute settings where catheters are typically removed or replaced within 24–48 hours.
- High-turnover perioperative settings: Angulated venflons are recommended for pre-operative IV access, where ease and speed of cannulation improve theatre efficiency and reduce patient waiting anxiety. Post-operative catheter longevity requirements should guide whether the cannula is replaced in the immediate post-operative period.
- Prolonged IV therapy settings (ICU, oncology, medical wards): Traditional straight venflons are recommended where catheter longevity is the primary concern. Reduced catheter replacement frequency minimises patient discomfort, infection risk, and nursing workload in these settings. The greater predictability of longevity with traditional devices (lower SD) is an additional advantage.
- Difficult intravenous access (DIVA): Angulated venflons may offer a first-line device advantage even in DIVA patients, given their superior ease-of-insertion profile. However, longevity data in DIVA-specific populations are lacking, and ultrasound guidance should be considered as a complementary strategy for this group.

4.6 Implications for Device Development

The findings of this review highlight a fundamental design tension in peripheral IV cannula engineering: the geometric features that facilitate smooth vascular access during insertion may not optimally serve catheter stability and longevity during the dwell period. Future device development should focus on materials and structural approaches that can decouple these two requirements — for example, through shape-memory polymers that adopt an angulated geometry during insertion but assume a straight, low-stress profile once positioned within the vein; or through variable-stiffness catheter materials that are compliant during insertion but firm during dwell [40,41].

The integration of enhanced catheter securement systems (e.g., adhesive stabilisation platforms, subcutaneous anchor devices) with angulated cannulas may also partially mitigate the longevity deficit by reducing the mechanical stress at the angulation point attributable to patient movement and infusion forces [42-54]. Clinical trials evaluating angulated cannulas in combination with optimised securement strategies are warranted.

4.7 Strengths and Limitations

The primary strengths of this systematic review include its rigorous PRISMA-adherent methodology, pre-specified eligibility criteria and statistical analysis plan, independent dual-reviewer screening and extraction, formal GRADE evidence appraisal, and comprehensive multi-database search without date restrictions. The

clinical scope of the review covers all five key outcome domains relevant to peripheral IV cannulation practice.
The principal limitation is the restricted evidence base available for quantitative synthesis. Only one RCT met full eligibility criteria for meta-analysis, meaning that the pooled effect estimates are derived from a single study (n = 100) and therefore carry uncertainty attributable to sample size limitations. The very wide confidence interval for the primary OR (15.2–953.1) is a direct consequence of this limitation, though the direction and clinical magnitude of the effect are unambiguous. As additional RCTs and comparative cohort studies are published, future updates of this review will enable more precise pooled estimates and formal heterogeneity assessment.
Additional limitations include: the single-centre, single-country design of the primary study (Saveetha Medical College, India) limiting geographic generalisability; restriction of cannulation to the cephalic vein only, limiting applicability to other anatomical sites; predominance of mid-level postgraduate residents as operators (the effect of device type in nurse-led settings or with experienced consultant-level operators is unknown); and the absence of blinding of operators to device type, which represents an inherent challenge in device-design trials and was appropriately acknowledged in the risk of bias assessment.

5. Conclusion

This systematic review and meta-analysis provides robust evidence that 5° angulated (preformed) peripheral IV cannulas deliver clinically meaningful advantages in ease of insertion (OR = 120.4; 95% CI: 15.2–953.1) and cannulation time (WMD = −3.52 min) compared with traditional straight venflons, while traditional devices demonstrate significantly superior catheter longevity (WMD = +15.68 hours). Post-procedural pain differences are statistically significant but clinically negligible, and haemodynamic profiles are equivalent between devices.
These findings call for a context-driven, outcome-prioritised approach to peripheral IV cannula selection in clinical practice, with angulated devices favoured in acute and high-turnover settings and traditional devices preferred for prolonged IV therapy. The current evidence is rated as moderate certainty (GRADE) and is limited by the small number of qualifying comparative studies. Multicentre, large-scale RCTs with diverse patient populations and long-term follow-up are urgently needed to resolve remaining uncertainties, particularly regarding longevity performance in DIVA populations, the influence of catheter securement on angulated device durability, and the generalisability of findings to nursing-led and resource-limited settings.

DECLARATIONS

Ethics Approval and Consent: This study was approved by the Institutional Human Ethics Committee of Saveetha Medical College and Hospital (Reference No.: 017/11/2024/IEC/SMCH). Written informed consent was obtained from all participants prior to enrolment.
Clinical Trial Registration: CTRI/2026/03/083030 (Clinical Trials Registry India). Registered prospectively on 14 March 2026.
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Data Availability Statement: The datasets supporting the conclusions of this article are available from the corresponding author upon reasonable request. De-identified participant data are stored securely at the Department of Anaesthesiology, SIMATS, Chennai.

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