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SYSTEMATIC REVIEW

Point-of-Care Ultrasound for Pediatric Urethral Catheterization: A Systematic Review and Meta-Analysis of Randomized Controlled Trials

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ABSTRACT

Background: Urethral catheterization is the standard method for obtaining sterile urine in nontoilet-trained children, but the conventional blind technique frequently results in futile attempts ("dry taps") on empty bladders. Point-of-care ultrasound (POCUS) offers the clinical advantage of confirming adequate urine volume to prevent mucosal trauma and procedural distress. However, its routine implementation may be limited by operator training requirements and potential workflow delays while waiting for bladder filling. Therefore, this study aims to evaluate the efficacy of real-time POCUS-assisted versus standard blind urethral catheterization in pediatric patients.

Methods: We conducted a systematic review and meta-analysis of randomized controlled trials (RCTs) adhering to PRISMA guidelines (PROSPERO: CRD420251247483). We searched PubMed, Embase, and CENTRAL for trials comparing POCUS-guided versus standard catheterization in children aged ≤36 months. The primary outcome was the first-attempt success rate. The certainty of evidence was evaluated using the GRADE approach.

Results: Three trials comprising 337 participants were included. POCUS-assisted catheterization significantly increased first-attempt success compared to the conventional technique (89.7% vs. 72.5%; RR 1.25, 95% CI 1.08–1.45, $p = 0.0022$), yielding a Number Needed to Treat (NNT) of 6. Furthermore, ultrasound guidance significantly reduced the rate of "dry taps" (3.6% vs. 23.9%; RR 0.25, 95% CI 0.13–0.47, $p < 0.0001$), representing an NNT of 5 to prevent one futile attempt. The certainty of evidence for the primary outcome was rated as moderate. Secondary descriptive outcomes indicated higher caregiver satisfaction, lower perceived patient discomfort, and comparable overall workflow times despite required waiting periods for bladder filling.

Conclusions: Real-time POCUS significantly improves first-attempt catheterization success and drastically reduces futile attempts in young children. Furthermore, it enhances caregiver satisfaction and minimizes patient distress without intrinsically delaying emergency department workflow. These highly actionable findings support the integration of ultrasound guidance into routine pediatric emergency care.

1 | Introduction

Urethral catheterization remains the gold standard for obtaining sterile urine specimens in febrile infants and young children, a critical step in the diagnostic workup of fever without a source [1–3]. Given that Urinary Tract Infections (UTI) affect approximately 7% of this population and represent the most common serious bacterial infection in infants, accurate diagnosis is paramount [4, 5]. The clinical stakes are high: nonspecific symptomatology in this age group often makes the

diagnosis difficult, and delayed initiation of antibiotic therapy is strongly associated with the progression to acute pyelonephritis and permanent renal scarring [3, 5]. These structural sequelae are established precursors to long-term morbidity, including hypertension and chronic kidney disease [6]. While noninvasive collection methods such as urine bags exist, their high false-positive rates due to contamination render them sometimes unsuitable for definitive culture, compelling clinicians to rely on invasive instrumentation [1, 7]. Consequently, the American Academy of Pediatrics (AAP) and the National Institute for Health and Care Excellence (NICE) guidelines recommend catheterization or suprapubic aspiration for diagnostic confirmation [3, 8]. As suprapubic aspiration is consistently rated as more painful and technically complex than catheterization, the latter remains the preferred first-line method in most emergency settings [9, 10].

Despite its established role, urethral catheterization in infants is technically demanding. The standard technique is performed "blindly," guided solely by surface anatomical landmarks, without objective assessment of bladder volume [11]. This approach is particularly problematic in the emergency setting, where febrile infants are frequently dehydrated or may have voided unintentionally during triage [12]. Consequently, clinicians often attempt to catheterize an empty bladder—a phenomenon known as a "dry tap." These attempts are futile by definition and constitute the most common cause of procedural failure [12, 13]. Beyond clinical inefficiency, repeated instrumentations significantly escalate patient distress and caregiver anxiety [14]. Furthermore, multiple blind attempts directly increase the risk of iatrogenic complications, with studies reporting urethral trauma, gross hematuria, and significant pain in up to 21% of procedures [15].

To address these limitations, point-of-care ultrasound (POCUS) and portable bladder scanners have been proposed as noninvasive screening tools to estimate bladder volume prior to catheterization [12, 16]. The rationale is to confirm the presence of adequate urine volume, allowing clinicians to defer the procedure until the bladder is full, thereby increasing the likelihood of first-pass success. However, adoption has been inconsistent due to a fragmented evidence base. While recent systematic reviews have supported the use of ultrasound for suprapubic aspiration [17], evidence regarding urethral catheterization has historically relied on small trials conducted nearly two decades ago [11, 13]. The recent publication of larger, high-quality randomized controlled trials provides new data that necessitates an updated synthesis [18]. Therefore, this systematic review and meta-analysis aims to evaluate the efficacy and safety of ultrasound-assisted versus standard urethral catheterization in pediatric patients, specifically assessing first-attempt success rates, traumatic complications, and procedure-related pain.

2 | Methods

2.1 | Study Design and Protocol

This systematic review was conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA 2020) statement [19]. The study protocol was prospectively registered in the International Prospective Register of Systematic Reviews (PROSPERO) under the registration number CRD420251247483.

2.2 | Information Sources and Search Strategy

A systematic search was performed on December 8, 2025, in the PubMed/MEDLINE, Embase, and Cochrane Central Register of Controlled Trials (CENTRAL) databases. Additionally, a manual search of the reference lists of included studies and relevant reviews was conducted to identify potential additional studies. The complete search strategies are provided in the Supporting Information.

2.3 | Eligibility Criteria

We included randomized controlled trials (RCTs) evaluating the use of ultrasonography—including point-of-care ultrasound (POCUS)—for urinary catheterization in pediatric patients (neonates to adolescents). Studies reporting outcomes related to procedure performance, success rates, safety, or overall effectiveness were eligible. We excluded observational studies, case reports, case series, narrative reviews, editorials, animal studies, and trials involving adult populations.

2.4 | Study Selection

After removing duplicates using Rayyan software, two independent authors screened the records in two stages: title and abstract evaluation followed by a full-text assessment. Disagreements were resolved by consensus. The study selection process is detailed in the PRISMA flow diagram.

2.5 | Data Extraction

Two independent authors extracted data using a standardized form and subsequently cross-checked the information. Extracted data included study characteristics (author, year, country), population demographics (sample size, age, sex, eligibility criteria), and intervention details (ultrasound protocol [e.g., static vs. dynamic/real-time], transducer type, and operator qualification). The primary clinical outcome was the first-attempt success rate. Secondary outcomes included total procedure duration, drained urine volume, and adverse events (e.g., hematuria, pain).

2.6 | Risk of Bias Assessment

Two independent authors assessed the methodological quality of the included RCTs using the Cochrane Risk of Bias 2 (RoB 2) tool.

2.7 | Effect Measures and Statistical Analysis

Treatment effects for dichotomous outcomes were expressed as risk ratios (RRs) with 95% confidence intervals (CIs). A

random-effects model was applied due to anticipated methodological heterogeneity among the studies. Statistical heterogeneity was evaluated using the chi-square test and the I^2 statistic, with $I^2 > 30\%$ indicating moderate heterogeneity. Data synthesis and statistical analyses were performed using R software (version 4.3.1) with the "meta" package. Publication bias was not formally assessed via funnel plots due to the limited number of included studies ($n < 10$).

2.8 | Certainty of Evidence Assessment

The certainty of the evidence was assessed using the GRADE (Grading of Recommendations Assessment, Development and Evaluation) approach [20] via GRADEpro GDT software [21]. The assessment considered the domains of risk of bias, inconsistency, indirectness, imprecision, and publication bias. Additionally, a sensitivity analysis was performed for the primary outcome by excluding studies deemed at high risk of bias (e.g., quasi-randomized trial designs) to test the robustness of the pooled results. Details are available in the Supporting Information.

3 | Results

3.1 | Study Selection

The initial search identified 452 records. Following duplicate removal and title/abstract screening, four full-text reports were assessed and found eligible. However, these articles represent three independent studies [11, 13, 14, 18], as the publications by Baumann et al. [11, 14] regarding the technical success of catheterization and the satisfaction of caregivers and professionals derive from the same sample group. The selection process is detailed in the PRISMA flow diagram (Figure 1).

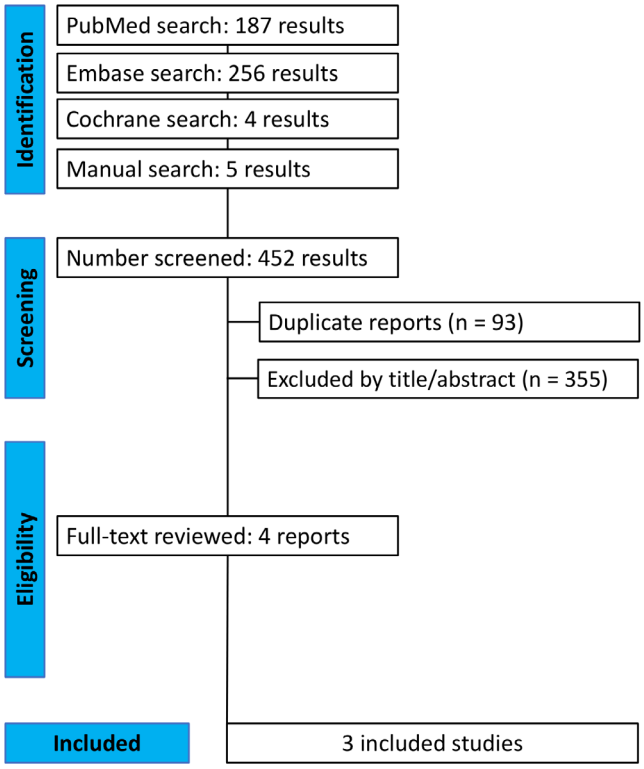

FIGURE 1 | PRISMA flow diagram detailing the study screening and selection process for the systematic review and meta-analysis. PRISMA, Preferred Reporting Items for Systematic Reviews and Meta-Analyses.

3.2 | Study Characteristics and Population

Three randomized controlled trials [11, 13, 18] comprised the sample for this meta-analysis, totaling 337 participants, specifically nontoilet-trained infants aged ≤ 36 months. The studies compared ultrasound-guided bladder catheterization using real-time point-of-care ultrasound (POCUS) performed in 166 patients versus the conventional blind technique in 171. Demographic characteristics of the included studies are compiled in Table 1.

Training for ultrasound execution varied in duration and modality (Table 2). In the studies by Baumann et al. [11, 14] and Ng et al. [18], the procedure was performed by trained nurses. In the former, training consisted of a 30-min theoretical lecture and five supervised examinations, while in the latter, an individualized in-person session of approximately 20 min was implemented. For Witt et al. [13], a one-hour practical instruction on estimating bladder volume using a real-time portable ultrasound device (referred to by the authors as VBUS) was described, although the operator's professional background was not reported. The ultrasound volume cutoff was unanimous across trials (≥ 2 cm), and the definitions of success were consistent (≥ 2.0–2.5 mL of urine obtained). Table 2 presents the analyzed data regarding the protocols.

3.3 | Primary Outcome: First-Attempt Success Rate

Ultrasound-assisted bladder catheterization significantly increased first-attempt success rates compared with the conventional technique (149/166 [89.7%] vs. 124/171 [72.5%]; RR 1.25, 95% CI 1.08–1.45, $p = 0.0022$). Statistical heterogeneity across the three trials was not significant ($I^2 = 37.5\%$, $p = 0.2020$) (Figure 2).

A sensitivity analysis excluding the quasi-randomized trial [18] confirmed the robustness of our findings. The significant improvement in first-attempt success associated with ultrasound guidance was maintained (RR 1.38, 95% CI 1.17–1.63, $p = 0.0002$; Supporting Information).

3.4 | Secondary Outcomes

3.4.1 | Rate of "Dry Tap" (Unsuccessful Catheterization)

POCUS-guided approach significantly outperformed the blind method in preventing "dry taps" during catheterization (6/166 [3.6%] vs. 41/171 [23.9%]; RR 0.25, 95% CI 0.13–0.47, $p < 0.0001$). There was no evidence of significant statistical heterogeneity

TABLE 1 | Baseline demographic and clinical characteristics of the included studies.

Author	Year	Study design	Randomization method	Analyzed *N*		Age (mo), mean		Sex (% male)	
				US	Conventional	US	Conventional	US	Conventional
Baumann et al. [11, 14]	2007|2008	RCT	Block randomization (sealed envelopes)	48	45	9.1 (95% CI 6.4–11.8)	10.2 (95% CI 7.7–12.6)	47	53
Ng et al. [18]	2025	RCT	Allocation by calendar date	85	95	6 (IQR 2,13)	6 (IQR 1,12)	51	37
Witt et al. [13]	2005	RCT	NR	33	31	7.7 (SD 5.5)	9.4 (SD 7.8)	39	39

Abbreviations: CI, confidence interval; IQR, interquartile range; mo, months; NR, not reported; RCT, Randomized Controlled Trial; SD, standard deviation.

to account for variability between the trials ($I^2 = 0\%$, $p = 0.91$) (Figure 3).

3.5 | Patient and Caregiver Experience

Caregiver satisfaction was reported using different scales across studies (4, 7, and 10-point Likert scales), precluding a meta-analysis. In the study by Baumann et al. [14], mean satisfaction was significantly higher with the imaging-guided technique (6.4, 95% CI 6.1–6.8) compared to the traditional approach (4.5, 95% CI 3.9–5.2; $p < 0.0001$). Similarly, Ng et al. [18] observed a higher frequency of "Very Satisfied" caregivers in the assisted arm across all survey categories, particularly regarding overall experience (62% vs. 45%; $p = 0.02$) and satisfaction with the time required (74% vs. 49%; $p = 0.005$). In contrast, Witt et al. [13] found no statistical difference for this outcome ($p > 0.15$). Concerning patient discomfort, Baumann et al. [14] reported that caregivers perceived significantly lower child discomfort in the ultrasonographic group (3.4, 95% CI 2.8–4.0 vs. 4.4, 95% CI 3.7–5.0; $p = 0.02$), which was assessed via a 7-point Likert scale rather than a standardized pain scale.

Regarding operational efficiency, Witt et al. [13] estimated the number of required catheterizations using an $n+1$ hypothesis for initial failures, reporting a significantly lower mean of attempts in the guided approach (1.06 vs. 1.39; $p = 0.009$). The clinical relevance of minimizing attempts is underscored by Baumann et al. [11], who noted that nearly all caregivers (except one) declined further catheterizations following an initial blind failure. On workflow, while no study measured the duration of the catheterization itself, pre-procedural times varied. Baumann et al. [11] found no significant differences in early ED intervals (triage to evaluation, evaluation to consent; both $p > 0.8$); however, the interval from consent to the first attempt was significantly longer in the assisted group (28 min vs. 12 min; $p < 0.001$), largely due to protocol-mandated 30-min delays for insufficiently filled bladders. Conversely, Ng et al. [18] found no median difference between the procedure order and the initial attempt (imaging: 34 min [IQR: 24–53] vs. standard care: 32 min [IQR: 19–47.5]; $p = 0.123$), suggesting that POCUS integration does not intrinsically delay care.

3.6 | Risk of Bias Assessment

The methodological quality of the included trials is summarized in Figure 4. Overall, one trial [18] was categorized at high risk of bias, while the remaining two [11, 13] were assessed as having some concerns.

Regarding the randomization process (Domain 1), Baumann et al. [11] utilized a robust block randomization approach with sequentially numbered, opaque, sealed envelopes to ensure allocation concealment. Witt et al. [13] described their trial as randomized but failed to report specific sequence generation or allocation concealment methods, leading to some concerns. Conversely, Ng et al. [18] employed a quasi-randomization strategy based on calendar dates (alternating even and odd days), which drove its high-risk classification.

TABLE 2 | Ultrasound devices, operator characteristics, and procedural protocols of the included trials.

Author	US device type	Operator	Training protocol	Volume cutoff (transverse diameter)	Definition of success (urine collection)
Baumann et al. [11, 14]	Real-time POCUS	Nurse	30 min lecture +5 supervised exams	≥ 2 cm (≥ 2.5 cm^3 bladder volume)	≥ 2.5 cm^3
Ng et al. [18]	Real-time POCUS	Nurse	20 min training session	≥ 2 cm	≥ 2 mL
Witt et al. [13]	Real-time POCUS	NR	1-h practical VBUS	≥ 2 cm	≥ 2 mL

Abbreviations: NR, not reported; POCUS, point-of-care ultrasound; US, ultrasound; VBUS, volumetric bladder ultrasound.

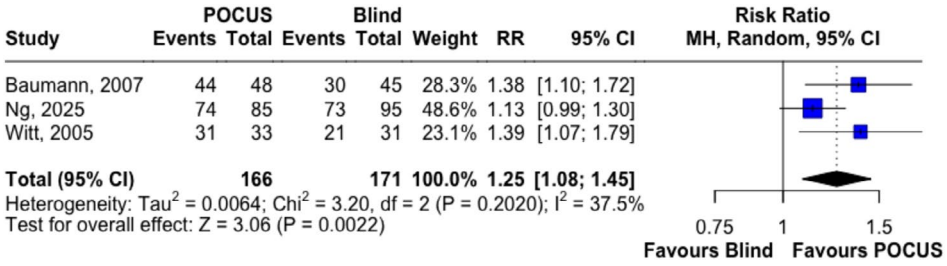

FIGURE 2 | Forest plot comparing the first-attempt success rate of ultrasound-assisted (POCUS) versus conventional (Blind) urethral catheterization. CI, confidence interval; POCUS, point-of-care ultrasound; RR, risk ratio.

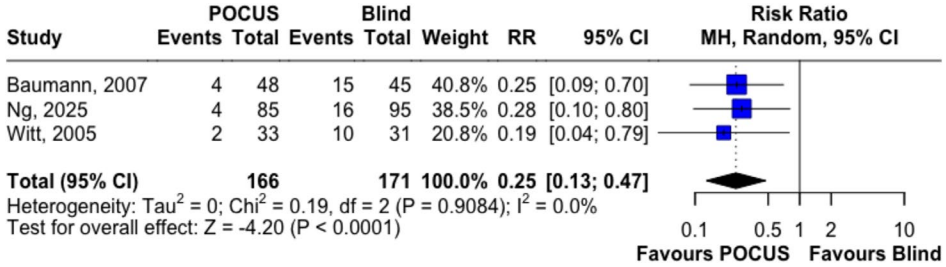

FIGURE 3 | Forest plot comparing the rate of "dry taps" (unsuccessful catheterization attempts due to insufficient urine volume) between the ultrasound-assisted (POCUS) and conventional (Blind) groups. CI, confidence interval; POCUS, point-of-care ultrasound; RR, risk ratio.

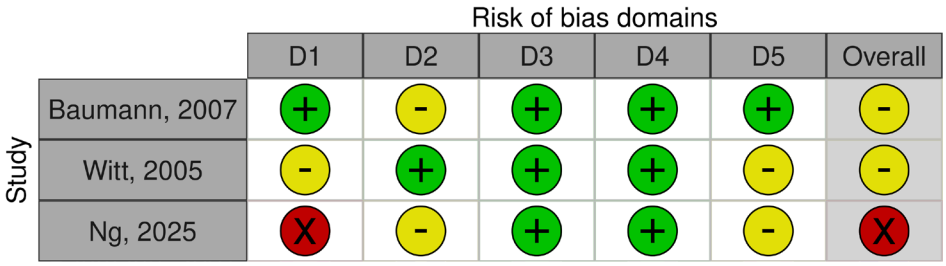

FIGURE 4 | Risk of bias assessment of the included randomized controlled trials using the Cochrane Risk of Bias 2 (RoB 2) tool. D1: Bias arising from the randomization process; D2: Bias due to deviations from intended interventions; D3: Bias due to missing outcome data; D4: Bias in measurement of the outcome; D5: Bias in selection of the reported result. Green circles (+) indicate low risk of bias; yellow circles (–) indicate some concerns; red circles (x) indicate high risk of bias.

Concerning deviations from intended interventions (Domain 2), the inherent impossibility of blinding operators to the ultrasound procedure was the central methodological challenge across all studies. While a lack of blinding intrinsically introduces the potential for performance bias, we classified the trial by Witt et al. [13] as having a low risk of bias in this domain. This methodological decision was justified by the study's strict adherence to the intention-to-treat (ITT) principle and the complete absence of protocol violators, which effectively preserved the effect of assignment despite the open-label design. In contrast, both Baumann et al. [11] and Ng et al. [18] were downgraded to "some concerns" because, alongside the lack of blinding, they

reported protocol violators and subsequent deviations from a strict ITT analysis.

Attrition bias (Domain 3) was considered low across all studies due to minimal missing outcome data. For the measurement of the outcome (Domain 4), the primary endpoint of successful urine collection was objective, and outcome assessors were successfully blinded in the Baumann et al. [11] and Ng et al. [18] trials.

Finally, regarding the selection of the reported result (Domain 5), none of the included trials had prospectively registered protocols available. While this absence is anticipated for the older trials [11, 13] conducted prior to widespread mandatory trial registration, the lack of a registered protocol or supplementary statistical analysis plan for the recent trial by Ng et al. [18] raises specific methodological concerns regarding potential reporting bias.

3.7 | GRADE Assessment

We assessed the certainty of evidence for the primary outcome using the GRADE (Grading of Recommendations Assessment, Development and Evaluation) approach and reported the ratings in the Supporting Information. Certainty of evidence for first-attempt success was rated as moderate. Although all included studies were randomized trials [11, 13, 18], we downgraded one level due to methodological limitations (one trial at high risk of bias and others with some concerns, including quasi-random allocation).

4 | Discussion

Our study showed that ultrasound-assisted bladder catheterization significantly improves first-attempt success in nontoilet-trained children over the conventional blind technique by nearly 17%. This finding is consistent with existing pediatric literature, which shows that utilizing POCUS to evaluate bladder volume prior to instrumentation elevates procedural success [11–14, 18]. A previous cohort study investigating ultrasound guidance for urethral catheterization has reported shifts in first-pass success, jumping from baseline rates of 78% up to 93% when guided by sonography [18]. These findings suggest that measured bladder volume—rather than subjective clinical judgment—helps avoid ineffective or unnecessary catheterization attempts, reinforcing the role of ultrasound as a promising adjunct to improve procedural precision.

Prior to this systematic review with meta-analysis, recommendations regarding ultrasound-guided urethral catheterization relied predominantly on trials conducted nearly two decades ago with limited sample sizes. By incorporating the recent, large-scale trial by Ng et al. [18]—which alone accounts for more than half of the total pooled participants in this analysis—our synthesis effectively doubles the weight of the available evidence. This not only validates historical findings but confirms that the clinical benefits of POCUS remain robust, reproducible, and highly applicable in contemporary pediatric emergency settings.

Beyond the primary outcome, the secondary findings—including caregiver satisfaction, procedural pain, number of attempts, dry tap rates, and procedure duration—further reinforce the clinical utility of ultrasound.

The trend toward higher caregiver satisfaction and reduced pediatric discomfort likely reflects improved first-attempt success, which minimizes repeated instrumentation and procedural distress. Although one study did not demonstrate statistical significance [13], the overall direction of effect favors visualization-assisted techniques. Importantly, the observed variability in workflow metrics indicates that efficiency is not inherently compromised but rather dependent on institutional familiarity and integration of imaging into routine practice. Thus, the benefit of imaging guidance appears to extend beyond technical success, influencing both experiential outcomes and procedural dynamics within pediatric care settings. It is important to highlight that all included trials utilized real-time 2D ultrasound devices rather than automated blind bladder scanners [11, 13, 18]. This methodological consistency is clinically relevant, as preprogrammed automated scanners have shown significant volume overestimation and inaccuracy in young children [22]. In contrast, real-time POCUS provides consistent and reliable visualization to safely estimate urine volume and guide catheterization.

Although heterogeneous reporting precluded the quantitative pooling of pain data, the descriptive improvements in patient comfort highlight how ultrasound guidance protects patients from the cumulative mucosal microtrauma [23, 24] caused by repetitive, futile instrumentation on an empty bladder. Driven by a relative reduction in mean attempts (e.g., from 1.39 to 1.06) [13] and consistently lower "dry tap" rates, ultrasound fundamentally shifts the procedure from a blind anatomical approach to a targeted, volume-guided one. From a clinical perspective, these absolute risk reductions are highly actionable. The implementation of POCUS yields a Number Needed to Treat (NNT) of approximately 6 to achieve one additional first-attempt success, and an NNT of 5 to prevent one futile "dry tap". In high-volume pediatric emergency departments, this translates to a substantial reduction in cumulative procedural trauma.

Finally, while the time from consent to the first catheterization attempt was prolonged in some ultrasound groups—allowing clinicians to wait for adequate diuresis rather than performing a futile procedure—overall throughput and total workflow times were comparable to standard care. This mirrors recent findings indicating that implementing nurse-performed POCUS reduces futile attempts without causing overarching departmental delays [18]. Furthermore, the clinical feasibility of this intervention is strongly supported by the brief training protocols reported across the included trials, which required merely 20–60 min of instruction for nursing staff [11, 13, 18]. Ultimately, this suggests that the initial time invested in operator training and waiting for adequate bladder filling is clinically justified, highly practical for emergency settings, and effectively offset by reductions in repeated attempts.

This systematic review and meta-analysis possesses some strengths. The methodology strictly adhered to the PRISMA 2020 guidelines [19] and the protocol was prospectively registered in

PROSPERO, ensuring high transparency and reproducibility. The analysis exclusively included randomized controlled trials, representing the highest level of primary evidence, and utilized the GRADE approach to rigorously evaluate the certainty of the pooled findings. The execution of a sensitivity analysis further reinforced the robustness of the primary outcome against potential methodological biases.

4.1 | Limitations

The most prominent constraint is the small number of eligible randomized controlled trials ($n = 3$) and the correspondingly limited total sample size of 337 participants, which restricts the broader generalizability of our findings and highlights the need for larger trials to confirm the robustness of the pooled estimate.

Furthermore, a substantial risk of bias exists across the literature. While the inherent impossibility of blinding operators is a common and unavoidable challenge in device-intervention trials, the presence of protocol violators and deviations from a strict intention-to-treat (ITT) analysis in two of the trials further compounded this risk [11, 18]. Moreover, the reliance on a quasi-randomized allocation method in the most recent trial [18], coupled with an overarching absence of prospectively registered protocols across all studies [11, 13, 18], introduces potential selection and reporting biases. However, our sensitivity analysis showed that excluding this specific study [18] does not alter the significance or direction of the primary outcome, reinforcing the robustness of the overall evidence despite this specific methodological limitation. Additionally, profound reporting heterogeneity—specifically the varying Likert scales used for satisfaction and the lack of standardized, synthesizable numerical data for procedural pain—prevented a comprehensive quantitative meta-analysis of these crucial secondary metrics [11, 13, 18].

Future studies could overcome these limitations by employing large, multicenter, cluster-randomized designs to mitigate individual operator bias. Furthermore, prospective trials should universally adopt standardized, validated pediatric pain scales, such as the Face, Legs, Activity, Cry, Consolability (FLACC) scale or the Neonatal Infant Pain Scale (NIPS), and strictly define time-to-completion metrics to allow for rigorous and uniform statistical pooling.

5 | Conclusion

In summary, ultrasound-assisted bladder catheterization increases first-attempt success in nontoilet-trained children when compared to standard urethral catheterization. These findings strongly support the use of POCUS as an adjunct in pediatric urinary sampling. Larger, high-quality multicenter studies are required before routine replacement of blind catheterization can be universally recommended. However, in emergency settings where equipment and trained personnel are available, ultrasound guidance is a highly practical and clinically justified strategy to maximize procedural success and protect pediatric patients from the distress of futile, repeated instrumentation.

Author Contributions

H.F.V.S.: study concept and design, analysis and interpretation of the data, drafting of the manuscript, critical revision of the manuscript for important intellectual content. E.T.W.: acquisition of the data, analysis and interpretation of the data, drafting of the manuscript. M.C.T.: acquisition of the data, drafting of the manuscript. A.C.R.B.: acquisition of the data, drafting of the manuscript. L.S.D.F.: acquisition of the data, drafting of the manuscript. A.C.S.S.: study concept and design, critical revision of the manuscript for important intellectual content.

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The authors have nothing to report.

Conflicts of Interest

The authors declare no conflicts of interest.

Data Availability Statement

All data generated or analyzed during this study are included in this published article and its Supporting Information files.

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Supporting Information

Additional supporting information can be found online in the Supporting Information section. **Figure S1:** Leave-one-out meta-analysis. **Figure S2:** Meta-analysis without Ng, 2025. **Figure S3:** Critical appraisal according to the ROB2 tool: traffic light plot. **Figure S4:** Critical appraisal according to the ROB2 tool: summary plot. **Table S1:** GRADE assessment.