

Tools, Clinical Prediction Rules, and Algorithms for the Insertion of Peripheral Intravenous Catheters in Adult Hospitalized Patients: A Systematic Scoping Review of Literature

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BACKGROUND: First-time peripheral intravenous catheter (PIVC) insertion success is dependent on patient, clinician, and product factors. Failed PIVC insertion are an under-recognized clinical phenomenon.

OBJECTIVE: To provide a scoping review of decision aids for PIVC insertion including tools, clinical prediction rules, and algorithms (TRAs) and their findings on factors associated with insertion success.

METHODS: In June 2016, a systematic literature search was performed using the medical subject heading of peripheral catheterization and tool* or rule* or algorithm*. Data extraction included clinician, patient, and/or product variables associated with PIVC insertion success. Information about TRA reliability, validity, responsiveness, and utility was also extracted.

RESULTS: We screened 36 studies, and included 13 for review. Seven papers reported insertion success ranging from

61%–90% (4030 insertion attempts), 6 on validity, and 5 on reliability, with none reporting on responsiveness and utility. Failed insertions were associated with obesity (odds ratio [OR], 0.71–1.7; 2 studies) and smaller gauge PIVCs (OR, 6.4; 95% Confidence Interval [CI], 3.4–11.9). Successful insertions were associated with visible veins (OR, 0.87–3.63; 3 studies) or palpable veins (OR, 0.79–5.05; 3 studies) and inserters with greater procedural volume (OR, 4.4; 95% CI, 1.6–12.1) or who predicted that insertion would be successful (OR, 1.06; 95% CI, 1.04–1.07). Definitions of insertion difficulty are heterogeneous such as time to insert to a number of failed attempts.

CONCLUSION: Few well-validated reliable TRAs exist for PIVC insertion. Patients would benefit from a validated, clinically pragmatic TRA that matches insertion difficulty with clinician competency. *Journal of Hospital Medicine* 2017;12:XXX-XXX. © 2017 Society of Hospital Medicine

Up to a billion peripheral intravenous catheters (PIVCs) are inserted annually; therefore, the importance of this invasive device in modern medicine cannot be argued.¹ The insertion of a PIVC is a clinical procedure undertaken by a range of clinical staff and in a variety of patient populations and settings. In many clinical environments (for example, the emergency department [ED]), PIVCs are the predominant first-choice vascular access device (VAD).^{2,3} Researchers in one study estimated over 25 million PIVCs are used in French EDs each year,³ and intravenous therapy is the leading ED treatment in the United States.⁴

First-time insertion success (FTIS) for PIVCs has been reported at 18% to 98% in adult populations.^{5,6} The variability of FTIS likely reflects not just a variety of clinician groups and patient populations but also the absence of uniform ap-

proaches to PIVC insertion. Terms frequently used to describe or formalize a pattern of care or a clinical procedure include the following: diagnostic and prognostic tools and/or plans, frameworks, predictive assessment tools, prediction models, rules, decision-making rules, scores, scales, risk factors, risk algorithms, and algorithms.^{7–12} In this paper, we use the terms tools, clinical prediction rules, and algorithms (TRAs) to review such frameworks that have been reported in the context of promoting FTIS for PIVCs.

The purpose of this systematic scoping review was to investigate what PIVC decision-making approaches exist to facilitate FTIS of PIVCs in adult hospitalized patients. Our intention was to systematically synthesize the research on TRAs, to review significant associations identified with these TRAs, and to critique TRA validity and reliability.

METHODS Scoping Review

We selected a scoping review method that, by definition, maps the evidence to identify gaps^{13,14}, set research agendas, and identify implications for decision-making. This allowed a targeted approach to answering our 3 research questions:

- What published clinical TRAs exist to facilitate PIVC insertion in adults?

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TABLE 1. Characteristics of Included Studies

Authors	Year	Country	Study Aim	Study Design and Setting	Study Population and Sample Size	Variables Identified	Analytics and Measurement Property Reported	FTIS	Category of TRA
Carr et al. ²³	2016	Australia	To identify factors affecting FTIS.	Prospective cohort (self-report) single center ED	Adult patients in ED (N = 460)	Visible and palpable veins; weight status, skin shade; number of sites; location; vein size; Clinician variables: Role; numerical experience; likelihood of success; PIVC gauge.	Face validity; multivariate logistic regression model; ROC curve	86%	Clinical prediction rule
de la Torea et al. ²⁶	2013	Spain	To develop a PIVC insertion scale that classifies easy to difficult PIVC insertion.	Prospective observational single center oncology	Initial sample to assess patient characteristics, (N = 16); Evaluation phase (N = 108) Oncology and non-oncologic background (as control).	Number of veins ACF--Hand; PIVC gauge; extravasation risk determined by the clinician.	Descriptive statistics; reliability	N/A	Scale
Fields et al. ²⁶	2014	USA	To identify risk factor for difficult venous access in the ED.	Prospective observational single center ED	Adult patients (N = 767)	Diabetes; intravenous drug abuse; sickle cell disease.	Multivariate logistic regression model	77%	Risk factors
Jacobson and Winslow ²⁵	2005	USA	To identify clinical variables associated with PIVC insertion difficulty and those associated with success and failure.	Descriptive study both in-patient and outpatient settings.	PIVC insertions (N = 339)	A combination of patient, clinician, and product variables.	Content validity described; Likert scale; descriptive statistics chi-square, t test, Pearson correlation	65%	Clinical prediction rule
Kelly and Eger-ton-Warburton ²⁹	2014	Australia	Define criteria for PIVC insertion.	Cross-sectional survey	Medical and nursing emergency clinicians	39 potential presenting complaints.	Modified Delphi technique	N/A	Score
Pagnutti et al. ¹⁹	2016	Italy	Development of a tool for measuring difficulty in patients receiving chemotherapy.	A pilot validated study; two phases: Phase 1: Expert opinion and literature review. Phase 2: Cohort study	Adult patients (N = 260)	A number of vein assessment criteria; chemotherapy treatment; duration and multiple venepuncture.	Validity; face and content and construct; Reliability; IRR Cohen's Kappa	N/A	Tool
Piredda et al. ²⁷	2017	Italy	To identify risk factors for difficult intravenous cannulation.	Prospective observational (self-report) single center radiology	Adult patients undergoing a radiologic scan (N = 763)	Vein characteristics (visibility; palpability; vein fragility; veins with many valves).	Univariate and multivariate logistic regression model	90%	Clinical prediction rule
Sebbane, et al. ³	2013	France	To investigate the relationship between BMI and PIVC insertion difficulty.	Prospective observational single center ED	Adult patients (N = 563)	Extremes of BMI vein assessment.	Reliability; interrater; multi-variable logistic regression model; ROC curve	79%	Clinical prediction rule
Ung et al. ²⁰	2002	Australia	Results from the use of a standardized assessment tool to investigate the impact nursing education and experience has on PIVC performance.	Correlational design oncology units and wards	Registered nurses (N = 38)	Patient education; PIVC gauge/ type; site selection; insertion technique.	Validity; face and content; 2 x 2 factorial analysis of variance; Hierarchical multiple regression analysis	N/A	Tool

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TABLE 1. Characteristics of Included Studies (continued)

Authors	Year	Country	Study Aim	Study Design and Setting	Study Population and Sample Size	Variables Identified	Analytics and Measurement Property Reported	FTIS	Category of TRA
van Loon et al. ²⁴	2016	Netherlands	To develop a predictive scale to identify adult patients with PIVC difficulty	Prospective observational cross-sectional cohort single center anesthesiology department	Adult patients (N = 1063)	Predominately patient assessment factors, such as vein diameter, visibility, and palpability; DIVA history; PIVC gauge.	Univariate and multivariate logistic regression model; ROC curve	83%	Clinical prediction rule
Webster, Morris, Robinson, Sanderson ²¹	2007	Australia	To assess the validity and reliability of a VAT.	Cohort survey medical imaging	10 nurses (5 oncology nurses and 8 medical imaging nurses); 2 radiographers) Adult patients (N = 10)	Vein visibility, vein size, vein palpation.	Reliability; interrater; ICC; validity; face	N/A	Tool
Wells ²²	2008	UK	To develop 2 tools: the validity of the VAT and the reliability of a tool to select a VAD.	Cohort survey	VAT study: patients (N = 14) and nurses (N = 8) Second study: patients (N = 30) and nurses (N = 2)	Vein assessment; patient vascular access history.	Reliability; interrater K stat; validity; face (expert opinion)	N/A	Tool
Witting ³⁰	2012	USA	To estimate the incidence of PIVC insertion difficulty and its impact on time.	Prospective cohort single center ED	Adult patients (N = 125)	Specific patient variables; patient self-report of insertion difficulty from none-severe.	Descriptive statistics; relative risk	61%	Incidence report

NOTE: Abbreviations: ACF, ; BMI, body mass index; DIVA, difficult intravenous access; ED, emergency department; FTIS, first-time insertion success; ICC, interclass correlation; IRR, ; N/A, not applicable; PIVC, peripheral intravenous catheter; ROC, receiver operating characteristic curve; TRA, tools, clinical prediction rules, and algorithms; VAD, vascular access device; VAT, vein assessment tool.

- What clinical, patient and/or product variables have been identified using TRAs as having significant associations with FTIS for PIVCs in adult patients?
- What is the reported reliability, validity, responsiveness, clinical feasibility, and utility of existing TRAs for PIVC insertion in adults?

Our aim was to identify the amount, variety and essential qualities of TRA literature rather than to critically appraise and evaluate the effectiveness of TRAs, a process reserved for systematic review and meta-analysis of interventional studies.^{13,14} We followed scoping review guidelines published by members and collaborators of the Joanna Briggs Institute, an internationally recognized leader in research synthesis, evidence use, and implementation. The guidance is based on 5 steps: (i) scoping review objective and question, (ii) background of the topic to support scoping review, (iii) study selection, (iv) charting the results, and (v) collating and summarizing results.¹⁵ Clinicometric assessment of a TRA or any clinical prediction rule requires 4 specific phases: (i) development (identification of predictors from data), (ii) validation (testing the rule in a separate population for reliability), (iii) impact analysis or responsiveness (How clinically useful is the rule in the clinical setting? Is it resource heavy or light? Is it cost effective?), and (iv) implementation and adoption (uptake into clinical practice).¹⁶

Search Strategy

We included studies that described the use or development of any TRA regarding PIVC insertion in the adult hospitalized population.

Inclusion Criteria. Studies were included if they were published in the English Language, included TRAs for PIVC insertion in adult hospital patients, and prospectively assessed a clinical category of patient for PIVC insertion using a traditional approach. We defined a traditional PIVC insertion approach as an assessment and/or insertion with touch and feel, therefore, without vessel-locating technology such as ultrasound and/or near infrared technology.

Exclusion Criteria. Exclusion criteria included pediatric studies, authors' personal (nonresearch) experience of tools, TRAs focused on postinsertion assessment of the cannula (such as phlebitis, infiltration, and/or dressing failure), and papers with a focus on VADs other than PIVCs. We excluded studies using PIVC ultrasound and/or near infrared technology because these are not standard in all insertions and greatly change the information available for pre-insertion assessment as well as the likelihood of insertion success.

In June 2016, a systematic search of the Cochrane library, Ovid Medline® In-process & Other Non-Indexed Citations and Ovid MEDLINE(R) <1946 to Present>, EBSCO CINAHL databases, and Google Scholar with specific keywords to identify publications that identified or defined

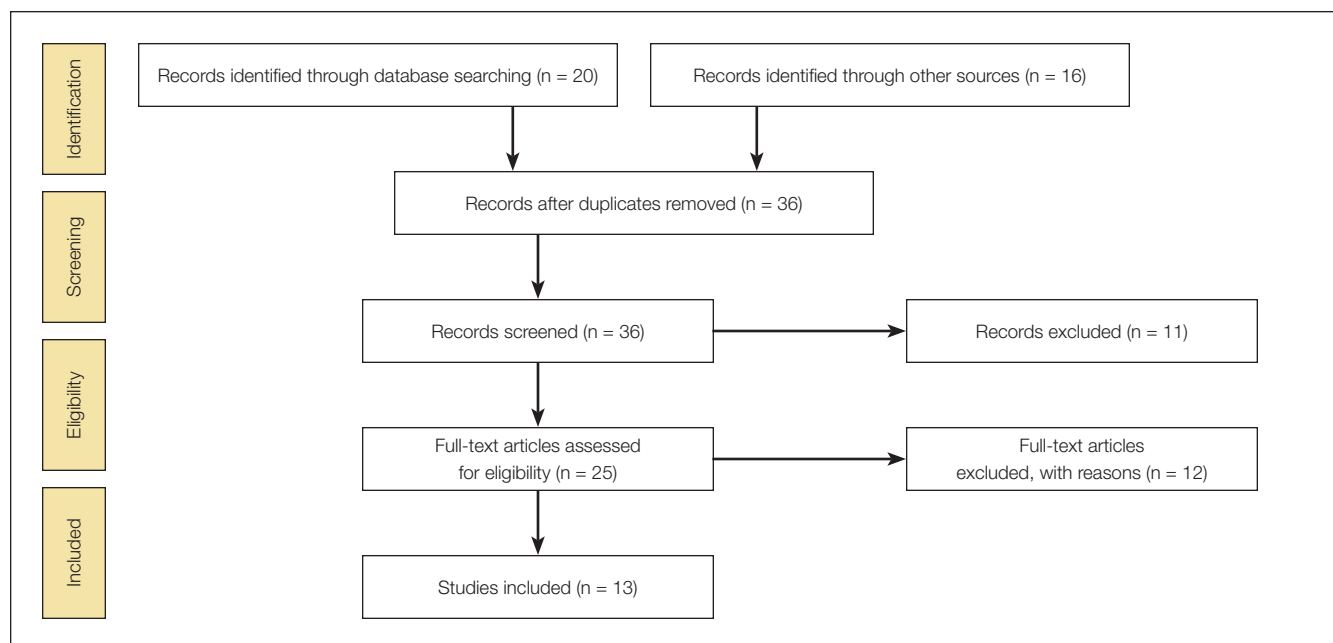


FIG. Prisma flowchart.

TRAs was undertaken. Medical subject headings were created with assistance from a research librarian using tailored functions within individual databases. With key search terms, we limited studies to those related to our inclusion criteria. See Appendix 1 for our search strategy for Medline and CINAHL.

We used Covidence, a web-based application specifically designed for systematic reviews to screen and evaluate eligible publications.¹⁷ Two authors (PJC and NSH) screened the initial retrieved searches based upon the predetermined inclusion and exclusion criteria.

Data Extraction

A paper template was developed and used by 2 reviewers (PJC and NSH). Data included the following: study sample, aim(s), design, setting and country in which the study took place, clinical and patient variables, and how the TRAs were developed and tested. Studies were categorized by TRA type. We also sought to identify if clinical trial registration (where appropriate) was evidenced, in addition to evidence of protocol publication and what standardized reporting guidelines were used (such as those outlined by the EQUATOR Network).¹⁸

Data Synthesis

Formal meta-analysis was beyond the scope and intention of this review. However, we provide the FTIS rate and the ranges of odds ratios (ORs) with 95% confidence intervals (CIs) for certain independent predictors.

RESULTS

Thirty-six references were imported for screening against title and abstract content, with 11 studies excluded and 25 studies

assessed for full-text eligibility (see Figure, PRISMA Flowchart). We then excluded a further 12 studies (6 did not meet inclusion criteria, 2 were focused on the prehospital setting, 2 were personal correspondence and focused on another type of VAD, 1 was a protocol to establish a TRA, and 1 was a framework for all device types), leaving 13 studies included in the final review (see Figure). These studies presented data on 4 tools,¹⁹⁻²² 4 predictive models^{3,23-25} (of which 3 present receiver operating characteristic/area under the curve scores),^{3,23,24} 2 framed as risk factor studies,^{26,27} and 1 of each of the following: a scale,²⁸ a score,²⁹ and an estimation of the incidence report rate (Table 1).³⁰ Seven studies had “difficult” or “difficulty” in their title as a term to use to describe insertion failure.^{3,19,24-27,30} One study was titled exclusively for the nursing profession,²⁰ 5 studies were reported in medical journals,^{3,24,26,29,30} and 6 were reported in nursing journals,^{19-22,25,27} with the remainder published in a vascular access journal.^{23,28}

General Characteristics of Included Studies

One TRA which was registered as a clinical trial²⁴ involved a standardized reporting tool as is recommended by the EQUATOR Network.¹⁸

Nine of the 13 papers reported that TRA components were chosen based on identified predictors of successful insertion from observational data^{3,19,23-28,30}, with 5 papers using multivariate logistic regression to identify independent predictors.^{3,23,24,26,2} At least 4330 insertion attempts on patients were reported. Seven papers reported FTIS, which ranged from 61%-90%.^{3,23-27,30}

Two clinical settings accounted for 10 of the 13 included studies. We identified 5 papers from the ED setting^{3,23,26,29,30} and 5 studies specific to cancer settings.^{19-22,28} Two ED papers identified clinical predictors of insertion difficulty, with 1

identifying an existing medical diagnosis (such as sickle cell disease, diabetes, or intravenous drug abuse) and the other reporting a pragmatic patient self-report of difficulty.^{26,30} Three studies focused on patient-exclusive variables (such as vein characteristics)^{19,21,28} and some with a combined clinician and patient focus.^{3,23-25,27,30}

Relatively few studies reported interobserver measurements to describe the reliability of clinical assessments made.^{3,19,21,28} Webster et al. in Australia assessed interrater reliability of a vein assessment tool (VAT) and found high agreement (kappa 0.83 for medical imaging nurses and 0.93 for oncology nurses).²¹ Wells compared reliability with Altman's K scores obtained from a different VAT when compared with the Deciding on Intravenous Access tool and found good agreement.²² Vein deterioration was proposed as a variable for inclusion when developing an assessment tool within an oncological context.³¹ In Spain, de la Torea and colleagues²⁸ demonstrated good interrater agreement (with kappa, 0.77) for the Venous International Assessment (VIA) tool. The VIA offers a grading system scale to predict the patient's declining vessel size while undergoing chemotherapy via peripheral veins with PIVCs. Grade I suggests little or no insertion failure, whereas a Grade V should predict insertion failure.

We could not find any reported evidence that the included studies we reviewed were clinically adopted and with what degree of success and impact. Therefore, it is unknown how clinically responsive or, indeed, what the clinical utility of these TRAs is. From the retrieved papers, a triad of variables influence PIVC insertion success and include patient characteristics, clinician characteristics, and product characteristics.

Patient Variables

Vein characteristics were significant independent factors associated with insertion success in a number of studies.^{3,19,23,24,27,28} These included the number of veins, descriptive quality (eg, small, medium, large), size, location, visible veins, and palpable veins. Other factors appear to be patient specific (such as chronic conditions), including diabetes (OR, 2.1 [adjusted to identify demographic risk factors]; 95% CI, 1.3-3.4), sickle cell disease (OR, 3.5; 95% CI, 1.4-4.8), and intravenous drug abuse (OR, 2.4; 95% CI, 1.1-5.3).²⁶ It is unclear if a consistent relationship between weight classification and insertion outcomes exists. Despite a finding that BMI was not independently associated with insertion difficulty,²⁶ one study reports that BMI was independently associated with insertion failure (BMI <18.5 [OR, 2.24; 95% CI, 1.07-4.67], BMI >30 [OR, 1.98; 95% CI, 1.9-3.60])³ and another reports emaciated patients were associated with greater failure when compared to normal weight patients (OR, 0.07; 95% CI, 0.02-0.34).²³ Consequently, extremes of BMI appear to be associated with insertion outcomes despite 1 study reporting no significant association with BMI as an independent factor of insertion failure.²⁶ A history of difficult intravenous access (DIVA) was reported in 1 study and independently associated with insertion failure (OR, 3.86;

95% CI, 2.39-6.25; see Table 2). DIVA appears to be the motivating factor in the title of 7 studies. When defined, the definitions of DIVA are heterogeneous and varied and include the following: >1 minute to insert a PIVC and requiring >1 attempt²⁷; 2 failed attempts³⁰; 3 or more PIVC attempts.²⁶ In the remaining 4 studies, variables associated with difficulty are identified and, therefore, TRAs to target those in future with predicted difficulty prior to any attempts are proposed.^{3,19,24,25}

Clinician Variables

Specialist nurse certification, years of experience, and self-report skill level ($P < 0.001$) appear to be significantly associated with successful insertions.²⁵ This is in part validated in another study reporting greater procedural inserting PIVCs as an independent predictor of success (OR, 4.404; 95% CI, 1.61-12.06; see Table 2).²³ Two studies involved simple pragmatic percentage cut offs for PIVCs: likelihood of use²⁹ and likelihood of insertion success.²³ One paper using a cross-sectional design that surveyed ED clinicians suggested if the clinician's predicted likelihood of the patient needing a PIVC was >80%, this was a reasonable trigger for PIVC insertion.²⁹ The other, in a self-report cohort study, reported that a clinician's likelihood estimation of PIVC FTIS prior to insertion is independently associated with FTIS (OR, 1.06; 95% CI, 1.04-1.07).²³

Product Variables

In this review, higher failure rates were identified in smaller sizes (22-24 g).²⁶ One study revealed gauge size was significantly associated with a failed first attempt in a univariate analysis (OR, 0.44; 95% CI, 0.34-0.58), but this was not retained in a multivariate model.²⁴ Matching the PIVC size with vein assessment is considered in the VIA tool.²⁸ It suggests a large PIVC (18 g) can be considered in patients with at least 6 vein options; smaller PIVCs of 22 to 24 g are recommended when 3 or fewer veins are found.²⁸ One paper describes a greater proportion of success between PIVC brands.²⁵

DISCUSSION

The published evidence for TRAs for PIVCs is limited, with few studies using 2 or more reliability, validity, responsiveness, clinical feasibility, or utility measurements in their development. There is a clear need to assess the clinical utility and clinical feasibility of these approaches so they can be externally validated prior to clinical adoption.¹⁶ For this reason, a validated TRA is likely required but must be appropriate for the capability of the healthcare services to use it. We suggest the consistent absence of all of these phases is owing to the variety of healthcare practitioners who are responsible for the insertion, the care and surveillance of peripheral cannulae, and the fragmentation of clinical approaches that exist.³²

Previously, a comprehensive systematic review on the subject of PIVCs found that the presence of a visible and/or palpable vein is usually associated with FTIS.³³ This current

TABLE 2. Patient, Clinician and Product Characteristics of PIVC Insertion Outcomes

Patient Predictor	Study	Total Cases	Standard error	Effect Size (OR)	95% CI	Comparison
Weight	Carr et al ²³	460		0.07	0.02-0.34	Emaciated (n=10) vs Normal (n=250)
				0.4	0.16-1.02	Underweight (n=73) vs Normal
				1.07	0.43-2.64	Overweight (n=91) vs Normal
				0.71	0.23-2.20	Obese n=(36) vs Normal
						Obese 36 v Nonobese= 424
	Piredda et al ²⁷	667		1.7	1.37-2.10	Obese n=94 (12.4%) vs Nonobese n=667 (87.6%)
Sebanne et al ³	563		2.24	1.07-4.67	Obese n=94 (12.4%) vs Nonobese n=667 (87.6%) Underweight (BMI <18.5) n= 45 (8%) 18 +/- 0.7 vs Normal (BMI 18.5-<25) n=266 (47%) 22 +/-1.8 Overweight (BMI 25-<30) n=138 (24%) 27 +/- 1.3 vs Normal Obese (BMI >30) n=114 (20%) 37 +/- 8.6 vs Normal Obese=114 vs Nonobese= 449	
Visible Vein	Carr et al ²³	460		2.7	.17-9.86	Visible Vein Yes 379 (82.39%) vs No 81(17.61%)
Visible Vein	Piredda et al ²⁷	763		0.87	0.83-0.91	Visible Vein Yes vs No
Visible Vein	van Loon et al ²⁴	1063	0.282	3.63	2.09-6.32	Visible Vein
Palpable Vein	Carr et al ²³	460		5.05	1.37-18.64	Palpable Vein Yes 445 (96.74%) vs No 15 (3.26%)
Palpable Vein	Piredda et al ²⁷	763		0.79	0.74-0.83	Palpable Vein Yes vs No
Palpable Vein	van Loon et al ²⁴	1063	0.28	4.94	2.85-8.56	Palpable Vein
Vein Diameter	van Loon et al ²⁴	1063		3.37	2.12-5.36	
H/O DIVA	van Loon et al ²⁴	1063		3.86	2.39-6.25	
Diabetes	Fields ²⁶	743		2.1	1.3-3.4	
IVD	Fields ²⁶	743		2.4	1.1-5.3	
Sickle Cell Disease	Fields ²⁶	743		3.5	1.4-4.8	
Clinician Predictor	Study			Effect Size	95% CI	
Likelihood of FTIS	Carr et al ²³	460		1.07	1.05-1.08	N/A
Procedural Volume >800	Carr et al ²³	460		4.404	1.61-12.06	N/A
Product and Technology Predictor	Study			Effect Size	95% CI	
Smaller Size PIVC assoc with DIVA	Fields et al ²⁶	743		6.4	3.4-11.9	N/A

*Results are exclusive and not grouped in the main abstract because of heterogeneity.

NOTE: Abbreviations: BMI, body mass index; DIVA, difficult intravenous access; FTIS, first-time insertion success; IVD, ; N/A, not applicable; PIVC, peripheral intravenous catheter.

review found evidence of simple scores or cutoff percentage estimates in 2 TRA reports to predict either appropriate PIVC insertion or FTIS.^{23,29} If such methods are supported by future experimental trials, then such simple approaches could initiate huge clinical return, particularly given that idle or unused PIVCs are of substantial clinical concern.³⁴⁻³⁶ PIVCs transcend a variety of clinical environments with excessive use identified in the ED, where it may be performed for blood sampling alone and, hence, are labeled as “just in case” PIVCs and contribute to the term “idle PIVC.”^{23,34} Therefore, a clinical indication to perform PIVC insertion in the first instance must be embedded into any TRA; for example, clinical deterioration is likely and the risks are

outweighed by benefit, intravenous fluids and/or medicines are required, and/or diagnostic or clinical procedures are requested (such as contrast scans or procedural sedation).

In the majority of papers reviewed, researchers described how to categorize patients into levels of anticipated and predicted difficulty, but none offered corresponding detailed recommendations for strategies to increase insertion success, such as insertion with ultrasound or vascular access expert. Hypothetically, adopting a TRA may assist with the early identification of difficult to cannulate patients who may require a more expert vascular access clinician. However, in this review, we identify that a uniform definition for DIVA is lacking. Both Webster et al.²¹ and Wells²² suggest that an

expert inserter is required if difficult access is identified by their tools, but there is no clear description of the qualities of an expert inserter in the literature.³⁷ Recently, consensus recommendations for the definition of vascular access specialist add to discussions about defining vascular access as an interdisciplinary specialist role.³⁸ This is supported by other publications that highlight the association between PIVC procedural experience and increased insertion success.^{6,23,39-41}

With regards to products, PIVC gauge size may or may not be significantly associated with insertion success. For identifying a relationship of PIVC gauge with vein quality, both the vein diameter and description will help with the clinical interpretation of results. For example, it may be the case that bigger veins are easier to insert a PIVC and, thus, larger PIVCs are inserted. The opposite can occur when the veins are small and poorly visualized; hence, one may select a small gauge catheter. This argument is supported by Prottegeier et al.⁴² in a prehospital study that excluded PIVC size in a multivariate analysis because of confounding. However, gauge size is very likely to influence postinsertion complications. Prospective studies are contradictory and suggest 16 to 18 g PIVCs are more likely to contribute to superficial thrombus,⁴³ phlebitis, and, thus, device failure, in contrast to others reporting more frequent dislodgement with smaller 22 g PIVCs.^{6,44}

Finally, the studies included did not assess survival times of the inserted PIVCs, given postinsertion failure in the hospitalized patient is prevalent⁴⁵ and, importantly, modifiable.⁴⁶ A TRA may yield initial insertion success, but if postinsertion the PIVC fails because of a modifiable reason that the TRA has not acknowledged, then it may be of negligible overall benefit. Therefore, TRAs for PIVC insertion need calibration, further development, and ongoing refinement

prior to external validation testing.²⁴ Future research should also examine the role of TRAs in settings where ultrasound or other insertion technology is routinely used.

CONCLUSION

This review identifies a clinically significant gap in vascular access science. The findings of this review support recent work on vessel health and preservation⁴⁷⁻⁴⁹ and appropriate device insertion.⁵⁰ It also points to the need for further research on the development and testing of an appropriate clinical TRA to improve vascular access outcomes in clinical practice.

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All authors have made substantial contributions with this review. Each author has contributed to drafting and editing the manuscript and approves the final version for publishing.

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