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Factors associated with peripheral intravenous cannulation first-time insertion success in the emergency department. A multicentre prospective cohort analysis of patient, clinician and product characteristics

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ABSTRACT

Objectives This study aimed to identify the incidence of and factors associated with peripheral intravenous catheter/cannula (PIVC) first time insertion success (FTIS) in the emergency department (ED).

Design Prospective cohort study.

Setting Two tertiary EDs in Western Australia.

Participants 879 ED patients.

Primary outcome To identify factors affecting FTIS using univariate and multivariate logistic regression modelling. We created four models: *patient factors only; clinician factors only; products and technology factors only and all factors model*. We assessed each model's performance using area under the receiver operating characteristic curve.

Results A total of 1201 PIVCs were inserted in 879 patients. The mean age was 60.3 (SD 22) years with slightly more females (52%). The FTIS rate was 73%, with 128 (15%) requiring a second attempt and 83 (9%) requiring three or more attempts. A small percentage (3%) had no recorded number of subsequent attempts. FTIS was related to the following patient factors: age (for a 1-year increase in age: OR 0.99, 95% CI 0.983 to 0.998; p=0.0097); and target vein palpability: (always palpable vs never palpable: OR 3.53 95% CI 1.64 to 7.60; only palpable with tourniquet vs never palpable: OR 2.20, 95% CI 1.06 to 4.57; p=0.0014). Clinician factors related to FTIS include: clinicians with greater confidence (p<0.0001) and insertion experience (301–1000 vs <301: OR 1.54, 95% CI 1.02 to 2.34; >1000 vs <301: OR 2.07, 95% CI 1.41 to 3.04; p=0.0011). The final *all factors model* combining patient factors; clinician factors and product and technology factors has greater discriminative ability than specific factors models. It has a sensitivity of 74.26%, specificity of 57.69%, positive predictive value of 82.87% and negative predictive value of 44.85%.

Conclusion A clinical decision, matching patients who have no palpable veins and are older, with clinicians with greater confidence and experience, will likely improve FTIS.

Strengths and limitations of this study

- The study used researcher observations rather than self-report.
- Validated data on patient, clinician, product and technology factors were obtained to assess any relationship with FTIS.
- We performed our analysis as per protocol.
- The degree of sampling bias is unknown given the use of a convenience sample.
- We did not cluster patients with specific operators.

Trialregistration number ANZCTRN12615000588594; Results.

INTRODUCTION

The peripheral intravenous catheter/cannula (PIVC) is the most pervasive vascular access device used in healthcare worldwide.[1] In the emergency department (ED), it facilitates access to the circulatory system for intravenous fluid and medicines, for diagnostic blood sampling and for use in diagnostic imaging.

A recent systematic scoping review on improving first-time insertion success (FTIS) decision approaches identified the lack of a robust clinical decision tool to guide clinicians inserting PIVCs in adults.[2] Despite the clinical utility and ubiquity of PIVC insertion in EDs, obtaining PIVC FTIS is a clinical problem which appears to be largely ignored. It is important to highlight that PIVC insertion failure has been described as painful,[3] with repeated punctures likely increasing the risk of infection,[4 5] all of which can negatively

impact on quality and safety of healthcare as well as the patient experience.

FTIS is influenced by patient and clinician factors. Patient characteristics reported in the literature which compromise FTIS include: few visible and or palpable veins; diabetes or cancer diagnoses and emaciated and obese weight.[2] Specific to the ED, Sebbane *et al* proposed extremes of body mass index (BMI) and absence of vein visibility and palpability to be independently associated with insertion difficulty.[6] In contrast, Fields *et al* reported medical conditions such as diabetes, intravenous drug abuse and sickle cell disease to be significantly associated with repeat attempts.[7] Clinician characteristics associated with FTIS include: greater years of experience; numerical quantity of PIVC insertions performed; professional roles such as specialist vascular access teams, specialist nurses or medical consultants.[8–10]

In the absence of a visible, palpable vein, the knowledge of landmark strategies becomes important. However, this may be unsafe given the normal variation in distribution of veins.[11] Reported ED FTIS rates using traditional attempts (ie, landmark/palpation guided insertion) range from 74% to 86%.[6 9 10] Failure to obtain FTIS may lead to cannulation of higher risk central, external jugular or lower limb veins, and ultrasound-guided peripheral intravenous catheter (USGPIVC) is a modality aimed to avoid this.[12] It is less than encouraging to know that FTIS rates of just 69% are obtained when USGPIVC methods are used in the ED.[12] This suggests that solving a problem with technology may not address the root cause of it.

Published vascular access frameworks are intended to assist with vascular access device selection[13 14] and the insertion process but lack decision-making rules specific to achieving FTIS. Very few clinical studies illustrate the efficacy of such decision rules.[2] One recent study by van Loon *et al* described an adult difficult intravenous access scale (A-DIVA).[15] Their work was based on risk factors for failed FTIS in patients presenting for surgery. A notable limitation of the A-DIVA is that all the modifiable factors associated with FTIS were patient related.[15] In the ED, repeated attempts contribute to inefficiency and impact on the clinician and the patient, and hinder patient flow through the department. Consequently, after two failed attempts, patients are referred to as difficult intravenous access (DIVA)[2] with some hospitals employing a dedicated team approach to manage this clinical problem.[16] Obtaining FTIS must be considered a clinical priority and we aimed to identify a broad range of clinical factors associated with FTIS rates in EDs (patient, clinician and product).

METHODS

We published the protocol and methods of how we intended to report risk factors for peripheral intravenous FTIS in the ED.[17] Our study is registered with the Australian and New Zealand Trials Registry (ANZCTRN12615000588594). We used the Strengthening the Reporting of Observational Studies in Epidemiology checklist to assist the reporting our results.[18]

Patient and public involvement

A local hospital working group had previously assessed our protocol and data collection tool for face validity prior to expert content validity testing. Included in this working group was a patient and public involvement (PPI) representative. Additionally, the data collection tool was sent to a PPI advocate specific to cancer care and familiar with this topic to review and provide feedback. Both PPI reviewers were satisfied with our approach.

Study design, setting and materials

We performed a registered prospective multicentre cohort study where data collectors directly observed the insertion of the PIVC. The study was performed in the EDs of Sir Charles Gairdner Hospital (SCGH) and Fiona Stanley Hospital (FSH)—two large academically affiliated institutions in Perth, Western Australia. SCGH is 650-bed hospital treating approximately 65 000 patients present annually in the ED. FSH is a 783-bed hospital with approximately 80 000 adult ED presentations.[17] PIVCs used in this study were made of polyurethane material and ranged in length from 25 to 48 mm and in gauge (g) from 14 to 24 g.

Primary outcome

Our primary outcome was FTIS. We defined FTIS per protocol as: after PIVC insertion there is the *visible presence of venous blood at the PIVC hub after the PIVC pierces through the skin into a vein, in addition to a small volume (up to 10 mL) of normal saline 0.9% connected to the PIVC being flushed into the vein without evidence of any complication such as infiltration.*[17]

Sampling and sample size

We used a convenience sampling method due to limited funding and included all patients who required the insertion of a PIVC on the day the researchers were present regardless of their Australasian Triage Scale (ATS) 1–5 assessment score. A target sample size of 1000 patients allowed for 10% attrition. Sample size estimate was intended to allow for clinically meaningful inferences.

Inclusion criteria

All patients who required a PIVC on the day the observers were present were eligible for inclusion in the study.

Exclusion criteria

Patients under the age of 18 and patients and/or clinicians who declined to be observed were excluded. We also excluded patients who were observed to have repeat presentations to the ED in the statistical analyses.

Data collection

We collected data from June 2015 to May 2016 using a case report form that we had developed prior to the main

study and which was assessed as having an item content validity index score of >0.78, suggesting good content validity.[19] Two research assistants and the lead author separately gathered data by direct observation of unique PIVC insertion attempts. This included patient, clinician and product factors. A sample of data from each was assessed initially and obtained high reliability scores. Kappa was above 0.90 suggesting a very high level of agreement.[20]

Statistical analysis and clinical prediction model

Summary statistics, including means and SD for continuous variables as well as counts and percentages for categorical variables are provided. Factors associated with FTIS were identified using univariate and multivariate logistic regression modelling (event='FTIS'). Models considered: patient only factors; clinician only factors; product and technology only factors and a combined model containing all factors subsequently described as the *all factors model*. Variables significant at the 5% level in the univariate models were retained for the multivariate models. Adjusted ORs, 95% CIs and p values are provided. Model performance was assessed using area under the receiver operating characteristic (ROC) curve and area under the curve (AUC). Model sensitivity, specificity, negative and positive predictive values were calculated at the optimal cut-off.[21] Data were analysed using the R environment for statistical computing.[22]

RESULTS

Overall summary

There were 997 episodes of planned PIVC treatment across the two EDs. Three patients were removed from analysis who declined PIVC insertion, and 27 patients who were repeat (on separate days) presentations. The first presentation per patient was used for ease of modelling. Of the remaining 967 patients included in the study, 879 had complete information recorded providing 1201 attempted insertions for analysis. The mean patient age was 60.3 (SD 22.1) years, 52% of which were female. The FTIS rate was 73%, with 142 (15%) patients receiving a successful PIVC insertion by the clinician on their second attempt, 51 (6%) on their third attempt, 19 (2%) on the clinician's fourth attempt and 13 (1%) patients were successfully cannulated after five and up to nine clinician attempts. There were a further 24 (3%) patients who did not have an accurate record of the number of attempts before successful PIVC insertion was achieved. Demographic patient and clinician characteristics are presented in table 1, both for the entire cohort as well as broken down by whether the clinician had FTIS. In terms of clinician experience, 7 (1%) clinicians had performed <10 PIVC insertions; 220 (25%) clinicians had inserted between 11 and 300 PIVCs; 102 (12%) clinicians had between 301 and 600 PIVCs insertions, while 62% had >601 PIVCs insertions. Resident medical officers (RMO) inserted the majority of PIVCs (n=359, 41%), followed by registrars (n=132; 15%); interns (n=91; 10%); registered

Table 1 Patient and clinician characteristics

	FTIS		Overall
	Yes (N=645)	No (N=234)	(N=879)
Patient gender			
Male	316 (74.5%)	108 (25.5%)	424 (48.2%)
Female	329 (72.3%)	126 (27.7%)	455 (51.8%)
Patient age			
Years (mean, SD)	59.2 (21.9)	63.4 (22.4)	60.3 (22.1)
BMI classification			
Emaciated	18 (58.1%)	13 (41.9%)	31 (3.5%)
Underweight	65 (67.7%)	31 (32.3%)	96 (10.9%)
Normal	317 (76.8%)	96 (23.2%)	413 (47%)
Overweight	154 (75.9%)	49 (24.1%)	203 (23.1%)
Obese	91 (66.9%)	45 (33.1%)	136 (15.5%)
Skin shade			
1 (lightest)	89 (67.4%)	43 (32.6%)	132 (15%)
2	328 (75.4%)	107 (24.6%)	435 (49.5%)
3	102 (65.8%)	53 (34.2%)	155 (17.6%)
4	78 (83%)	16 (17%)	94 (10.7%)
5	39 (75%)	13 (25%)	52 (5.9%)
6 (darkest)	9 (81.8%)	2 (18.2%)	11 (1.3%)
Skin temperature			
Cold	47 (59.5%)	32 (40.5%)	79 (9%)
Normal	464 (75%)	155 (25%)	619 (70.4%)
Warm	133 (74.3%)	46 (25.7%)	179 (20.4%)
Diaphoretic	1 (50%)	1 (50%)	2 (0.2%)
Skin condition			
Good	381 (78.7%)	103 (21.3%)	484 (55.1%)
Fair	154 (68.4%)	71 (31.6%)	225 (25.6%)
Poor	110 (64.7%)	60 (35.3%)	170 (19.3%)
Insertion site			
BOH	98 (76.0%)	31 (24.0%)	129 (14.7%)
Wrist	52 (78.8%)	14 (21.2%)	66 (7.5%)
Forearm	116 (69.5%)	51 (30.5%)	167 (19.0%)
ACF	365 (74.0%)	128 (26.0%)	493 (56.1%)
Upper arm	14 (58.3%)	10 (41.7%)	24 (2.7%)
VIA score			
I (6 VV)	214 (83.3%)	43 (16.7%)	257 (29.2%)
II (4 VV)	112 (75.2%)	37 (24.8%)	149 (17%)
III (3 VV)	147 (75%)	49 (25%)	196 (22.3%)
IV (1 VV)	98 (69%)	44 (31%)	142 (16.2%)
V (0 VV)	74 (54.8%)	61 (45.2%)	135 (15.4%)
	Yes (N=645)	No (N=234)	(N=879)
Target vein visibility			
Visible with and without tourniquet	317 (80.3%)	78 (19.8%)	395 (44.9%)
Only visible with tourniquet	150 (74.3%)	52 (25.7%)	202 (23%)
Never visible	178 (63.1%)	104 (36.9%)	282 (32.1%)

Continued

Table 1 Continued

	FTIS		Overall
	Yes (N=645)	No (N=234)	(N=879)
Target vein palpability			
Palpalpabilityand without tourniquet	305 (82%)	67 (18%)	372 (42.3%)
Only palpable with tourniquet	324 (69.8%)	140 (30.2%)	464 (52.8%)
Never palpable	16 (37.2%)	27 (62.8%)	43 (4.9%)
Triage category			
1—Immediately life-threatening	21 (77.8%)	6 (22.2%)	27 (3.1%)
2—Imminently life-threatening	206 (69.6%)	90 (30.4%)	296 (33.7%)
3—Potentially life-threatening	280 (75.3%)	92 (24.7%)	372 (42.3%)
4—Potentially life-serious	133 (75.1%)	44 (24.9%)	177 (20.1%)
5—Less urgent	5 (71.4%)	2 (28.6%)	7 (0.8%)
Role			
Nurse	63 (63.6%)	36 (36.4%)	99 (11.3%)
Med student	31 (68.9%)	14 (31.1%)	45Med.1%)
Intern	55 (60.4%)	36 (39.6%)	91 (10.4%)
RMO	274 (76.3%)	85 (23.7%)	359 (40.8%)
Registrar	101 (76.5%)	31 (23.5%)	132 (15%)
Consultant	45 (77.6%)	13 (22.4%)	58 (6.6%)
US consultant	11 (84.6%)	2 (15.4%)	13 (1.5%)
Phlebotomist	65 (79.3%)	17 (20.7%)	82 (9.3%)
Experience			
<10	5 (71.4%)	2 (28.6%)	7 (0.8%)
11-50	30 (58.8%)	21 (41.2%)	51 (5.8%)
51–100	38 (63.3%)	22 (36.7%)	60 (6.8%)
101–300	74 (67.9%)	35 (32.1%)	109 (12.4%)
301–600	72 (70.6%)	30 (29.4%)	102 (11.6%)
601–1000	107 (75.4%)	35 (24.7%)	142 (16.2%)
>1000	319 (78.2%)	89 (21.8%)	408 (46.4%)
Clinician confidence			
Percentage (mean, SD)	79.8 (17.8)	68.1 (21.9)	76.7 (19.6)
	Yes (N=645)	No (N=234)	(N=879)
Ultrasound			
Yes	4 (19.1%)	17 (81%)	21 (2.4%)
No	641 (74.7%)	217 (25.3%)	858 (97.6%)
Cannula size (g)			
14	1 (100%)	0 (0%)	1 (0.1%)
16	6 (75%)	2 (25%)	8 (0.9%)
18	191 (80.3%)	47 (19.8%)	238 (27.1%)
20	412 (72.2%)	159 (27.9%)	571 (65%)
22	34 (56.7%)	26 (43.3%)	60 (6.8%)
24	1 (100%)	0 (0%)	1 (0.1%)
Diabetes			
Yes	54 (62.1%)	33 (37.9%)	87 (9.9%)
No	591 (74.6%)	201 (25.4%)	792 (90.1%)
Sepsis			
Yes	26 (57.8%)	19 (42.2%)	45 (5.1%)
No	619 (74.2%)	215 (25.8%)	834 (94.9%)
Chemotherapy			
Yes	37 (77.1%)	11 (22.9%)	48 (5.5%)
No	608 (73.2%)	223 (26.8%)	831 (94.5%)
DIVA			
Yes	10 (66.7%)	5 (33.3%)	15 (1.7%)
No	635 (73.5%)	229 (26.5%)	864 (98.3%)
Hospital			
SCGH	349 (75.2%)	115 (24.8%)	464 (52.8%)
FSH	296 (71.3%)	119 (28.7%)	415 (47.2%)

ACF, ante cubital fossa; BMI, Body Mass Index; BOH, back of hand; DIVA, difficult intravenous access; FSH, Fiona Stanley Hospital; VIA, venous international score; VV, visible vein; SCGH, Sir Charles Gairdner Hospital.

nurses (n=99; 11%) and phlebotomists at FSH site only (n=82; 9%). Consultant emergency physicians inserted 71 (8%) of the PIVCs. The location of the first attempt insertions were back of the hand (n=129; 15%); wrist (n=66; 7%); forearm (n=167; 19%); antecubital fossa (n=493; 56%) and upper arm (n=24; 3%).

Analysis results

Table 2 displays the univariate and multivariate binary logistic regression results from modelling FTIS. Multivariate models were conducted for patient factors only, clinician factors only, product and technology factors only and all factors combined.

Patient FTIS factors

Following multivariate analysis of the patient factors only model, FTIS was found to be significantly related to the following patient factors: whether the patient had sepsis (p=0.0427), skin quality (p=0.0050), venous international assessment (VIA) score (p=0.0250) and target vein palpability (p=0.0004). Specifically, patients with sepsis were less likely to have FTIS (OR 0.51, 95% CI 0.26 to 0.98) and patients with good skin quality were more likely to have FTIS than those with poor skin quality (OR 1.78, 95% CI 1.12 to 2.67).

Patients with a VIA score of I (at least six visible veins), II (four visible veins), III (three visible veins), IV (one visible vein) were all significantly more likely to have a FTIS than patients with a VIA grade of V (0 visible veins; I vs V: OR 2.45, 95% CI 1.41 to 4.25); II vs V: OR 1.77,

Table 2 Univariate and multivariate modelling

	Univariate		Multivariate all factor model			Multivariate patient model			Multivariate clinician model			Multivariate product model		
Variables	**OR**	**95% CI**	**OR**	**95% CI**	**P Value**	**OR**	**95% CI**	**P Value**	**OR**	**95% CI**	**P Value**	**OR**	**95% CI**	**P Value**
Patient factors														
Patient gender														
Female vs male	0.89	0.66 to 1.20		Not significant			Not significant			Not included			Not included	
Patient age														
For a 1-year increase	0.99	0.984 to 0.998	0.99	0.983 to 0.998	0.0097		Not significant			Not included			Not included	
Triage category														
1 vs 5	1.40	0.22 to 9.12												
2 vs 5	0.92	0.17 to 4.81		Not significant			Not significant			Not included			Not included	
3 vs 5	1.22	0.23 to 6.38												
4 vs 5	1.21	0.23 to 6.45												
BMI classification														
Normal vs emaciated/ underweight	1.75	1.14 to 2.69												
Obese vs emaciated/ underweight	1.07	0.64 to 1.79		Not significant			Not significant			Not included			Not included	
Overweight vs emaciated/ underweight	1.67	1.02 to 2.71												
Sepsis														
Yes vs no	0.48	0.26 to 0.88		Not significant		0.51	0.26 to 0.98	0.0427		Not included			Not included	
Chemotherapy														
Yes vs no	1.23	0.62 to 2.46		Not significant			Not significant			Not included			Not included	
Diabetes														
Yes vs no	0.56	0.35 to 0.88		Not significant			Not significant			Not included			Not included	
Skin shade														
Dark (4/5/6)	1.59	1.04 to 2.43		Not significant			Not significant			Not included			Not included	
Light (1/2/3)														
Skin temperature														
Normal vs cold	2.04	1.26 to 3.31		Not significant			Not significant			Not included			Not included	
Warm/diaphoretic vs cold	1.94	1.11 to 3.39												
Skin condition														
Fair vs poor	1.18	0.78 to 1.80		Not significant		1.10	0.71 to 1.72	0.005		Not included			Not included	
Good vs poor	2.02	1.38 to 2.96				1.78	1.12 to 2.67							
Insertion site														
ACF vs forearm	1.25	0.85 to 1.84		Not significant			Not significant			Not included			Not included	
BOH vs forearm	1.39	0.83 to 2.34												
Upper arm vs forearm	0.62	0.26 to 1.48												

Continued

Table 2 Continued

	Univariate		Multivariate all factor model			Multivariate patient model			Multivariate clinician model			Multivariate product model		
Variables	**OR**	**95% CI**	**OR**	**95% CI**	**P Value**	**OR**	**95% CI**	**P Value**	**OR**	**95% CI**	**P Value**	**OR**	**95% CI**	**P Value**
Wrist vs orearm	1.63	0.83 to 3.21												
VIA score														
I (6 VV) vs V (0 VV)	4.10	2.56 to 6.57		Not significant		2.45	1.41 to 4.25			Not included			Not included	
II (4 VV) vs V (0 VV)	2.50	1.51 to 4.13				1.77	1.03 to 3.05							
III (3 VV) vs V (0 VV)	2.47	1.55 to 3.95				1.96	1.19 to 3.24	0.025						
IV (1 VV) vs V (0 VV)	1.84	1.12 to 3.00				1.69	1.01 to 2.84							
Target vein visibility														
Only visible with tourniquet vs never visible	1.69	1.13 to 2.51		Not significant			Not significant			Not included			Not included	
Always visible vs never visible	2.38	1.68 to 3.36												
Target vein palpability														
Only palpable with tourniquet vs never palpable	3.91	2.04 to 7.48	2.2	1.06 to 4.57	0.0014	2.85	1.44 to 5.63	0.0004		Not included			Not included	
Always palpable vs never palpable	7.68	3.92 to 15.05	3.53	1.64 to 7.60		4.38	2.08 to 9.25							
DIVA														
Yes vs no	0.72	0.24 to 2.13		Not significant			Not significant			Not included			Not included	
Clinician factors														
Hospital														
FSH vs SCGH	0.82	0.61 to 1.11												
Staff role														
Consultant* vs nurse	2.13	1.06 to 4.30		Not significant			Not included			Not Significant			Not included	
Intern vs nurse	0.87	0.49 to 1.57												
Med student vs nurse	1.27	0.60 to 2.69												
Phlebotomist vs nurse	2.19	1.12 to 4.28												
RMO vs nurse	1.84	1.14 to 2.97												
Registrar vs nurse	1.86	1.05 to 3.31												
Staff experience														
301–1000 vs <301	1.50	1.01 to 2.22	1.54	1.02 to 2.34	0.0011		Not included			0.98 to 2.20	0.0095		Not included	
>1000vs <301	1.95	1.36 to 2.80	2.07	1.41 to 3.04						1.23 to 2.58				
Clinician confidence														
For a 1% increase	1.03	1.02 to 1.04	1.02	1.01 to 1.03	<0.0001		Not included		1.03	1.02 to 1.04	<0.0001		Not included	
Technology and product factors														
Ultrasound														
Yes vs no	0.08	0.03 to 0.24	0.13	0.04 to 0.41	0.0006		Not significant			Not included		0.08	0.03 to 0.23	<0.0001

Continued

Table 2 Continued

Variables	Univariate		Multivariate all factor model			Multivariate patient model			Multivariate clinician model			Multivariate product model		
	OR	95% CI	OR	95% CI	P Value	OR	95% CI	P Value	OR	95% CI	P Value	OR	95% CI	P Value
Cannula size														
14–18 vs 20g	1.56	1.09 to 2.24					Not significant			Not included		2	1.10 to 2.31	0.0009
22–24 vs 20g	0.52	0.30 to 0.89										0.52	0.30 to 0.90	

*Consultants combines ultrasound and non-ultrasound
BMI, Body Mass Index; DIVA, difficult intravenous access; FSH, Fiona Stanley Hospital; SCGH, Sir Charles Gairdner Hospital; US, ultrasound; VIA, venous international assessment; VV, visible vein.

95% CI 1.03 to 3.05; III vs V: OR 1.96, 95% CI 1.19 to 3.24; IV vs V: OR 1.69, 95% CI 1.01 to 2.84).

Patients with a target vein that the clinician was able to palpate with the aid of a tourniquet (but not without) were significantly more likely to have FTIS than patients who did not have a palpable target vein (OR 2.85, 95% CI 1.44 to 5.63) and when the target vein was always palpable versus never palpable (OR 4.38, 95% CI 2.08 to 9.25). Patients with normal BMI and darker skin shades (Fitzpatrick score 4–6 (20)) had higher rates of FTIS than patients with non-normal BMI and lighter skin shades, respectively; however, these relationships did not reach significance.

Clinician FTIS factors

Factors significant in the final multivariate clinician factors model include: clinician confidence (p<0.0001) and clinician experience (p=0.0095). Specifically, clinicians with greater confidence were more likely to achieve FTIS than clinicians with lesser confidence (for a 1% increase in clinician confidence: OR 1.03, 95% CI 1.02 to 1.04), as were staff with more PIVC insertion experience (301–1000 vs <301: OR 1.47, 95% CI 0.98 to 2.20; >1000 vs <301: OR 1.78, 95% CI 1.23 to 2.58). The clinician roles which returned the best FTIS rates were: consultant emergency physicians who were ultrasound accredited (85%); phlebotomists (79%); consultants emergency physicians not ultrasound accredited (76%); registrars (77%); RMOs (76%); medical students (69%); nurses (64%) and interns (60%); however, this trend did not reach significance in the final multivariate clinician factors model.

Products and technology

Following multivariate analysis of the product only factors, FTIS was found to be associated with PIVC gauge size (p=0.0009) and if the patient had an ultrasound (p=0.0001). Specifically, PIVC gauge size was associated with greater success when a 14–18 g PIVC was used compared with 20 g (OR 2.00, 95% CI 1.10 to 2.31), but had less success when 22–24 g was compared with 20 g (OR 0.52, 95% CI 0.30 to 0.90). Those who had an ultrasound-guided access were less likely to experience FTIS (OR 0.08, 95% CI 0.03 to 0.23).

All factors model

Following multivariate analysis considering all factors, FTIS was found to be associated with patient age (p=0.0097), target vein palpability (p=0.0014), ultrasound use (p=0.0006), staff experience (p=0.0011) and clinician confidence (p<0.0001). Specifically, older patients were significantly less likely to have FTIS than younger patients (for a 1-year increase in age: OR 0.99, 95% CI 0.983 to 0.998). Clinicians that could palpate a patient's target vein with or without a tourniquet were significantly more likely to have FTIS than when attempting to cannulate patients who never had a palpable target vein (only visible with tourniquet vs never palpable: vs 2.20, 95% CI 1.06 to 4.57; always palpable vs never palpable: vs 3.53, 95% CI

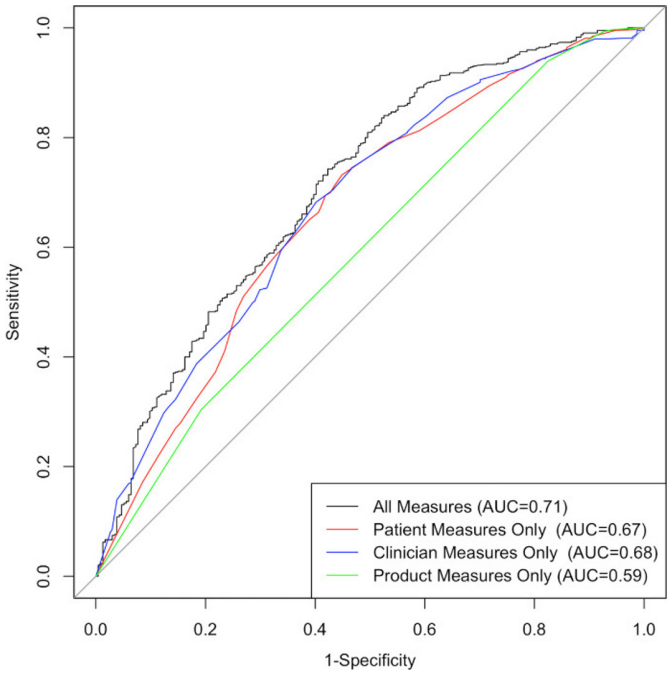

Figure 1 Receiver operating characteristic curves for each of the multivariate models. AUC, area under the curve.

1.64 to 7.60). Clinicians requiring the use of ultrasound were significantly less likely to have FTIS than those who did not require assistance with ultrasound technology (OR 0.13, 95% CI 0.04 to 0.41, p=0.0006). More experienced staff were more likely to have FTIS than less experienced staff (301–1000 vs <301: OR 1.54, 95% CI 1.02 to 2.34; >1000 vs <301: OR 2.07, 95% CI 1.41 to 3.04). Also, clinicians with greater confidence were more likely to have FTIS than clinicians with lesser confidence (for a 1% increase in confidence: OR 1.02, 95% CI 1.01 to 1.03).

Comparison of multivariate models

Figure 1 displays the ROC curves for each of the multivariate models, while table 3 contains the AUC for each of the multivariate models, as well as p values from the pairwise comparison of each model's AUC. The statistical model considering all factors (AUC=0.71) has significantly greater discriminative ability for identifying FTIS factors than each of the models that contain only patient factors (AUC=0.67, p=0.0178), clinician factors (AUC=0.68, p=0.0209) or product and technology factors (AUC=0.59, p<0.0001). The model considering all factors had a sensitivity of 74.26%, specificity of 57.69%, a positive predictive value of 82.87% and a negative predictive value of 44.85%.

Table 3 AUC for each of the different multivariate models, as well as p values from the pairwise comparison of each model's AUC

AUC	Patient 0.67	Clinician 0.68	Product 0.59
All 0.71	P=0.0178	P=0.0209	P≤0.0001
Patient 0.67		P=0.6372	P=0.0035
Clinician 0.68			P=0.0013
Product and technology 0.59			

DISCUSSION

The findings of this study demonstrate that FTIS is a clinically significant issue that needs improvement with 27% of patients requiring one or many subsequent attempts. We identified both patient factors (eg, non-palpable vein, being elderly) and clinician factors (eg, number of insertions and pre-insertion confidence) independently associated with reduced and increased odds of success, respectively. Ultrasound-guided insertions predicted a failure of FTIS; however, this is an expected finding as these devices were used by clinicians on patients as a last resort for locating a peripheral vein, or where the clinician had already failed with previous insertion attempts. Although other studies have suggested that extremes of BMI are independently associated with insertion failure,[6 9] our results do not support this viewpoint. Surprisingly, we found BMI to be non-significant in any multivariate analysis, which is in agreement with a previous study identifying that failure was not independently associated with BMI.[10]

Traditional palpation/landmark-based approaches using 32 mm length PIVC for insertion were favoured first by clinicians in both study sites. Furthermore, ultrasound-guided insertion using 48 mm length PIVCs were generally only considered when multiple failures had already occurred. That 27% of patients in our study were subjected to a repeat PIVC insertion is 13% more than our previous inserter-reported study in one of the same hospitals, indicating that our self-report method led to a large degree of under-reporting.[9] If we assume that DIVA patients are >2 failed attempts, then approximately 12% of the population recruited in our study could be categorised as such. Recently, van Loon *et al*[15] identified that patients with a history of first-time insertion failure had a fourfold increase of failure with future attempts. Accepting this, are we perhaps too lenient with current policy initiatives that require escalation after *two failed attempts* and perhaps healthcare organisations should advocate for decisions after one failed attempt to escalate to more advanced techniques? It is common that after >2 failed attempts ultrasound-guided insertion approach is used[12] and yet recent systematic reviews and meta-analyses on ultrasound and other vein-locating technologies do not overwhelmingly acknowledge their clinical advantage when compared with traditional techniques.[23 24] Conceivably, this is owing to an additional skill and expertise that needs to be well developed before optimum insertion success frequency is obtained.

As to what clinician role is paired with this clinical expertise is interesting given the variety of clinicians who perform PIVC insertion. Our descriptive results from one site showed that phlebotomists, performing PIVC procedures had similar success to ultrasound trained consultant

emergency physicians and better success than consultant emergency physicians without additional ultrasound training. Typically, consultants with additional ultrasound training will likely be called for DIVA cases, given their seniority and advanced skills with ultrasound techniques. The economic cost implications are clear as phlebotomists are paid less than nurses and doctors, yet have a better FTIS rate. One rationale is that the particular clinical procedure they provide is not affected by multiple competing clinical tasks; such as patient assessment and only includes venesection and PIVC insertion. Nurses performing this skill consistently has also been attributed to very high FTIS rates 98%–99%.[25 26] In our multivariate logistic regression, more experienced inserters had significantly better FTIS rates than less experienced staff. While some argue that all medical personnel should be skilled in PIVC insertion, a more nuanced approach based on skill and experience may be needed to improve outcomes. When clinicians are unable to visualise and palpate a visible vein for potential PIVC insertion this should prompt the assistance of a more skilled and proficient clinician. Additionally, the competent use of ultrasound by a skilled and proficient clinician would better inform an assessment that would lead to successful insertion.

Although these findings are preliminary, they provide evidence to assist with the derivation of a clinical prediction score, once validated on a separate population of patients and clinicians. This is particularly important as a limitation of the convenience sample used is the potential for selection bias related to clinicians observed and patients requiring a PIVC. While we used accepted statistical approaches, that is, calibration and internal validation, our AUC is fair and lower than we had hoped in terms of the patient and clinician models' discriminative ability to predict those who are likely to have a FTIS. No scoring tool or rule will be able to precisely predict every PIVC insertion success[15]; however, we did include the clinician variable in our modelling, as clinicians insert the PIVC into a vein which they independently select.

We acknowledge that we may have accounted for multiple PIVCs inserted by the same individual clinicians and that lack of variation could explain improved FTIS. Therefore, a limitation of this study is that a unique clinician identifier was not collected and so clustering of patients to specific clinicians could not be included in the modelling. However, clinician experience and role were included to adjust for differences between staff. In future research, individual clinician factors could include in-depth detail on the level and description of vascular access education, and account for non-independence of measures.

Additionally, our results are limited by an underrepresentation of dark-skinned patients and perhaps DIVA patients. The DIVA patient responses were low, as we could not ask all patients if they had a DIVA history. Additionally, it is likely other factors would confound this variable and perhaps better classifications are needed.[2] As a cohort study, we can report statistical associations between patient, clinician, products and technology factors with FTIS but cannot definitively conclude cause and effect relationships. Randomised studies will be needed to confirm if a clinical decision rule applying these results to guide insertions leads to improvements in FTIS. How the transfer of a skill to those less practiced or with less recent practice is a local matter for individual EDs and their clinical simulation centres. The skills and knowledge associated with PIVC insertion are not profession dependent and a team approach should be encouraged to the benefit of both patient and clinician, but would require changes to current workforce models and institutional workflows. The personal and financial cost of repeated insertions, and the impact on patients and clinicians should be a target for future quality improvements projects to address. In conclusion, a clinical decision rule that matches patients who have no palpable veins and are older, with clinicians who have greater confidence and experience will likely yield greater FTIS.

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