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| Keywords: | first time insertion success, peripheral intravenous catheters, emergency department, logistic regression, receiver-operator characteristic curve |
Risk factors associated with first-time insertion success for peripheral intravenous cannulation in the Emergency Department. A multi-centre analysis of patient, clinician, and product characteristics.

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Abstract

**Introduction:** The peripheral intravenous catheter/cannula (PIVC) is omnipresent in the Emergency Department (ED). This study aimed to identify the incidence of and risk factors for FTIS.

**Methods:** Observation of PIVC insertions in two EDs occurred using a validated tool regarding patient, clinician, and product variables. We identified predictors of FTIS using univariate and multivariate logistic regression modeling. We created 4 models: patient predictors only; clinician predictors only; products predictors only; and all variables model.

We assessed each model’s performance using area under the receiver-operator characteristic curve. Additionally, model sensitivity, specificity, negative and positive predictive values were calculated.

**Results:** A total of 1,201 PIVC insertions 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. The model considering all variables had greater discriminative ability than the others. FTIS was related to the following patient factors: age (for a one year increase in age: Odds Ratio [OR] 0.99, 95% confidence interval (CI) 0.983-0.998; p=0.0097); and target vein palpability: (always palpable vs. never palpable: OR 3.53 95% CI 1.64-7.60; only palpable with tourniquet vs. never palpable: OR 2.20, 1.06-4.57; p=0.0014). Clinician factors related to FTIS include: clinicians with greater confidence (p<0.0001) and insertion experience (301-1000 versus <301: OR 1.54 95% CI (1.02-2.34); >1000 vs. <301: OR 2.07 95% CI 1.41-3.04; p=0.0011). The final model has a sensitivity of 74.26%, specificity of 57.69%, positive predictive value of 82.87%, and negative predictive value of 44.85%.

**Conclusion:** FTIS can be improved. A clinical decision rule that matches patients, who have no palpable veins and are older, with clinicians with greater confidence and experience, will likely improve FTIS.

**Keywords:** first time insertion success; peripheral intravenous catheters; emergency department; logistic regression; receiver-operator characteristic curve.
Article Summary

Strength and limitations of this study

- By using obtaining data by researcher observations this study reports a first time PIVC insertion success rate of 73%, lower than a previous self report study.
- We identify a variety of clinical disciplines and levels performing PIVC insertion.
- We performed our analysis as per protocol.
- The use of a convenience sample is a limitation as it can result in selection bias as to who was observed.
- Some patient groups are under-represented.
Introduction

The peripheral intravenous catheter/cannula (PIVC) is the most common invasive vascular access device used in the Emergency Department (ED) as it facilitates access to the circulatory system for intravenous fluid and medicines, for diagnostic blood sampling, and for use in diagnostic imaging.

Despite the clinical utility and ubiquity of PIVC insertion in EDs, obtaining PIVC first-time insertion success (FTIS) is a clinical problem. When traditional attempts (i.e. landmark/palpation guided insertion) are employed in the ED, FTIS rates range from 74%-86% (1–3). Contrast this to FTIS rates of 69% when ultrasound-guided peripheral intravenous catheter (USGPIVC) methods are used in the ED (4). Additionally, a recent systematic scoping review on improving FTIS decision approaches identified the lack of a robust clinical decision tool to guide clinicians inserting PIVCs in adults (5).

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 diagnosis; and, emaciated and obese weight (5). Specific to the ED, Sebbane and colleagues proposed extremes of BMI, and absence of vein visibility and palpability to be independently associated with insertion difficulty (2). Clinician characteristics associated with better FTIS are reported to include: greater years of experience; numerical quantity of PIVC insertions performed; professional roles of specialist nurse or medical consultant (1,3,6).

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 (7). Failed FTIS may lead to cannulation of higher risk central, external jugular or lower limb veins, and USGPIVC is a new modality aimed to avoid this (4). PIVC insertion failure has been described as painful (8), with repeated punctures likely increasing the risk of infection (9,10), all which can negatively impact on the patient experience and safety in healthcare settings. In the ED, repeated attempts contribute to inefficiency and impact on the clinician and the patient, and retard patient flow through the department. Consequently, after two failed attempts, patients are referred to as difficult intravenous access (DIVA) (5).

Published vascular access frameworks are intended to assist with vascular access device
selection (11,12) and the insertion process but lack decision-making rules specific to achieving FTIS for PIVC, and very few clinical studies illustrate the efficacy of such interventions (5). One recent study by van Loon and colleagues described an adult difficult intravenous access scale (A-DIVA) (13). Their work was based on risk factors for failed FTIS in patients presenting for surgery. However, a notable limitation of the A-DIVA is that all the modifiable predictors of FTIS are patient related (13).

Obtaining FTIS must be considered a clinical priority and we aimed to identify the full range of clinical predictors of FTIS rates in ED (patient, clinician, product and technology).

Methods

We published the protocol and methods of how we intended to develop a clinical prediction model for FTIS in the ED in an openly accessible journal (14). Our study is registered with the Australian and New Zealand Trials Registry (ANZCTR12615000588594). We used the STROBE checklist to explain our model and validation (15).

Study Design, Setting and Participants

We performed a registered prospective multi-centre 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 academic 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 (14).

Primary outcome

Our primary outcome was FTIS. We defined FTIS as per protocol: 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 10ml) of normal saline 0.9% connected to the PIVC being flushed into the vein without evidence of any complication such as infiltration (14).

Sampling and Sample Size

We used a convenience sampling method due to limited funding and included all patients who were assessed by the Australasian Triage Score (ATS) 1-5, requiring the insertion of a
PIVC on the day the researchers were present. An attempt was made to gather a sample
size of 1,000 patients allowing for 10% attrition and was our per protocol sample size
estimate to allow clinically meaningful inferences.

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 was assessed as having an item content validity
index score of greater than 0.78, suggesting good content validity (16). Two research
assistants and the lead author separately gathered observation data of PIVC insertions. 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 (17).

Statistical Analysis and Clinical Prediction Model

Summary statistics, including means and standard deviations (SD) for continuous variables
as well as counts and percentages for categorical variables are provided. Predictors of FTIS
were identified using univariate and multivariate logistic regression modeling
(event="FTIS"). Models considered: patient only factors; clinician only factors; product only
factors; and then a combined model containing all factors which we called the all model.
Variables significant at the 5% level in the univariate models were retained for the
multivariate models. Adjusted odds ratios (OR), 95% confidence intervals (CI), and P-values
are provided. Model performance was assessed using area under the receiver-operator
characteristic (ROC) curve and area under the ROC curve (AUC). Model sensitivity,
specificity, negative and positive predictive values were calculated at the optimal cut-off
(18). Data were analysed using the R environment for statistical computing (19).

Ethical Approval

Full ethical approval for this study was obtained from The Sir Charles Gairdner Hospital
(SCGH) Human Research Ethics office ref: HR 2015-149 with reciprocated approval gained at
Fiona Stanley Hospital and Griffith University.

Results

Overall Summary
There were 997 episodes of planned PIVC treatment across the two EDs. Removing the three patients from analysis who declined PIVC insertion, and 27 patients who were repeat (on separate days) presentations, left 967 patients who were studied. Of these, 879 patients had complete information recorded. Only the first presentation per patient was used for ease of modeling. Of these 879 patients, there were 1,201 attempted insertions. The mean patient age was 60.3 (SD 22.1) years, and 52% were female. The FTIS rate was 73%, with 142 (15%) of patients gaining a successful PIVC insertion by the clinician on their second attempt, 51 (6%) on their third attempt, 19 (2%) of patients on the clinician's fourth attempt, 13 (1%) were successfully cannulated after five to nine clinician attempts. There were a further 24 (3%) patients who did not have FTIS, however, there was no accurate record by clinicians of the number of attempts they performed before achieving successful PIVC insertion. 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 PIVCs to date; 220 (25%) clinicians had inserted between 11-300 PIVCs; 102 (12%) clinicians had between 301-600 PIVCs insertions; while 62% had more than 601 PIVCs insertions to date. Resident medical officers (RMO) inserted the majority of PIVCs (n = 359, 41%), followed by registrars (n = 132; 15%); then interns (n = 91; 10%); followed by registered nurses (RN; n = 99; 11%) and phlebotomists (FSH site only) (n = 82; 9%). Consultants inserted 71 (8%) of the PIVCs. The location of the first attempt insertions were back of the hand (BOH; n = 129; 15%); wrist (n = 66; 7%); forearm (n = 167; 19%); antecubital Fossa (ACF; n = 493; 56%); and upper arm (n = 24; 3%).
Table 1. Patient and Clinician characteristics

| Characteristic         | Yes (N=645) | No (N=234) | Overall (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)     |
| **Size**               |             |            |                 |
| 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%)       |
| **VV grade**           |             |            |                 |
| 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%)     |
| FTIS                      | Yes (N=645) | No (N=234) | Overall (N=879) |
|--------------------------|-------------|------------|-----------------|
| Target Vein Visibility   |             |            |                 |
| Visible with and         | 317 (80.3%) | 78 (19.8%) | 395 (44.9%)     |
| without tourniquet       |             |            |                 |
| Only visible with        | 150 (74.3%) | 52 (25.7%) | 202 (23%)       |
| tourniquet               |             |            |                 |
| Never visible            | 178 (63.1%) | 104 (36.9%)| 282 (32.1%)     |
| Target Vein Palpability  |             |            |                 |
| Palpable with and        | 305 (82%)   | 67 (18%)   | 372 (42.3%)     |
| without tourniquet       |             |            |                 |
| Only palpable with       | 324 (69.8%) | 140 (30.2%)| 464 (52.8%)     |
| tourniquet               |             |            |                 |
| 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%) | 45 (5.1%)       |
| 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               | 79.8 (17.8) | 68.1 (21.9)| 76.7 (19.6)     |
| (Mean, SD)               |             |            |                 |
| Variable       | FTIS Yes (N=645) | FTIS No (N=234) | Overall (N=879) |
|----------------|------------------|------------------|-----------------|
| Ultrasound     |                  |                  |                 |
| Yes            | 4 (19.1%)        | 17 (81%)         | 21 (2.4%)       |
| No             | 641 (74.7%)      | 217 (25.3%)      | 858 (97.6%)     |
| Cannula Size   |                  |                  |                 |
| 14g            | 1 (100%)         | 0 (0%)           | 1 (0.1%)        |
| 16g            | 6 (75%)          | 2 (25%)          | 8 (0.9%)        |
| 18g            | 191 (80.3%)      | 47 (19.8%)       | 238 (27.1%)     |
| 20g            | 412 (72.2%)      | 159 (27.9%)      | 571 (65%)       |
| 22g            | 34 (56.7%)       | 26 (43.3%)       | 60 (6.8%)       |
| 24g            | 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%)     |

**Analysis Results**

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

**Patient FTIS factors**

Following multivariate analysis of the patient variables 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), VIA score (p=0.0250) and target vein palpability (p=0.0004). Specifically, patients with sepsis were less likely to have FTIS by the clinician (OR 0.51 95% CI 0.26-0.98) and patients with good skin quality were more likely to have FTIS than those with poor skin quality (OR 1.78, CI 95% 1.12-2.67). Patients with a VIA score of I (at least 6 visible veins), II (4 visible veins), III (3 visible veins), IV (1 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 1.41-4.25); II vs. V: OR 1.77 95% CI 1.03-3.05; III vs. V: OR 1.96 95% CI...
1.19-3.24; IV vs. V: OR 1.69 95% CI 1.01-2.84). Patients with a target vein that the clinician was able to palpate with a tourniquet (but not without) were significantly more likely to have FTIS than patients who never had a palpable target vein (OR 2.85, 95% CI 1.44-5.63) and when the target vein was always palpable versus never palpable (OR 4.38 95% CI 2.08-9.25). The highest incidence where clinicians obtained FTIS (n = 317; 77%) was in patients with normal BMI and Fitzpatrick skin shades 4-6 (20) with the latter being the darkest skin shade with more FTIS frequencies than lighter skin shades, however these relationships did not reach significance.
### Table 2. Univariate and Multivariate modeling

| Variables                  | UNIVARIATE | MULTIVARIATE | MULTIVARIATE | MULTIVARIATE | MULTIVARIATE | MULTIVARIATE |
|----------------------------|------------|--------------|--------------|--------------|--------------|--------------|
|                            | OR         | 95% CI       | OR           | 95% CI       | P-Value      | OR           | 95% CI       | P-Value      | OR           | 95% CI       | P-Value      | OR           | 95% CI       | P-Value      |
| **Patient Variables**      |            |              |              |              |              |              |              |              |              |              |              |              |              |              |
| **Patient Gender**         |            |              |              |              |              |              |              |              |              |              |              |              |              |              |
| Female v Male              | 0.89       | 0.66-1.20    |              |              |              |              |              |              |              |              |              |              |              |              |
| **Patient Age**            |            |              |              |              |              |              |              |              |              |              |              |              |              |              |
| For a one year increase    | 0.99       | 0.984-0.998  | 0.99         | 0.983-0.998  | 0.0097       |              |              |              |              |              |              |              |              |              |
| **Triage Category**        |            |              |              |              |              |              |              |              |              |              |              |              |              |              |
| 1 vs. 5                    | 1.40       | 0.22-9.12    |              |              |              |              |              |              |              |              |              |              |              |              |
| 2 vs. 5                    | 0.92       | 0.17-4.81    |              |              |              |              |              |              |              |              |              |              |              |              |
| 3 vs. 5                    | 1.22       | 0.23-6.38    |              |              |              |              |              |              |              |              |              |              |              |              |
| 4 vs. 5                    | 1.21       | 0.23-6.45    |              |              |              |              |              |              |              |              |              |              |              |              |
| **Weight BMI Class**       |            |              |              |              |              |              |              |              |              |              |              |              |              |              |
| Normal vs. Emaciated/Underweight | 1.75       | 1.14-2.69    |              |              |              |              |              |              |              |              |              |              |              |              |
| Obese vs. Emaciated/Underweight | 1.07       | 0.64-1.79    |              |              |              |              |              |              |              |              |              |              |              |              |
| Overweight vs. Emaciated/Underweight | 1.67       | 1.02-2.71    |              |              |              |              |              |              |              |              |              |              |              |              |
| Variables            | UNIVARIATE | MULTIVARIATE all Model | MULTIVARIATE Patient Model | MULTIVARIATE Clinician Model | MULTIVARIATE Product |
|----------------------|------------|------------------------|-----------------------------|-----------------------------|----------------------|
|                      | OR         | 95% CI                 | P-Value                     | OR                          | 95% CI               | P-Value             | OR | 95% CI | P-Value | OR | 95% CI | P-Value |
| **Patient Variables**|            |                        |                             |                             |                      |                     |    |        |         |    |        |         |
| Sepsis               |            |                        |                             |                             |                      |                     |    |        |         |    |        |         |
| Yes vs. No           | 0.48       | 0.26-0.88               | Not Significant             | 0.51                        | 0.26-0.98             | 0.0427              | Not Included       | Not Included |
| Chemotherapy         |            |                        |                             |                             |                      |                     |    |        |         |    |        |         |
| Yes vs. No           | 1.23       | 0.62-2.46               | Not Significant             |                             | Not Significant       | Not Included         | Not Included       | Not Included |
| Diabetes             |            |                        |                             |                             |                      |                     |    |        |         |    |        |         |
| Yes vs. No           | 0.56       | 0.35-0.88               | Not Significant             |                             | Not Significant       | Not Included         | Not Included       | Not Included |
| Skin Shade           |            |                        |                             |                             |                      |                     |    |        |         |    |        |         |
| Dark (4/5/6) vs. Light (1/2/3) | 1.59   | 1.04-2.43               | Not Significant             |                             | Not Significant       | Not Included         | Not Included       | Not Included |
| Skin Temperature     |            |                        |                             |                             |                      |                     |    |        |         |    |        |         |
| Normal vs. Cold      | 2.04       | 1.26-3.31               | Not Significant             |                             | Not Significant       | Not Included         | Not Included       | Not Included |
| Warm/Diaphoretic vs. Cold | 1.94 | 1.11-3.39               | Not Significant             |                             | Not Significant       | Not Included         | Not Included       | Not Included |
| Skin Condition       |            |                        |                             |                             |                      |                     |    |        |         |    |        |         |
| Fair vs. Poor        | 1.18       | 0.78-1.80               | Not Significant             | 1.10                        | 0.71-1.72             | 0.0050              | Not Included       | Not Included |
| Good vs. Poor        | 2.02       | 1.38-2.96               | Not Significant             | 1.78                        | 1.12-2.67             |                      |                     | Not Included |

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| Variables                          | UNIVARIATE | MULTIVARIATE all Model | MULTIVARIATE Patient Model | MULTIVARIATE Clinician Model | MULTIVARIATE Product |
|-----------------------------------|------------|------------------------|----------------------------|-----------------------------|----------------------|
|                                   | OR         | 95% CI                 | P-Value                    | OR                          | 95% CI               | P-Value             | OR            | 95% CI | P-Value |
| **Patient Variables**             |            |                        |                            |                             |                      |                     |               |        |         |
| Insertion Site                    |            |                        |                            |                             |                      |                     |               |        |         |
| ACF vs. Forearm                   | 1.25       | 0.85-1.84              |                            |                             |                      |                     |               |        |         |
| BOH vs. Forearm                   | 1.39       | 0.83-2.34              | Not Significant            |                             |                      |                     |               |        |         |
| Upper Arm vs. Forearm             | 0.62       | 0.26-1.48              | Not Significant            |                             |                      |                     |               |        |         |
| Wrist vs. Forearm                 | 1.63       | 0.83-3.21              |                            |                             |                      |                     |               |        |         |
| **VIA SCORE**                     |            |                        |                            |                             |                      |                     |               |        |         |
| I (6 VV) vs. V (0 VV)             | 4.10       | 2.56-6.57              | 2.45                       | 1.41-4.25                   |                      |                     |               |        |         |
| II (4 VV) vs. V (0 VV)            | 2.50       | 1.51-4.13              | Not Significant            |                             |                      |                     |               |        |         |
| III (3 VV) vs. V (0 VV)           | 2.47       | 1.55-3.95              | Not Significant            |                             |                      |                     |               |        |         |
| IV (1 VV) vs. V (0 VV)            | 1.84       | 1.12-3.00              | 1.69                       | 1.01-2.84                   |                      |                     |               |        |         |
| **Target Vein Visibility**        |            |                        |                            |                             |                      |                     |               |        |         |
| Only visible with tourniquet vs. Never visible | 1.69 | 1.13-2.51 | Not Significant | Not Significant | Not Included | Not Included |               |        |         |
| Always visible vs. Never visible  | 2.38       | 1.68-3.36              |                            |                             |                      |                     |               |        |         |
| **Target Vein Palpability**       |            |                        |                            |                             |                      |                     |               |        |         |
| Only palpable with tourniquet vs. Never palpable | 3.91 | 2.04-7.48 | 2.20 | 1.06-4.57 | 2.85 | 1.44-5.63 | 0.0014 | 0.0004 | Not Included | Not Included |
| Always palpable vs. Never palpable | 7.68 | 3.92-15.05 | 3.53 | 1.64-7.60 | 4.38 | 2.08-9.25 |                      |                     |               |         |
| **DIVA**                          |            |                        |                            |                             |                      |                     |               |        |         |
| Yes vs. No                         | 0.72       | 0.24-2.13              |                            |                             |                      |                     |               |        |         |
| Variables               | UNIVARIATE | MULTIVARIATE | MULTIVARIATE | MULTIVARIATE | MULTIVARIATE | MULTIVARIATE | MULTIVARIATE |
|-------------------------|------------|--------------|--------------|--------------|--------------|--------------|--------------|
|                         | OR 95% CI  | OR 95% CI    | P-Value      | OR 95% CI    | P-Value      | OR 95% CI    | P-Value      |
| Clinician factors       |            |              |              |              |              |              |              |
| Hospital                |            |              |              |              |              |              |              |
| FSH vs. SCGH            | 0.82       | 0.61-1.11    |              |              |              |              |              |
| Staff Role              |            |              |              |              |              |              |              |
| Consultant/US           |            |              |              |              |              |              |              |
| Consultant vs. Nurse    | 2.13       | 1.06-4.30    |              |              |              |              |              |
| Intern vs. Nurse        | 0.87       | 0.49-1.57    |              |              |              |              |              |
| Med Student vs. Nurse   | 1.27       | 0.60-2.69    | Not Significant | Not Included | Not Significant | Not Included | Not Included |
| Phlebotomist vs. Nurse  | 2.19       | 1.12-4.28    |              |              |              |              |              |
| RMO vs. Nurse           | 1.84       | 1.14-2.97    |              |              |              |              |              |
| Registrar vs. Nurse     | 1.86       | 1.05-3.31    |              |              |              |              |              |
| Staff Experience        |            |              |              |              |              |              |              |
| 301-1000 vs. <301       | 1.50       | 1.01-2.22    | 1.54         | 1.02-2.34    | 0.0011       | 1.47         | 0.98-2.20    | 0.0095       | Not Included |
| >1000 vs. <301          | 1.95       | 1.36-2.80    | 2.07         | 1.41-3.04    |              | 1.78         | 1.23-2.58    |              |              |
| Clinician Confidence    |            |              |              |              |              |              |              |
| For a 1% Increase       | 1.03       | 1.02-1.04    | 1.02         | 1.01-1.03    | <0.0001      | 1.03         | 1.02-1.04    | <0.0001      | Not Included |

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| Technology and Product factors | UNIVARIATE | MULTIVARIATE all Model | MULTIVARIATE Patient Model | MULTIVARIATE Clinician Model | MULTIVARIATE Product |
|-------------------------------|------------|------------------------|---------------------------|---------------------------|---------------------|
|                               | OR 95% CI  | OR 95% CI P-Value      | OR 95% CI P-Value         | OR 95% CI P-Value        | OR 95% CI P-Value   |
| Ultrasound                    |            |                        |                           |                          |                     |
| Yes vs. No                    | 0.08       | 0.03-0.24              | 0.13 0.04-0.41 0.0006    | Not Significant          | Not Included        |
| Cannula Size                  |            |                        |                           |                          |                     |
| 14-18g vs. 20g                | 1.56       | 1.09-2.24              | Not Significant           | Not Included             | 2.00 1.10-2.31 0.0009 |
| 22g-24g vs. 20g               | 0.52       | 0.30-0.89              |                            |                          | 0.52 0.30-0.90      |
**Clinician FTIS factors**

Factors significant in the final multivariate clinician variables 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: \(\text{OR} \ 1.03, \ 95\% \ CI \ 1.02-1.04\)), as were staff with more PIVC insertion experience (\(301-1000 \text{ versus} <301: \ 1.47 \ 95\% \ CI \ 0.98-2.20; >1000 \text{ vs.} <301: \ 1.78 \ 95\% \ CI \ 1.23-2.58\)). The clinician roles which returned the best FTIS rates were: Ultrasound Consultants (85%); Phlebotomists (79%); Consultants (76%); Registrars (77%); RMO (76%); Medical Student (69%); Nurses (64%), and Interns (60%), however, this trend did not reach significance in the final multivariate clinician variables model.

**Products and Technology**

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

**All variables model**

Following multivariate analysis considering all variables, FTIS was found to be associated with patient age \((p=0.0097)\), target vein palpability \((p=0.0014)\), ultrasound \((p=0.0006)\), staff experience \((p=0.0011)\) and clinician confidence \((p<0.0001)\). Specifically, older patients are significantly less likely to have FTIS from a clinician than younger patients (for a one year increase in age: \(\text{OR} \ 0.99 \ 95\% \ CI \ 0.983-0.998\)). 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: \(\text{OR} \ 2.20, \ 95\% \ CI \ 1.06-4.57\); always palpable vs. never palpable: \(\text{OR} \ 3.53 \ 95\% \ CI \ 1.64-7.60\)). Clinicians requiring the use of ultrasound were significantly less likely to have FTIS than those who did not require assistance with ultrasound technology \((\text{OR} \ 0.13, \ 95\% \ CI \ 0.04-0.41, p=0.0006)\). More experienced staff were more likely to have FTIS than less experienced staff \((301-1000 \text{ vs.} <301: \ 1.54 \ 95\% \ CI \ 1.02-2.34; >1000 \text{ vs.} <301: \ 2.07 \ 95\% \ CI \ 1.41-3.04)\). 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 1.01-1.03).

Comparison of multivariate models

Figure 1 displays the ROC curves for each of the multivariate models whilst 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 variables (AUC=0.71) has significantly greater discriminative ability for identifying FTIS factors than each of the models that contain only patient variables (AUC=0.67, p=0.0178), only clinician variables (AUC=0.68, p=0.0209) or only product variables (AUC=0.59, p<0.0001). The model considering all variables 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 0.59   |             |               |             |

Discussion

The findings of this study suggest 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 (i.e. such as non-palpable vein, being elderly), and clinician factors (i.e. as number of insertions and pre-insertion confidence) independently associated with FTIS. Ultrasound guided insertions predicted failed FTIS; however, as these devices were used by clinicians on patients as a last resort for locating a peripheral vessel, or where the clinician had already failed with previous insertion attempts, this is an expected finding.

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, suggesting that self-report methods lead to a large degree of under-reporting (3). If we assume that DIVA patients are >2 failed attempts, then approximately 12% of the population recruited in our study could be categorized as such. Recently, van Loon et al., (13) identified that patients with a prior history of first-time insertion failure had a fourfold increase of failure with future attempts. Accepting this, are we perhaps too lenient in current policy initiatives of
requiring escalation after two failed attempts and perhaps providers should advocate for
decisions after one failed attempt to escalate to more advanced techniques? The accepted
default insertion procedure after >2 failed attempts is generally inclusive of ultrasound
guided insertion (4) and yet recent systematic reviews and meta-analyses on ultrasound
and other vein-locating technologies do not overwhelmingly acknowledged their clinical
advantage when compared with traditional techniques (21,22). Conceivably, this is owing to
an additional skill and expertise that needs to be developed. Traditional palpation/landmark
based approaches in both study sites are favoured first, with USGPIVC generally only
considered when multiple failures have already occurred.

Our descriptive results suggest dedicated personnel, phlebotomists, in one site had almost
similar success to US trained medical consultants, but had better success than other
medical consultants. Typically, medical consultants have greater clinical experience and will
likely be called for DIVA cases, given their seniority and advanced skills with ultrasound
techniques. The economic cost implication are clear as phlebotomists are paid less than
nurses and medical 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 in this case PIVC insertion.
Performing this skill consistently has been identified to result in very high FTIS rates 98-99%
(23,24). In our multivariate logistic regression, more experienced inserters had significantly
better FTIS rates than less experienced staff. Whilst 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.

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 (1). However, other studies suggest extremes of BMI are independently
associated with insertion failure (2,3). Our results indicate that PIVC insertion in patients
who are subjected to >2 attempts and are classified by clinicians as difficult should have
early intervention that matches them with clinical expertise. While we used accepted
statistical approaches, that is, calibration and internal validation, our AUC is 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 as fair. We included variables in the multivariate model
that were significant at the 5% level where previously 10% had been used in the van Loon
et al., study (13). No scoring tool or rule will be able to precisely predict every patient (13);
however, we did include the clinician variable into our modeling, as clinicians will insert the PIVC into the vein.

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 (5). As a cohort study, we can report statistical associations between risk factors and failed FTIS but cannot definitively conclude cause and effect relationships. Randomized studies will be needed to confirm if a clinical decision rule applying these results to guide insertions leads to improvements in FTIS.

Failure to visualize and palpate a visible vein for potential PIVC insertion should prompt the assistance of a more skilled and proficient clinician. How the transfer of a skill to those less practiced or with less recency of practice is a local matter for individual EDs. The skills associated with PIVC insertion are not profession dependent and a team approach should be encouraged to the benefit of both patient and clinician. This could impact clinical practice and contribute to policy change. The cost of repeated insertions and the impact on patients and clinicians should be a target strategy for future quality improvements.

In conclusion, we have identified risk factors that incorporate patient and clinician factors. A clinical decision rule that matches patients who have no palpable veins and are older with clinicians with greater confidence and experience will likely yield greater FTIS.

Word Count 3,000

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Author’s contribution.

All authors have made substantial contributions to the development of the study results. PJC conceived this study with JR and CMR and MC. MT contributed to the statistical analysis and with PJC, JR, NSH, MC, AF and CMR gave critical insight and interpretation of the findings. All authors reviewed the manuscript.

Competing Interest.

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Data sharing statement: Additional study data available on request.
Figure 1. ROC curves and AUCs for all multivariate models.
Figure 1. ROC curves and AUCs for all multivariate models.

169x169mm (72 x 72 DPI)
STROBE Statement—checklist of items that should be included in reports of observational studies

| Item No | Recommendation |
|---------|----------------|
| **Title and abstract** | |
| 1 | (a) Indicate the study’s design with a commonly used term in the title or the abstract |
|  | (b) Provide in the abstract an informative and balanced summary of what was done and what was found **pages 1 and 2** |
| **Introduction** | |
| 2 | Explain the scientific background and rationale for the investigation being reported **page 4** |
| **Objectives** | 3 State specific objectives, including any prespecified hypotheses **page 5** |
| **Methods** | |
| 4 | Present key elements of study design early in the paper **page 5** |
| 5 | Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection **pages 5-6** |
| **Participants** | 6 |
|  | (a) **Cohort study**—Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up **pages 5-6** |
|  | **Case-control study**—Give the eligibility criteria, and the sources and methods of case ascertainment and control selection. Give the rationale for the choice of cases and controls |
|  | **Cross-sectional study**—Give the eligibility criteria, and the sources and methods of selection of participants |
|  | (b) **Cohort study**—For matched studies, give matching criteria and number of exposed and unexposed |
|  | **Case-control study**—For matched studies, give matching criteria and the number of controls per case |
| **Variables** | 7 Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable **page 6** |
| **Data sources/measurement** | 8* For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group |
| **Bias** | 9 Describe any efforts to address potential sources of bias |
| **Study size** | 10 Explain how the study size was arrived at |
| **Quantitative variables** | 11 Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why |
| **Statistical methods** | 12 |
|  | (a) Describe all statistical methods, including those used to control for confounding **pages 5-6** |
|  | (b) Describe any methods used to examine subgroups and interactions |
|  | (c) Explain how missing data were addressed |
|  | (d) **Cohort study**—If applicable, explain how loss to follow-up was addressed |
|  | **Case-control study**—If applicable, explain how matching of cases and controls was addressed |
|  | **Cross-sectional study**—If applicable, describe analytical methods taking account of sampling strategy |
|  | (e) Describe any sensitivity analyses |

Continued on next page
Results

Participants 13*
(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed page 7
(b) Give reasons for non-participation at each stage
(c) Consider use of a flow diagram

Descriptive data 14*
(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders page 7
(b) Indicate number of participants with missing data for each variable of interest
(c) Cohort study—Summarise follow-up time (eg, average and total amount) pages 8-9

Outcome data 15*
Cohort study—Report numbers of outcome events or summary measures over time
Case-control study—Report numbers in each exposure category, or summary measures of exposure
Cross-sectional study—Report numbers of outcome events or summary measures

Main results 16
(a) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included pages 10-17
(b) Report category boundaries when continuous variables were categorized
(c) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period

Other analyses 17
Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses page 18

Discussion

Key results 18
Summarise key results with reference to study objectives pages 18-19

Limitations 19
Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias page 20

Interpretation 20
Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence page 20

Generalisability 21
Discuss the generalisability (external validity) of the study results page 20

Other information

Funding 22
Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based page 20

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.
Factors associated with first-time insertion success for peripheral intravenous cannulation in the Emergency Department. A multi-centre prospective cohort analysis of patient, clinician, and product characteristics.

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| Primary Subject Heading | Emergency medicine |
| Secondary Subject Heading | Health services research |
| Keywords | first time insertion success, peripheral intravenous catheters, emergency department, logistic regression, receiver-operator characteristic curve |
Factors associated with first-time insertion success for peripheral intravenous cannulation in the Emergency Department. A multi-centre 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 modeling. We created 4 models: patient factors only; clinician factors only; products factors only; and all factors model. We assessed each model’s performance using area under the receiver-operator characteristic curve.

Results: A total of 1,201 PIVC insertions 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 one-year increase in age: Odds Ratio [OR] 0.99, 95% confidence interval (CI) 0.983-0.998; p=0.0097); and target vein palpability: (always palpable vs. never palpable: OR 3.53 95% CI 1.64-7.60; only palpable with tourniquet vs. never palpable: OR 2.20, 1.06-4.57; p=0.0014). Clinician factors related to FTIS include: clinicians with greater confidence (p<0.0001) and insertion experience (301-1000 versus <301: OR 1.54 95% CI (1.02-2.34); >1000 vs. <301: OR 2.07 95% CI 1.41-3.04; 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.

Clinical Trial Registration: Australian and New Zealand Trials Registry: ANZCTR12615000588594.

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Article Summary

Strength 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.
- Some patient groups are under-represented.
Introduction

The peripheral intravenous catheter/cannula (PIVC) is the most pervasive invasive 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 and colleagues 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 and colleagues report 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 are reported to 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 (i.e landmark/palpation guided insertion) range from 74%-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 new modality aimed to avoid this [12]. However, FTIS rates of 69% when USGPIVC methods are used in the ED [12], are less than encouraging, perhaps suggesting 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 for PIVC, and very few clinical studies illustrate the efficacy of such
decision rules [2]. One recent study by van Loon and colleagues 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. However, a notable limitation of the A-DIVA is that
all the modifiable factors associated with FTIS are patient related [15]. In the ED, repeated
ttempts contribute to inefficiency and impact on the clinician and the patient, and retard
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 ED (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 in an openly accessible journal [17]. Our study is
registered with the Australian and New Zealand Trials Registry (ANZCTR12615000588594). We used the STROBE checklist to assist the reporting our
results [18].

Study Design, Setting and Participants

We performed a registered prospective multi-centre 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 academic
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].

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.

Primary outcome
Our primary outcome was FTIS. We defined FTIS as per protocol: 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 10ml) 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 were assessed by the Australasian Triage Scale (ATS) 1-5, required the insertion of a PIVC on the day the researchers were present. An attempt was made to gather a sample size of 1,000 patients allowing for 10% attrition and was our per protocol sample size estimate to allow clinically meaningful inferences.

**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 greater than 0.78, suggesting good content validity [19]. Two research assistants and the lead author separately gathered observation data of PIVC insertions. 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].

**Inclusion criteria**

We attempted to include all patient types who required a PIVC on the day the observers were present.

**Exclusion criteria**

Patients under the age of 18 and patients and/or clinicians who requested not to observed were excluded. We also excluded patients who had repeat presentations to the ED in the statistical analyses.

**Statistical Analysis and Clinical Prediction Model**

Summary statistics, including means and standard deviations (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 modeling (event="FTIS"). Models considered: patient only factors; clinician only factors; product only
factors; and then a combined model containing all factors which we called the **all factors model**. Variables significant at the 5% level in the univariate models were retained for the multivariate models. Adjusted odds ratios (OR), 95% confidence intervals (CI), and P-values are provided. Model performance was assessed using area under the receiver-operator characteristic (ROC) curve and area under the ROC 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].

**Ethical Approval**

Full ethical approval for this study was obtained from The Sir Charles Gairdner Hospital (SCGH) Human Research Ethics office ref: HR 2015-149 with reciprocated approval gained at Fiona Stanley Hospital (FSH) and Griffith University.

**Results**

**Overall Summary**

There were 997 episodes of planned PIVC treatment across the two EDs. Removing the three patients from analysis who declined PIVC insertion, and 27 patients who were repeat (on separate days) presentations, left 967 patients who were studied. Of these, 879 patients had complete information recorded. Only the first presentation per patient was used for ease of modeling. Of these 879 patients, there were 1,201 attempted insertions. The mean patient age was 60.3 (SD 22.1) years, and 52% 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 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 11-300 PIVCs; 102 (12%) clinicians had between 301-600 PIVCs insertions; while 62% had more than 601 PIVCs insertions. Resident medical officers (RMO) inserted the majority of PIVCs (n = 359, 41%), followed by registrars (n = 132; 15%); then interns (n = 91; 10%); followed by registered nurses (RN; n = 99; 11%) and phlebotomists (FSH site only) (n = 82; 9%). Consultants inserted 71 (8%) of the PIVCs. The location of the first attempt insertions were back of the hand (BOH) (n = 129; 15%); wrist (n = 66; 7%); forearm (n = 167; 19%); antecubital fossa (ACF) (n = 493; 56%); and upper arm (n = 24; 3%).
| Table 1. Patient and Clinician characteristics |
|-----------------------------------------------|
| | FTIS (N=645) | No (N=234) | Overall (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%) |
| FTIS | Target Vein Visibility | Target Vein Palpability | Triage Category | Role | Experience | Clinician Confidence |
|------|------------------------|-------------------------|-----------------|------|------------|---------------------|
|      | Yes (N=645)            | No (N=234)              | (N=879)         |      |            |                     |
|      | 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%) |
|      | Visible with and without tourniquet | 305 (82%) | 67 (18%) | 372 (42.3%) |
|      | Only palpable | 324 (69.8%) | 140 (30.2%) | 464 (52.8%) |
|      | Never palpable | 16 (37.2%) | 27 (62.8%) | 43 (4.9%) |
|      | 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%) |
|      | Nurse | 63 (63.6%) | 36 (36.4%) | 99 (11.3%) |
|      | Med Student | 31 (68.9%) | 14 (31.1%) | 45 (5.1%) |
|      | 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%) |
|      | <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%) |
|      | Percentage (Mean, SD) | 79.8 (17.8) | 68.1 (21.9) | 76.7 (19.6) |
|                  | FTIS               | Overall (N=879) |
|------------------|--------------------|----------------|
|                  | Yes (N=645)        | No (N=234)     |
| **Ultrasound**   |                    |                |
| Yes              | 4 (19.1%)          | 17 (81%)       | 21 (2.4%)       |
| No               | 641 (74.7%)        | 217 (25.3%)    | 858 (97.6%)     |
| **Cannula Size** |                    |                |
| 14g              | 1 (100%)           | 0 (0%)         | 1 (0.1%)        |
| 16g              | 6 (75%)            | 2 (25%)        | 8 (0.9%)        |
| 18g              | 191 (80.3%)        | 47 (19.8%)     | 238 (27.1%)     |
| 20g              | 412 (72.2%)        | 159 (27.9%)    | 571 (65%)       |
| 22g              | 34 (56.7%)         | 26 (43.3%)     | 60 (6.8%)       |
| 24g              | 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%)     |

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

### Analysis Results

Table 2 displays the univariate and multivariate binary logistic regression results from modeling FTIS. Multivariate models were conducted for patient factors only, clinician factors only, product 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 0.26-0.98) and patients with good skin quality were more likely to have FTIS than those with poor skin quality (OR 1.78, CI 95% 1.12-2.67).
Patients with a VIA score of I (at least 6 visible veins), II (4 visible veins), III (3 visible veins), IV (1 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 1.41-4.25; II vs. V: OR 1.77 95% CI 1.03-3.05; III vs. V: OR 1.96 95% CI 1.19-3.24; IV vs. V: OR 1.69 95% CI 1.01-2.84).

Patients with a target vein that the clinician was able to palpate with a tourniquet (but not without) were significantly more likely to have FTIS than patients who never had a palpable target vein (OR 2.85, 95% CI 1.44-5.63) and when the target vein was always palpable versus never palpable (OR 4.38 95% CI 2.08-9.25). 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 1.02-1.04), as were staff with more PIVC insertion experience (301-1000 versus <301: OR 1.47 95% CI 0.98-2.20; >1000 vs. <301: OR 1.78 95% CI 1.23-2.58). The clinician roles which returned the best FTIS rates were: ultrasound accredited Consultants (85%); Phlebotomists (79%); Consultants (76%); Registrars (77%); RMO (76%); Medical Student (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 size (p=0.0009) and whether the patient had an ultrasound (p<0.0001). Specifically, PIVC size was associated with greater success when a 14-18g PIVC was used compared with 20g (OR 2.00, 95% CI 1.10-2.31), but had less success when 22g-24g was compared with 20g (OR 0.52, 95% CI 0.30-0.90). Those who had an ultrasound guided access were less likely to experience FTIS (OR 0.08, 95% CI 0.03-0.23).
| Variables          | UNIVARIATE | MULTIVARIATE | All Factor | MULTIVARIATE Patient Model | MULTIVARIATE Clinician Model | MULTIVARIATE Product Model |
|--------------------|------------|--------------|------------|----------------------------|----------------------------|----------------------------|
|                    | OR 95% CI  | OR 95% CI    | P-Value    | OR 95% CI                  | OR 95% CI                  | OR 95% CI                  |
| **Patient factors**|            |              |            |                            |                            |                            |
| Patient Gender     |            |              |            |                            |                            |                            |
| Female v Male      | 0.89       | 0.66-1.20    | Not Significant | Not Significant | Not Included | Not Included |
| Patient Age        |            |              |            |                            |                            |                            |
| For a one year increase | 0.99       | 0.984-0.998 | 0.99       | 0.983-0.998 | 0.0097      | Not Significant | Not Included | Not Included |
| Triage Category    |            |              |            |                            |                            |                            |
| 1 vs. 5            | 1.40       | 0.22-9.12    |            |                            |                            |                            |
| 2 vs. 5            | 0.92       | 0.17-4.81    | Not Significant | Not Significant | Not Included | Not Included |
| 3 vs. 5            | 1.22       | 0.23-6.38    |            |                            |                            |                            |
| 4 vs. 5            | 1.21       | 0.23-6.45    |            |                            |                            |                            |
| BMI Classification |            |              |            |                            |                            |                            |
| Normal vs. Emaciated/Underweight | 1.75       | 1.14-2.69    |            |                            |                            |                            |
| Obese vs. Emaciated/Underweight | 1.07       | 0.64-1.79    | Not Significant | Not Significant | Not Included | Not Included |
| Overweight vs. Emaciated/Underweight | 1.67       | 1.02-2.71    |            |                            |                            |                            |
| 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         |
| **Patient factors** | | | | | |
| Sepsis    |            |                               |                           |                           |                           |
| Yes vs. No| 0.48 0.26-0.88 | Not Significant               | 0.51 0.26-0.98 0.0427     | Not Included              | Not Included              |
| Chemotherapy |            |                               |                           |                           |                           |
| Yes vs. No| 1.23 0.62-2.46 | Not Significant               | Not Significant           | Not Significant           | Not Included              |
| Diabetes  |            |                               |                           |                           |                           |
| Yes vs. No| 0.56 0.35-0.88 | Not Significant               | Not Significant           | Not Significant           | Not Included              |
| Skin Shade|            |                               |                           |                           |                           |
| Dark (4/5/6) vs. Light (1/2/3) | 1.59 1.04-2.43 | Not Significant               | Not Significant           | Not Included              | Not Included              |
| Skin Temperature |            |                               |                           |                           |                           |
| Normal vs. Cold | 2.04 1.26-3.31 | Not Significant               | Not Significant           | Not Included              | Not Included              |
| Warm/Diaphoretic vs. Cold | 1.94 1.11-3.39 | Not Significant               | Not Significant           | Not Included              | Not Included              |
| Skin Condition |            |                               |                           |                           |                           |
| Fair vs. Poor | 1.18 0.78-1.80 | Not Significant               | 1.10 0.71-1.72 0.0050     | Not Included              | Not Included              |
| Good vs. Poor | 2.02 1.38-2.96 | Not Significant               | 1.78 1.12-2.67            | Not Included              | Not Included              |
| Variables | UNIVARIATE | MULTIVARIATE | MULTIVARIATE | MULTIVARIATE | MULTIVARIATE | MULTIVARIATE |
|-----------|------------|--------------|--------------|--------------|--------------|--------------|
|           | OR 95% CI  | All Factor   | Patient Model| Clinician Model| Product Model|
| **Patient factors** | | | | | |
| Insertion Site | | | | | |
| ACF vs. Forearm | 1.25 0.85-1.84 | | | | |
| BOH vs. Forearm | 1.39 0.83-2.34 | Not Significant | Not Significant | Not Included | Not Included |
| Upper Arm vs. Forearm | 0.62 0.26-1.48 | | | | |
| Wrist vs. Forearm | 1.63 0.83-3.21 | | | | |
| VIA SCORE | | | | | |
| I (6 VV) vs. V (0 VV) | 4.10 2.56-6.57 | 2.45 1.41-4.25 | | | |
| II (4 VV) vs. V (0 VV) | 2.50 1.51-4.13 | Not Significant | | Not Included | Not Included |
| III (3 VV) vs. V (0 VV) | 2.47 1.55-3.95 | 1.96 1.19-3.24 0.0250 | | | |
| IV (1 VV) vs. V (0 VV) | 1.84 1.12-3.00 | 1.69 1.01-2.84 | | | |
| Target Vein Visibility | | | | | |
| Only visible with tourniquet vs. Never visible | 1.69 1.13-2.51 | Not Significant | | Not Included | Not Included |
| Always visible vs. Never visible | 2.38 1.68-3.36 | | | | |
| Target Vein Palpability | | | | | |
| Only palpable with tourniquet vs. Never palpable | 3.91 2.04-7.48 2.20 1.06-4.57 0.0014 2.85 1.44-5.63 0.0004 | | | Not Included | Not Included |
| Always palpable vs. Never palpable | 7.68 3.92-15.05 3.53 1.64-7.60 4.38 2.08-9.25 | | | | |
| DIVA | | | | | |
| Yes vs. No | 0.72 0.24-2.13 | | | | |
| Factors                        | UNIVARIATE | MULTIVARIATE Model | 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            | OR 95% CI P-Value           |
| **Clinician factors**         |            |                    |                  |                             |                              |                            |
| Hospital                      |            |                    |                  |                             |                              |                            |
| FSH vs. SCGH                  | 0.82       | 0.61-1.11          |                  |                             |                              |                            |
| **Staff Role**                |            |                    |                  |                             |                              |                            |
| *Consultant vs. Nurse         | 2.13       | 1.06-4.30          |                  |                             |                              |                            |
| Intern vs. Nurse              | 0.87       | 0.49-1.57          |                  |                             |                              |                            |
| Med Student vs. Nurse         | 1.27       | 0.60-2.69          | Not Significant  | Not Included                | Not Significant              | Not Included                |
| Phlebotomist vs. Nurse        | 2.19       | 1.12-4.28          | Not Significant  | Not Included                | Not Significant              | Not Included                |
| RMO vs. Nurse                 | 1.84       | 1.14-2.97          |                  |                             |                              |                            |
| Registrar vs. Nurse           | 1.86       | 1.05-3.31          |                  |                             |                              |                            |
| **Staff Experience**          |            |                    |                  |                             |                              |                            |
| 301-1000 vs. <301             | 1.50       | 1.01-2.22          | 1.54             | 1.02-2.34                   | 0.0011                       | 1.47 0.98-2.20 0.0095      |
| >1000 vs. <301                | 1.95       | 1.36-2.80          | 2.07             | 1.41-3.04                   | 0.0011                       | 1.78 1.23-2.58              |
| **Clinician Confidence**      |            |                    |                  |                             |                              |                            |
| For a 1% Increase             | 1.03       | 1.02-1.04          | 1.02             | 1.01-1.03                   | <0.0001                      | 1.03 1.02-1.04 <0.0001      |
|                               |            |                    |                  |                             |                              |                            |
| Technology and Product factors | UNIVARIATE | MULTIVARIATE all factors 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         |
| **Ultrasound**                |            |                               |                           |                           |                           |
| Yes vs. No                    | 0.08 0.03-0.24 0.13 0.04-0.41 0.0006 Not Significant Not Included | 0.08 0.03-0.23 <0.0001 |
| **Cannula Size**              |            |                               |                           |                           |                           |
| 14-18g vs. 20g                | 1.56 1.09-2.24 Not Significant Not Included | 2.00 1.10-2.31 0.0009 |
| 22g-24g vs. 20g               | 0.52 0.30-0.89 Not Significant Not Included | 0.52 0.30-0.90 |

SD standard deviation; BMI Body Mass Index; VIA venous international score; VV visible vein; DIVA difficult intravenous access; SCGH Sir Charles Gairdner Hospital; FSH Fiona Stanley Hospital; US ultrasound *Consultants in US and Consultants.
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 (p=0.0006), staff experience (p=0.0011) and clinician confidence (p<0.0001). Specifically, older patients are significantly less likely to have FTIS than younger patients (for a one year increase in age: OR 0.99 CI 95% 0.983-0.998). 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: OR 2.20, 95% CI 1.06-4.57; always palpable vs. never palpable: OR 3.53 CI 1.64-7.60). 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 0.04-0.41, 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 1.02-2.34; >1000 vs. <301: OR 2.07 95% CI 1.41-3.04). 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 1.01-1.03).

Comparison of multivariate models

Figure 1 displays the ROC curves for each of the multivariate models whilst 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 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 0.59  |              |              |                |              |
Discussion

The findings of this study suggest 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 (i.e. such as non-palpable vein, being elderly), and clinician factors (i.e. as number of insertions and pre-insertion confidence) independently associated with FTIS. Ultrasound guided insertions predicted failed FTIS; however, as these devices were used by clinicians on patients as a last resort for locating a peripheral vessel, or where the clinician had already failed with previous insertion attempts, this is an expected finding.

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, suggesting that self-report methods lead 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 categorized as such. Recently, van Loon et al., [15] identified that patients with a prior history of first-time insertion failure had a fourfold increase of failure with future attempts. Accepting this, are we perhaps too lenient in current policy initiatives of requiring escalation after two failed attempts and perhaps providers should advocate for decisions after one failed attempt to escalate to more advanced techniques? The accepted default insertion procedure after >2 failed attempts is generally inclusive of ultrasound guided insertion [12] and yet recent systematic reviews and meta-analyses on ultrasound and other vein-locating technologies do not overwhelmingly acknowledged their clinical advantage when compared with traditional techniques [23,24]. Conceivably, this is owing to an additional skill and expertise that needs to be developed. Traditional palpation/landmark based approaches using 32mm length PIVCs made of polyurethane material in both study sites are favored first. Furthermore, ultrasound guided insertion using 48mm length PIVCs are generally only considered when multiple failures have already occurred.

Our descriptive results suggest dedicated phlebotomists, in one site had almost similar success to ultrasound trained medical consultants but had better success than other medical consultants. Typically, medical consultants have greater clinical experience and will likely be called for DIVA cases, given their seniority and advanced skills with ultrasound techniques. The economic cost implication are clear as phlebotomists are paid less than nurses and medical 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 in this case PIVC insertion. Performing this skill consistently has been identified to result in 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. Whilst 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.

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]. However, other studies suggest extremes of BMI are independently associated with insertion failure [6,9]. Our results indicate that PIVC insertion in patients who are subjected to >2 attempts and are classified by clinicians as difficult should have early intervention that matches them with clinical expertise. While we used accepted statistical approaches, that is, calibration and internal validation, our AUC is 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 as fair. We included variables in the multivariate model that were significant at the 5% level where previously 10% had been used in the van Loon et al., study [15]. No scoring tool or rule will be able to precisely predict every patient [15] however, we did include the clinician variable into our modeling, as clinicians will insert the PIVC into a selected vein.

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]. For example, few visible veins as identified with the VIA score could be used as a classification for DIVA or more than 2 failed attempts as others have used. Failure to visualize and palpate a visible vein for potential PIVC insertion should prompt the assistance of a more skilled and proficient clinician and with the use of ultrasound to inform a better assessment. How the transfer of a skill to those less practiced or with less recency of practice is a local matter for individual EDs. 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. This could impact clinical practice and contribute to policy change. The cost of repeated insertions and the impact on patients and clinicians should be a target strategy for future quality improvements.

As a cohort study, we can report statistical associations between patient, clinician and technological factors and FTIS but cannot definitively conclude cause and effect relationships. Randomized studies will be needed to confirm if a clinical decision rule applying these results to guide insertions leads to improvements in FTIS.
In conclusion, a clinical decision rule that matches patients who have no palpable veins and are older with clinicians with greater confidence and experience will likely yield greater FTIS.

**Word Count** 3,235

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Author’s contribution.

All authors have made substantial contributions to the development of the study results. PJC conceived this study with JR and CMR and MC. MT contributed to the statistical analysis and with PJC, JR, NSH, MC, AF and CMR gave critical insight and interpretation of the findings. All authors reviewed the manuscript.

Competing Interest.

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Data sharing statement: Additional study data available on request.
Figure 1. ROC curves and AUCs for all multivariate models.
ROC curves and AUCs for all multivariate models.

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Factors associated with first-time insertion success for peripheral intravenous cannulation in the Emergency Department. A multi-centre 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 modeling. We created 4 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-operator characteristic curve.

Results: A total of 1,201 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 one-year increase in age: Odds Ratio [OR] 0.99, 95% confidence interval (CI) 0.983-0.998; p=0.0097); and target vein palpability: (always palpable vs. never palpable: OR 3.53 95% CI 1.64-7.60; only palpable with tourniquet vs. never palpable: OR 2.20, 1.06-4.57; p=0.0014). Clinician factors related to FTIS include: clinicians with greater confidence (p<0.0001) and insertion experience (301-1000 versus <301: OR 1.54 95% CI (1.02-2.34); >1000 vs. <301: OR 2.07 95% CI 1.41-3.04; 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.

Clinical Trial Registration: Australian and New Zealand Trials Registry: ANZCTR12615000588594.

Abstract Word Count 300
Article Summary

Strength 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.
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 and colleagues 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 and colleagues 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 (i.e. landmark/palpation guided insertion) range from 74%-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 for PIVC. Very few clinical studies illustrate the efficacy of such decision rules [2]. One recent study by van Loon and colleagues 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 (ANZCTR12615000588594). We used the STROBE 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 multi-centre 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 25mm to 48mm and from gauge (g) 14 - 24g.
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 10ml) 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 1,000 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 greater than 0.78, suggesting good content validity [19]. Two research assistants and the lead author separately gathered data by observation of PIVC insertions. 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 standard deviations (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 modeling (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 odds ratios (OR), 95% confidence intervals (CI), and P-values are provided. Model performance was assessed using area under the receiver-operator characteristic (ROC) curve and area under the ROC 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].

Ethical Approval

Full ethical approval for this study was obtained from The Sir Charles Gairdner Hospital (SCGH) Human Research Ethics office ref: HR 2015-149 with reciprocated approval gained at Fiona Stanley Hospital (FSH) and Griffith University.

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 modeling. Of the remaining 967 patients included in the study, 879 had complete information recorded providing 1,201 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 11-300 PIVCs; 102 (12%) clinicians had between 301-600 PIVCs insertions; while 62% had more than 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 nurses (RN; 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 (BOH) (n = 129; 15%); wrist (n = 66; 7%); forearm (n = 167; 19%); antecubital fossa
(ACF) (n = 493; 56%); and upper arm (n = 24; 3%).

Table 1. Patient and Clinician characteristics

|                       | FTIS Yes (N=645) | FTIS No (N=234) | Overall (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 (24.5%)     | 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%)     |
| FTIS                     | Overall          |
|-------------------------|------------------|
| Target Vein             |                  |
| Visibility              |                  |
| Visible with and without tourniquet | Yes (N=645) 317 (80.3%) No (N=234) 78 (19.8%) (N=879) 395 (44.9%) |
| Only visible with tourniquet | Yes (N=645) 150 (74.3%) No (N=234) 52 (25.7%) (N=879) 202 (23%) |
| Never visible           | Yes (N=645) 178 (63.1%) No (N=234) 104 (36.9%) (N=879) 282 (32.1%) |
| Target Vein             |                  |
| Palpability             |                  |
| Palpable with and without tourniquet | Yes (N=645) 305 (82%) No (N=234) 67 (18%) (N=879) 372 (42.3%) |
| Only palpable with tourniquet | Yes (N=645) 324 (69.8%) No (N=234) 140 (30.2%) (N=879) 464 (52.8%) |
| Never palpable          | Yes (N=645) 16 (37.2%) No (N=234) 27 (62.8%) (N=879) 43 (4.9%) |
| Triage Category         |                  |
| 1 - Immediately life-threatening | Yes (N=645) 21 (77.8%) No (N=234) 6 (22.2%) (N=879) 27 (3.1%) |
| 2 - Imminently life-threatening | Yes (N=645) 206 (69.6%) No (N=234) 90 (30.4%) (N=879) 296 (33.7%) |
| 3 - Potentially life-threatening | Yes (N=645) 280 (75.3%) No (N=234) 92 (24.7%) (N=879) 372 (42.3%) |
| 4 - Potentially life-serious | Yes (N=645) 133 (75.1%) No (N=234) 44 (24.9%) (N=879) 177 (20.1%) |
| 5 - Less urgent         | Yes (N=645) 5 (71.4%) No (N=234) 2 (28.6%) (N=879) 7 (0.8%) |
| Role                    |                  |
| Nurse                   | Yes (N=645) 63 (63.6%) No (N=234) 36 (36.4%) (N=879) 99 (11.3%) |
| Med Student             | Yes (N=645) 31 (68.9%) No (N=234) 14 (31.1%) (N=879) 45 (5.1%) |
| Intern                  | Yes (N=645) 55 (60.4%) No (N=234) 36 (39.6%) (N=879) 91 (10.4%) |
| RMO                     | Yes (N=645) 274 (76.3%) No (N=234) 85 (23.7%) (N=879) 359 (40.8%) |
| Registrar               | Yes (N=645) 101 (76.5%) No (N=234) 31 (23.5%) (N=879) 132 (15%) |
| Consultant              | Yes (N=645) 45 (77.6%) No (N=234) 13 (22.4%) (N=879) 58 (6.6%) |
| US Consultant           | Yes (N=645) 11 (84.6%) No (N=234) 2 (15.4%) (N=879) 13 (1.5%) |
| Phlebotomist            | Yes (N=645) 65 (79.3%) No (N=234) 17 (20.7%) (N=879) 82 (9.3%) |
| Experience              |                  |
| <10                     | Yes (N=645) 5 (71.4%) No (N=234) 2 (28.6%) (N=879) 7 (0.8%) |
| 11-50                   | Yes (N=645) 30 (58.8%) No (N=234) 21 (41.2%) (N=879) 51 (5.8%) |
| 51-100                  | Yes (N=645) 38 (63.3%) No (N=234) 22 (36.7%) (N=879) 60 (6.8%) |
| 101-300                 | Yes (N=645) 74 (67.9%) No (N=234) 35 (32.1%) (N=879) 109 (12.4%) |
| 301-600                 | Yes (N=645) 72 (70.6%) No (N=234) 30 (29.4%) (N=879) 102 (11.6%) |
| 601-1000                | Yes (N=645) 107 (75.4%) No (N=234) 35 (24.7%) (N=879) 142 (16.2%) |
| >1000                   | Yes (N=645) 319 (78.2%) No (N=234) 89 (21.8%) (N=879) 408 (46.4%) |
| Clinician               |                  |
| Confidence              |                  |
| Percentage (Mean, SD)   |                  |
| Clinician               | Yes (N=645) 79.8 (17.8) No (N=234) 68.1 (21.9) (N=879) 76.7 (19.6) |
|                  | FTIS                  | Overall               |
|------------------|-----------------------|-----------------------|
|                  | Yes (N=645)           | No (N=234)            |
|                  |                       | (N=879)               |
| Ultrasound       |                       |                       |
| Yes              | 4 (19.1%)             | 17 (81%)              |
|                  | 641 (74.7%)           | 217 (25.3%)           |
|                  | 858 (97.6%)           |                       |
| Cannula Size     |                       |                       |
| 14g              | 1 (100%)              | 0 (0%)                |
|                  | 1 (0.1%)              |                       |
| 16g              | 6 (75%)               | 2 (25%)               |
|                  | 8 (0.9%)              |                       |
| 18g              | 191 (80.3%)           | 47 (19.8%)            |
|                  | 238 (27.1%)           |                       |
| 20g              | 412 (72.2%)           | 159 (27.9%)           |
|                  | 571 (65%)             |                       |
| 22g              | 34 (56.7%)            | 26 (43.3%)            |
|                  | 60 (6.8%)             |                       |
| 24g              | 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%)           |                       |

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

Analysis Results

Table 2 displays the univariate and multivariate binary logistic regression results from modeling 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 0.26-0.98) and patients with good skin quality were more likely to have FTIS than those with poor skin quality (OR 1.78, CI 95% 1.12-2.67).
Patients with a VIA score of I (at least 6 visible veins), II (4 visible veins), III (3 visible veins), IV (1 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 1.41-4.25; II vs. V: OR 1.77 95% CI 1.03-3.05; III vs. V: OR 1.96 95% CI 1.19-3.24; IV vs. V: OR 1.69 95% CI 1.01-2.84).

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 1.44-5.63) and when the target vein was always palpable versus never palpable (OR 4.38 95% CI 2.08-9.25). 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 1.02-1.04), as were staff with more PIVC insertion experience (301-1000 versus <301: OR 1.47 95% CI 0.98-2.20; >1000 vs. <301: OR 1.78 95% CI 1.23-2.58). 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 14-18g PIVC was used compared with 20g (OR 2.00, 95% CI 1.10-2.31), but had less success when 22g-24g was compared with 20g (OR 0.52, 95% CI 0.30-0.90). Those who had an ultrasound guided access were less likely to experience FTIS (OR 0.08, 95% CI 0.03-0.23).
Table 2. Univariate and Multivariate modeling

| Variables          | UNIVARIATE | MULTIVARIATE Model | All Factor | MULTIVARIATE Patient Model | MULTIVARIATE Clinician Model | MULTIVARIATE Product Model |
|--------------------|------------|--------------------|------------|----------------------------|----------------------------|----------------------------|
|                    | OR 95% CI  | OR 95% CI          | P-Value    | OR 95% CI                  | OR 95% CI                  | OR 95% CI                  |
| Patient factors    |            |                    |            |                            |                            |                            |
| Patient Gender     |            |                    |            |                            |                            |                            |
| Female v Male      | 0.89       | 0.66-1.20          | Not Significant | Not Significant         | Not Included                | Not Included                |
| Patient Age        |            |                    |            |                            |                            |                            |
| For a one year increase | 0.99       | 0.984-0.998       | 0.99       | 0.983-0.998               | 0.0097                     | Not Significant            |
| Triage Category    |            |                    |            |                            |                            |                            |
| 1 vs. 5            | 1.40       | 0.22-9.12          |            |                            |                            | Not Included                |
| 2 vs. 5            | 0.92       | 0.17-4.81          | Not Significant | Not Significant         | Not Included                | Not Included                |
| 3 vs. 5            | 1.22       | 0.23-6.38          |            |                            |                            |                            |
| 4 vs. 5            | 1.21       | 0.23-6.45          |            |                            |                            |                            |
| BMI Classification |            |                    |            |                            |                            |                            |
| Normal vs. Emaciated/Underweight | 1.75       | 1.14-2.69          |            |                            |                            | Not Included                |
| Obese vs. Emaciated/Underweight | 1.07       | 0.64-1.79          | Not Significant | Not Significant         | Not Included                | Not Included                |
| Overweight vs. Emaciated/Underweight | 1.67       | 1.02-2.71          |            |                            |                            |                            |
| Variables         | UNIVARIATE Model | MULTIVARIATE All Factor Model | MULTIVARIATE Patient Model | MULTIVARIATE Clinician Model | MULTIVARIATE Product Model |
|-------------------|------------------|-------------------------------|----------------------------|------------------------------|---------------------------|
|                   | OR               | 95% CI                        | OR                         | 95% CI                      | OR                        |
| **Patient factors** |                  |                               |                            |                              |                           |
| Sepsis            |                  |                               |                            |                              |                           |
| Yes vs. No        | 0.48             | 0.26-0.88                     | Not Significant            | 0.51                        | 0.26-0.98                 | 0.0427                    | Not Included              | Not Included              |
| Chemotherapy      |                  |                               |                            |                              |                           |
| Yes vs. No        | 1.23             | 0.62-2.46                     | Not Significant            | Not Significant             | Not Included              |                           |
| Diabetes          |                  |                               |                            |                              |                           |
| Yes vs. No        | 0.56             | 0.35-0.88                     | Not Significant            | Not Significant             | Not Included              |                           |
| Skin Shade        |                  |                               |                            |                              |                           |
| Dark (4/5/6) vs.  | 1.59             | 1.04-2.43                     | Not Significant            | Not Significant             | Not Included              |                           |
| Light (1/2/3)     |                  |                               |                            |                              |                           |
| Skin Temperature  |                  |                               |                            |                              |                           |
| Normal vs. Cold   | 2.04             | 1.26-3.31                     | Not Significant            | Not Significant             | Not Included              |                           |
| Warm/Diaphoretic vs. Cold | 1.94 | 1.11-3.39 | Not Significant | Not Significant | Not Included |                           |
| Skin Condition    |                  |                               |                            |                              |                           |
| Fair vs. Poor     | 1.18             | 0.78-1.80                     | Not Significant            | 1.10                        | 0.71-1.72                 | 0.0050                    | Not Included              | Not Included              |
| Good vs. Poor     | 2.02             | 1.38-2.96                     | Not Significant            | 1.78                        | 1.12-2.67                 |                           |
| Variables                        | UNIVARIATE | MULTIVARIATE | All Factor | MULTIVARIATE | MULTIVARIATE | MULTIVARIATE | MULTIVARIATE | MULTIVARIATE |
|---------------------------------|------------|--------------|------------|--------------|--------------|--------------|--------------|--------------|
|                                 |            | Patient Model |            | Patient Model | Clinician Model | Product Model |              |              |
|                                 | OR         | 95% CI       | OR         | 95% CI       | P-Value      | OR           | 95% CI       | P-Value      |
| Insertion Site                  |            |              |            |              |              |              |              |              |
| ACF vs. Forearm                 | 1.25       | 0.85-1.84    |            |              |              |              |              |              |
| BOH vs. Forearm                 | 1.39       | 0.83-2.34    |            |              |              |              |              |              |
| Upper Arm vs. Forearm           | 0.62       | 0.26-1.48    |            |              |              |              |              |              |
| Wrist vs. Forearm               | 1.63       | 0.83-3.21    |            |              |              |              |              |              |
| VIA SCORE                       |            |              |            |              |              |              |              |              |
| I (6 VV) vs. V (0 VV)           | 4.10       | 2.56-6.57    | 2.45       | 1.41-4.25    |              |              |              |              |
| II (4 VV) vs. V (0 VV)          | 2.50       | 1.51-4.13    | 1.77       | 1.03-3.05    |              |              |              |              |
| III (3 VV) vs. V (0 VV)         | 2.47       | 1.55-3.95    | 1.96       | 1.19-3.24    | 0.0250       |              |              |              |
| IV (1 VV) vs. V (0 VV)          | 1.84       | 1.12-3.00    | 1.69       | 1.01-2.84    |              |              |              |              |
| Target Vein Visibility          |            |              |            |              |              |              |              |              |
| Only visible with tourniquet vs.| 1.69       | 1.13-2.51    |            |              |              |              |              |              |
| Never visible                   |            |              |            |              |              |              |              |              |
| Always visible vs. Never visible| 2.38       | 1.68-3.36    |            |              |              |              |              |              |
| Target Vein Palpability         |            |              |            |              |              |              |              |              |
| Only palpable with tourniquet vs.| 3.91       | 2.04-7.48    | 2.20       | 1.06-4.57    | 0.0014       | 2.85         | 1.44-5.63    | 0.0004       |
| Never palpable                  |            |              |            |              |              |              |              |              |
| Always palpable vs. Never palpable| 7.68       | 3.92-15.05   | 3.53       | 1.64-7.60    | 4.38         | 2.08-9.25    |              |              |
| DIVA                            |            |              |            |              |              |              |              |              |
| Yes vs. No                      | 0.72       | 0.24-2.13    |            |              |              |              |              |              |

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| Factors                  | UNIVARIATE | MULTIVARIATE Model | All Factor | MULTIVARIATE Patient Model | MULTIVARIATE Clinician Model | MULTIVARIATE Product Model |
|--------------------------|------------|--------------------|-----------|---------------------------|-----------------------------|----------------------------|
| Hospital                 |            |                    |           |                           |                             |                            |
| FSH vs. SCGH             | 0.82       | 0.61-1.11          |           |                           |                             |                            |
| Staff Role               |            |                    |           |                           |                             |                            |
| *Consultant vs. Nurse    | 2.13       | 1.06-4.30          |           |                           |                             |                            |
| Intern vs. Nurse         | 0.87       | 0.49-1.57          |           |                           |                             |                            |
| Med Student vs. Nurse    | 1.27       | 0.60-2.69          | Not Significant | Not Included | Not Significant | Not Included |
| Phlebotomist vs. Nurse   | 2.19       | 1.12-4.28          | Not Significant | Not Included | Not Significant | Not Included |
| RMO vs. Nurse            | 1.84       | 1.14-2.97          |           |                           |                             |                            |
| Registrar vs. Nurse      | 1.86       | 1.05-3.31          |           |                           |                             |                            |
| Staff Experience         |            |                    |           |                           |                             |                            |
| 301-1000 vs. <301        | 1.50       | 1.01-2.22          | 1.54      | 1.02-2.34                 | 0.0011                      |                             |
| >1000 vs. <301           | 1.95       | 1.36-2.80          | 2.07      | 1.41-3.04                 | 0.0001                      |                             |
| Clinician Confidence     |            |                    |           |                           |                             |                            |
| For a 1% Increase        | 1.03       | 1.02-1.04          | 1.02      | 1.01-1.03                 | <0.0001                     |                             |

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### Technology and Product factors

|                  | UNIVARIATE | 95% CI | MULTIVARIATE | P-Value | MULTIVARIATE | P-Value | MULTIVARIATE | P-Value | MULTIVARIATE | P-Value | MULTIVARIATE | P-Value |
|------------------|------------|--------|--------------|---------|--------------|---------|--------------|---------|--------------|---------|--------------|---------|
| **Ultrasound**   |            |        |              |         |              |         |              |         |              |         |              |         |
| Yes vs. No       | 0.08       | 0.03-0.24 | 0.13 | 0.04-0.41 | 0.0006 | Not Significant | | Not Included | | 0.08 | 0.03-0.23 | <0.0001 |
| **Cannula Size** |            |        |              |         |              |         |              |         |              |         |              |         |
| 14-18g vs. 20g   | 1.56       | 1.09-2.24 |     |          |         | Not Significant | | Not Included | | 2.00 | 1.10-2.31 | 0.0009 |
| 22g-24g vs. 20g  | 0.52       | 0.30-0.89 |     |          |         | Not Significant | | Not Included | | 0.52 | 0.30-0.90 |         |

SD standard deviation; BMI Body Mass Index; VIA venous international assessment; VV visible vein; DIVA difficult intravenous access; SCGH Sir Charles Gairdner Hospital; FSH Fiona Stanley Hospital; US ultrasound *Consultants in US and Consultants.

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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 one-year increase in age: OR 0.99 CI 95% 0.983-0.998). 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 did not have a palpable target vein (only visible with tourniquet vs. never palpable: OR 2.20, 95% CI 1.06-4.57; always palpable vs. never palpable: OR 3.53 CI 1.64-7.60). 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 0.04-0.41, 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 1.02-2.34; >1000 vs. <301: OR 2.07 95% CI 1.41-3.04). 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 1.01-1.03).

Comparison of multivariate models

Figure 1 displays the ROC curves for each of the multivariate models whilst 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 (e.g. non-palpable vein, being elderly), and clinician factors (e.g. 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 32mm length PIVC for insertion were favored first by clinicians in both study sites. Furthermore, ultrasound guided insertion using 48mm 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 categorized as such. Recently, van Loon et al., [15] identified that patients with a prior 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. Whilst 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. For example, others have used the VIA score as a classification for DIVA with those with few visible veins identified and was predictive of more than 2 failed attempts. When clinicians are unable to visualize 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 modeling, 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. Randomized 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.

**Word Count** 3,389

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Author’s contribution.

All authors have made substantial contributions to the development of the study results. PJC conceived this study with JR, CMR and MC. MT contributed to the statistical analysis and with PJC, JR, MC, MT, NSH, AF and CMR gave critical insight and interpretation of the findings. All authors reviewed the manuscript.

Competing Interest.

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Data sharing statement: Additional study data available on request.

Fig 1: ROC curves for each of the multivariate models
ROC curves for each of the multivariate models

61x61mm (300 x 300 DPI)