EMA Emergency Medicine Australasia

Emergency Medicine Australasia (2016) **28**, 658–665 doi: 10.1111/1742-6723.12695

ORIGINAL RESEARCH

Predicting and preventing peripheral intravenous cannula insertion failure in the emergency department: Clinician 'gestalt' wins again

James CR RIPPEY,[1,2,3] Peter J CARR,[1,3,4] Marie COOKE,[3,4] Niall HIGGINS[3,4] and Claire M RICKARD[3,4]

[1]Emergency Medicine, School of Primary, Aboriginal and Rural Health Care, Faculty of Medicine, Dentistry and Health Services, The University of Western Australia, Perth, Western Australia, Australia, [2]Emergency Department, Sir Charles Gairdner Hospital, Perth, Western Australia, Australia, [3]Alliance for Vascular Access Teaching & Research (AVATAR) Group, Menzies Health Institute Queensland, Griffith University, Brisbane, Queensland, Australia, and [4]NHMRC Centre for Excellence in Nursing, Centre for Health Practice Innovation, Menzies Health Institute Queensland, Griffith University, Brisbane, Queensland, Australia

Abstract

Objective: Failed attempts at peripheral i.v. cannula (PIVC) insertion in the ED are common. The psychological, physical and economic impact of these failures is significant. We sought to explore whether clinicians of differing experience levels can predict their own likelihood (clinician 'gestalt') of first-time cannula insertion success on any given patient.

Methods: Data analyses from a prospective self-reported study assessing risk factors for first-time insertion success in a tertiary adult ED. We constructed and compared two simple theoretical clinical decision algorithms in an attempt to improve first-time PIVC insertion success rates.

Results: This best algorithm identified a subgroup of 18% of the total PIVC population at higher risk of failure. This 18% comprised 57% of all PIVC failures, and implementation would result in a relative risk reduction of PIVC failure by 31%.

Conclusions: When applied to our sample population, an algorithm relying on clinician gestalt to identify patients at high risk of PIVC failure had the greatest potential impact. These patients would be referred to expert PIVC inserters prior to, rather than after, failed attempts.

Key words: *catheter*, *failure*, *insertion*, *intravenous*, *prevention*.

Introduction

'Gestalt' states that our minds organise information to a global perception, rather than by assessing each individual element. In other words, 'The whole is greater than the sum of its parts'. In the clinical realm, it is the synthesis of intuition, with what is often a subconscious analytical approach, to reach a conclusion that may be better than summating each individual element.[1,2]

The hypothesis on which this study and paper rests is that a clinician's gestalt, regarding the likelihood of their own success in achieving first-attempt peripheral i.v. cannula (PIVC) placement in a particular patient, is a better predictor than attempting to systematically analyse the myriad complex individual components that may contribute to the success or failure in that given case.

Key findings

- Clinicians with varying levels of expertise can prospectively predict how likely they are to be successful in placing a PIVC on the first attempt in any given patient.
- The 'clinical gestalt' appears to be better than using a combination of objective measures aimed at identifying patients in whom PIVC insertion will be difficult.
- An algorithm aimed at reducing failed PIVC insertion attempts has been created. It uses clinician gestalt as the major factor is determining whether a clinician should attempt PIVC insertion themselves, or refer to a more experienced operator.

First-time PIVC insertion success rates in the literature are varied and range from 18 to 98%.[2–5] Both clinician and patient factors contribute to PIVC insertion difficulty.[5–9] The major operator factor is previous PIVC insertion experience.[7,8] Australian EDs have PIVC inserters ranging from novice students to highly experienced, ultrasound-trained emergency physicians. Patient factors associated with higher failure rates include clinical factors like hypovolaemia, recent chemotherapy and i.v. drug use and anatomical factors such as extremes of body mass index; skin shade; and

Correspondence: Dr James CR Rippey, Emergency Department, Sir Charles Gairdner Hospital, Hospital Avenue, Nedlands, Perth, WA 6009, Australia. Email: drjamesrippey@gmail.com

James CR Rippey, MBBS, DCH, DDU, FACEM, Emergency Physician; Peter J Carr, RN, Dip HE Adult Nurs, H Dip A&E Nurs, BSc, MMedSc, PhD (C), Lecturer Emergency Medicine; Marie Cooke, RN, PhD, Professor of Nursing; Niall Higgins, RN, G Dip e-Health, PhD, Senior Research Fellow; Claire M Rickard, RN, PhD, Professor of Nursing.

Accepted 14 September 2016

the number, presence and size of visible and palpable veins.[3,5,9–11]

The ED is widely regarded as a clinical environment where junior clinicians develop procedural competency in a real-world setting.[12–16] In addition, PIVC insertion is often considered a simple task and a poor use of senior clinician time. As a result of both these factors, PIVC insertion is frequently allocated to junior practitioners. It is acknowledged that two failed attempts constitutes a difficult PIVC insertion, and this, together with the limited availability of senior clinicians, means repeated failed attempts prior to more senior intervention is commonplace.[17–20]

In emergency medicine literature, there has been recent recognition of the importance of PIVC placement,[21] the distress it can cause patients,[22] the associated costs[23] and potential complications,[24] leading to renewed enthusiasm and focus on improving performance.

Identifying patients where difficulty with PIVC insertion is anticipated prior to a failed attempt would enable earlier expert intervention. This could save time and expense as well as avoid the physical and psychological morbidity associated with multiple failed attempts at PIVC insertion.

Materials and methods

Study design

This study used data from a prospective cohort study conducted from 11 December 2013 to 3 January 2014. That study aimed to identify factors associated with first-time insertion success.[25] The Sir Charles Gairdner Hospital human research ethics committee approved the study as a Quality Initiative (QI3065).

This study was designed to address the following questions:

- Is clinician 'gestalt' accurate in estimating the likelihood of first-time cannulation success in any given patient?
- What other factors predict initial PIVC placement success or failure in an adult ED population?
- What is the difference between a clinical decision algorithm incorporating clinician gestalt with one based on objective clinician, patient and vessel factors?

Study setting and population

This study took place in the ED of Sir Charles Gairdner Hospital, an adult metropolitan tertiary hospital in Western Australia. Approximately 64 000 patients present to the ED annually, and there is a 55% admission rate. A total of 33 228 PIVC insertions were recorded on the ED Information System in 2012–2013. In this ED, PIVCs are inserted predominantly by medical staff and occasionally by nursing staff.

Data collection

The PIVC survey data collection form was designed to allow self-report by the PIVC inserter. It was based on a review of the literature related to vascular access difficulty. Studies that had previously identified factors associated with difficult insertion were examined. Senior ED clinicians assessed face validity so that the document was clinically relevant and practical for use in the ED. It had two sections, a pre-insertion and post-insertion section, to be completed before and after the attempt at PIVC insertion, respectively (for information on exact data collected see Fig. S1).

Medical and nursing staff of all levels received education regarding the study and data collection. Each of the 12 PIVC trolleys had custom-made form holders attached in a prominent position. These had separate compartments for blank and completed forms.

Completion was encouraged but ultimately optional. Prior to a cannulation attempt, the pre-insertion page of the form was completed by the operator. After the PIVC attempt, the post-insertion page was completed and the form stored in the appropriate container. Every morning, completed forms were collected and details entered into a database. After 24 days, the data collection phase ended. The time period chosen coincided with the last few weeks of the junior doctor annual rotation. This meant the junior doctors were familiar with their role in the ED, more comfortable about PIVC insertion and, it was felt, more likely to complete a non-compulsory data collection form.

Data analysis

Completed forms were collated and data entered into SPSS for statistical analysis.

Where key data points were missing, cases were excluded from the analysis. To maintain the maximal patient inclusion, each calculation was completed with the entire sample that documented relevant data points. For example, in 0.5% of the study population, there was failure to document whether the first attempt was a success or failure, and subsequently, these patients were excluded from calculations. The overall first-time success rate was therefore presented as a proportion of the 99.5%, with documentation of first-time PIVC insertion success. Of the study population, 6.7% did not document the clinician experience level. Calculations focusing on clinician experience were thus based on the remaining 93.3% of the study sample. This method was used throughout; where key data points were missing, cases were excluded from the analysis. The proportion of missing data for each calculation is detailed in the Results section. Datasets with confidence intervals were calculated, and data are presented in tabulated form.

Clinical decision algorithm creation

Two clinical decision algorithms aimed at identifying subgroups of patients with high risk of PIVC insertion failure were constructed. Any factor associated with a rate of first-time PIVC insertion success of <75% was identified (Table 1), and these factors were used to create the algorithms (Figs 2,3). The gestalt algorithm used clinician experience and their prediction of PIVC success as

TABLE 1. *Clinician's predicted versus actual first-attempt PIVC insertion success rate by experience level†*

Clinician's confidence at first-attempt success	Beginner (<100 PIVC insertions)		Intermediate (100–800 PIVC insertions) first-time success		Experienced (>800 PIVC insertions) first-time success	
	First-time success rate	Success rate 95% confidence interval	First-time success rate	Success rate 95% confidence interval	First-time success rate	Success rate 95% confidence interval
<50%	0	—	50% (5/10)	(18.7%, 81.3%)	12.5% (1/8)	(0.3%, 52.7%)
50–59%	55.6% (5/9)	(21.2%, 86.3%)	57.6% (19/33)	(39.2%, 74.5%)	50% (14/28)	(30.6%, 69.4%)
60–69%	50.0% (2/4)	(6.8%, 93.2%)	44.4% (4/9)	(13.7%, 78.8%)	81.8% (9/11)	(48.2%, 97.7%)
70–79%	58.3% (7/12)	(27.7%, 84.8%)	83.8% (62/74)	(73.4%, 91.3%)	86.8% (46/53)	(74.7%, 94.5%)
80–89%	63.6% (7/11)	(30.8%, 89.1%)	93.1% (27/29)	(77.2%, 99.2%)	91.7% (44/48)	(80.0%, 97.7%)
90–100%	90.9% (10/11)	(58.7%, 99.8%)	95.7% (134/140)	(90.9%, 98.4%)	97.4% (190/195)	(94.1%, 99.2%)
Overall	66.0% (31/47)	(50.7%, 79.1%)	85.1% (251/295)	(80.5%, 88.9%)	88.6% (304/343)	(84.8%, 91.8%)

†Missing data 49 of 734 (6.7%). PIVC, peripheral i.v. cannula.

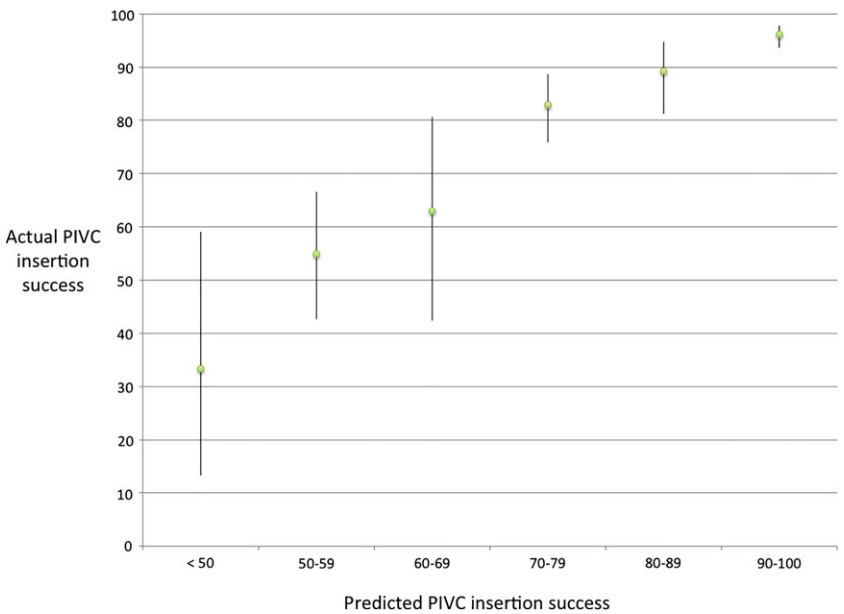

Figure 1. *Clinician's predicted versus actual first-attempt peripheral i.v. cannula insertion success rate with 95% confidence intervals (refer to Table S1 for additional information).*

the primary factor in creating the algorithm. For the second algorithm, objective measures of PIVC difficulty were identified and then incorporated into a separate clinical decision algorithm. Comparison of the two algorithms and their potential impact on PIVC insertion using our dataset was completed. For comparison of the algorithms, it was assumed that where patients were referred to more expert operators, a first-time insertion success rate of 80% would be achieved. This is felt to be a conservative estimate. The number of failed cannulations that would potentially be prevented by referring each subgroup was then calculated, and the relative reduction in failed cannulation was also calculated.

Results

Overall first-attempt PIVC success

During the study period, 4433 patients attended the ED. A total of 734 patients were entered into the study. Overall, there was an 86% (626/730) first-attempt PIVC insertion success rate, with 10% (73/730) requiring a second attempt, 3% (22/730) needing three attempts and 0.4% (3/730) requiring four attempts to achieve i.v. access. Four insertion attempts (0.5%; 4/730) were abandoned. In 0.5% (4/734), key data were missing, and these cases were excluded from further calculations.

Clinician's 'gestalt'

Clinicians' PIVC pre-attempt prediction of success rate and the final outcomes are shown in Figure 1. The accuracy of the prediction by inserter's experience level is shown in Table 1. This demonstrates that when an operator of any experience level predicts that their likelihood of PIVC insertion success will be over 90%, they are correct. In attempting to identify groups where success rates were below 75%, it was found that where a beginner estimated their success would be below 90%, it was below 75%; where an intermediate estimated their success was below

TABLE 2. *Patient groups at high risk of PIVC first-time insertion failure*

	Group identified as having a <75% chance of successful insertion	Success at first-attempt PIVC	Proportion of entire sample		% of all failures identified
Gestalt	Expert i.v. inserter with <60% prediction of success	42%	5.3%	Combine to 18.2%	56.6%
	Intermediate i.v. inserter with <70% prediction of success	54%	7.6%		
	Beginner i.v. inserter with <90% prediction of success	58%	5.3%		
Objective	0 reasonable sites	50%	2.5%	Many of these overlap. Combine to 22.4%	48.3%
	No palpable vein	52%	3.7%		
	Emaciated	56%	2.6%		
	Intravenous drug user	57%	2.9%		
	Size of target vessel <2 mm	60%	5.0%		
	Recent attempts	64%	1.5%		
	Beginner PIVC inserter	66%	6.9%		
	Dehydration	67%	2.9%		
	Skin abnormality	69%	3.6%		

PIVC, peripheral i.v. cannula.

70%, it was below 75%; and where an experienced inserter estimated their success would be below 60%, it was below 75% (graphically demonstrated in Fig. S2).

Other factors

Numerous other factors potentially contributing to PIVC insertion failure were assessed. These included vessel factors such as size of the target vessel, the number of reasonable target sites, the presence or absence of palpable or visible veins and any recent prior admissions requiring PIVC insertion. Patient factors were also explored, and patient size (obesity or emaciation), previous i.v. drug use, recent chemotherapy, skin abnormality, chronic disease, dehydration, agitation and haemodynamic instability were all considered (refer to Tables S2, S3 and S4 for additional information).

PIVC clinical decision algorithm construction

Any group where the subsequent PIVC first-attempt success rate was below 75% was identified as being at high risk of failure and was considered further for inclusion in the PIVC failure prevention algorithms (Table 2).

Two separate potential PIVC algorithms were constructed, one relying only on clinician prediction measures or 'gestalt' and the other on objective measures.

Gestalt PIVC insertion algorithm

A clinical PIVC decision algorithm was developed that relied on clinicians' experience level and their prediction of their own likely success at a particular PIVC insertion (Fig. 2).

The algorithm uses a stepwise approach, where the level of experience, as well as predictions of success, is taken into account. Where the algorithm suggests referral to a more experienced operator, referral occurs in a stepwise sequence, to the next most experienced group, rather than being referred directly to the department's most experienced operator – who may then become inundated. A beginner would therefore refer to an intermediate practitioner, an intermediate to an experienced and an experienced to someone with ultrasound expertise. The more experienced user could re-refer if they predicted they too were likely to fail. To determine the impact of the algorithm, it was assumed that the more experienced users would have an 80% success rate (which is felt to be a conservative estimate).

In our sample, this algorithm identified 18% of sample population who would need referral to a more experienced user prior to a PIVC attempt being made. This 18% comprised 57% of all failures, and assuming a post-referral success rate of 80%, 31% of all failures could be prevented (Table 3).

Objective PIVC insertion algorithm

An alternative algorithm took into account only objective measures of clinician experience, vessel and patient data (Fig. 3).

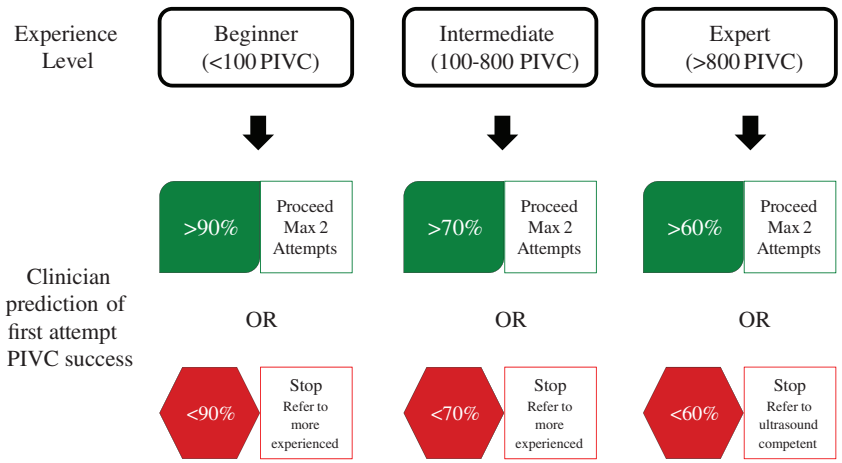

Figure 2. *Algorithm to improve first-attempt peripheral i.v. cannula success – relying on clinician experience and their pre-attempt prediction of likelihood of success or 'gestalt'.*

From Table 2, it is evident there are nine objective measures of PIVC first-attempt failure, where the subsequent rate of success is <75%. There is considerable overlap in these factors, so patients often fulfilled more than one of these categories. These factors are integrated into the algorithm shown in Figure 3. As the factors are present no matter what level the clinician, referral needs to be directed to experts rather than in the stepwise approach utilised in the gestalt algorithm. As beginner inserters have an overall success rate of <75%, strictly speaking, this algorithm should forbid them from performing any insertions. As the 'learning' environment of the ED needs to be maintained, a compromise is to have them perform insertions only under supervision. Expert users should attempt any insertion, but if two failures occur, refer for ultrasound guided insertion.

In our sample, this algorithm identified 22% of people who needed referral to a more experienced user. This 22% comprised 48% of all failures, and 17% of all failures could then theoretically be prevented (Table 3).

Discussion

Objective measures incorporating clinician experience, patient factors (like extremes of body mass index, history of i.v. drug use, diabetes) and vessel factors (such as the absence of visible and palpable veins) have previously been demonstrated to correlate with failed insertion attempts,[9–11] and many of these findings are reinforced in our study. Unfortunately, difficult vascular access is usually multifactorial, and using single objective measures to define difficult vascular access cases prospectively only identifies a minority of cases. This means that for an effective clinical decision algorithm aimed at identifying difficult PIVC patients, numerous, often overlapping factors have to be identified.

Our results demonstrate that a clinician's 'gestalt' or 'gut feeling' in predicting his or her own likelihood of PIVC insertion success or failure is remarkably accurate. As clinicians get more experienced, a higher proportion of their patients fit into the >90% likely to achieve first-attempt PIVC success group, and this is demonstrated in their actual success rates. Presumably, the clinician integrates the numerous personal, patient and vessel factors that play a part in PIVC difficulty and can estimate his or her own likely success at PIVC insertion in any given case reliably through tacit and/or intuitive reasoning. This thought mode, as Pelaccia and colleagues argue, is consistent with the recognition-primed decision model that is based on previous experiences in complex clinical settings.[26] It enables the matching of current situations with patterns learned to identify cues and promptly act, which is crucial in emergency practice.[27]

Two simple potential clinical decision algorithms were developed for comparison. The first relied on clinician gestalt, which is a novel addition to the literature, and the second on objective measures of PIVC difficulty, similar to those used in previous research. The algorithm based on clinician gestalt out-performed the objective measures algorithm in every area. This algorithm fulfils all desired criteria for a suggested PIVC insertion model in the ED as it:

TABLE 3. *Comparison of the two different clinical decision algorithms and impact on insertion failures*

Clinical decision algorithm	Success pre-intervention	% of sample identified for referral	% of failed PIVC identified	Success post-intervention	Relative % of failures prevented
Experience and gestalt	86% (586/685)	18% (124/685)	57% (56/99)	90% (617/685)	31% (31/99)
Objective measures	86% (544/633)	22% (142/633)	48% (43/89)	88% (559/633)	17% (15/89)

PIVC, peripheral i.v. cannula.

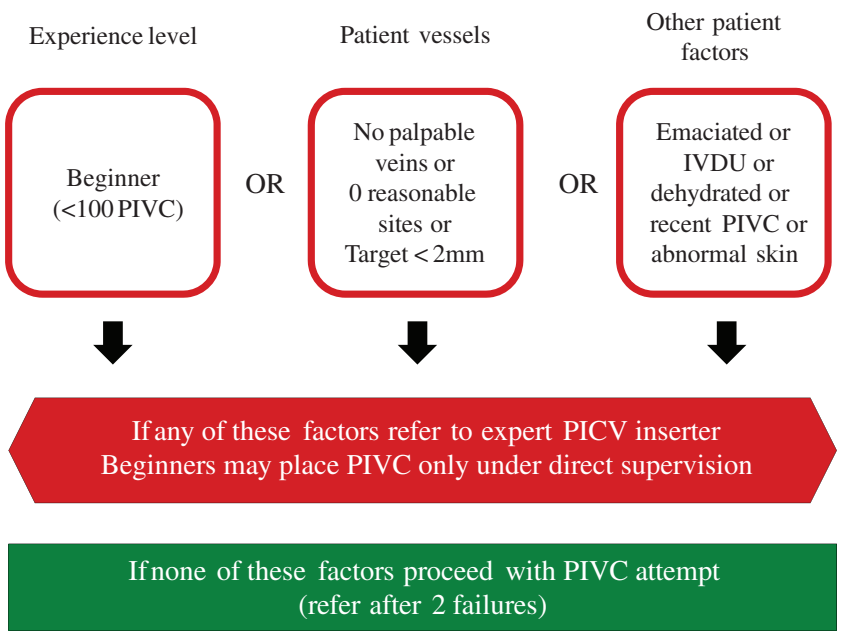

Figure 3. *Algorithm to improve first-attempt peripheral i.v. cannula success – relying on objective measures including operator experience, patient clinical state and target vessel factors.*

- enables recognition of a small subgroup of patients (18%) in whom PIVC attempts are likely to fail, allowing referral to more expert inserters prior to a failed attempt.
- rapidly identifies the majority of situations of PIVC failure (57%).
- achieves an overall first-attempt success rate at PIVC insertion of 90% and results in relative risk reduction of failed PIVC insertion of 31%.
- achieves a model where no group of patients has a PIVC attempt where the likelihood of success is <75%.
- maintains the 'teaching and learning' environment of the ED by ensuring novice inserters still have the opportunity to place PIVC to gain expertise.
- ensures that a specialist vascular access team does not get overwhelmed as not all potential difficult cases are referred immediately to the highest tier of vascular access, but rather upward in a stepwise fashion.

If the algorithm results are reproducible, then its introduction into an ED with measures of the impact on patient and resource outcomes is essential. Australian EDs see 6.7 million patients each year (2012–2013), and it is thought that around 3.35 million of these patients receive a PIVC.[28] Even assuming our data, which has an unusually high PIVC success rate, are representative of the nation, there is the potential to save A$5.5 million annually by avoiding about 145 000 unsuccessful insertion procedures with their associated labour and material costs. A model based on a lower first-attempt PIVC success rate would save even more. In 2011, an Australian study reported the cost of one PIVC insertion and removal as A$38.[26] Patients would also avoid the pain, complications and treatment delays involved in each insertion failure.

Limitations

This study relied on self-report by PIVC inserters. The decision to make this a self-reported study was based on resource constraints and the aim to understand a clinician's own predicted likelihood of insertion success in the course of their usual clinical practice rather than under observation. Self-reporting lends itself to many inherent potential errors. Under-reporting occurred in our study, with 734 patients entered over the study period, when 4433 patients were seen in ED.

Study inclusion may have been overlooked when the department was particularly busy or when patients were critically ill, and this may have missed more difficult (and failed) PIVC insertion cases. In addition, clinical staff performing PIVC placement may deliberately not have entered cases where PIVC placement failed.

Conclusion

When there is a clinical indication for PIVC insertion in the ED, it seems a clinician's 'gestalt' is excellent in determining the probability of PIVC first-time insertion success or failure. It can be used to prospectively stratify patients into groups according to their risk of PIVC placement failure.

In the first instance, repeating the study using an observational, rather than a self-reported, model is required. If the findings are similar, then validation of the clinical decision algorithm in an ED would be required.

Acknowledgements

Thanks to all the ED staff of Sir Charles Gairdner Hospital (SCGH) who contributed to this study. Thanks to Michelle Sin and staff at the Centre for Nursing Research Harry Perkins Institute for Medical Research at SCGH. Thanks also to the SCGH statistics team, particularly Charley Budgeon.

Competing interests

PJC's PhD studies are supported by an Australian Postgraduate Award (APA) Scholarship and an AVATAR Group Top-Up Scholarship funded by an unrestricted donation by Becton Dickinson. CMR's employer has received unrestricted research and educational grants and consultancy research payment from suppliers of PIVCs and associated products. These were for projects unrelated to this study. No commercial entity had any

role in the concept, design, execution, analysis or reporting of this study.

References

1. Cervellin G, Borghi L, Lippi G. Do clinicians decide relying primarily on Bayesians principles or on Gestalt perception? Some pearls and pitfalls of Gestalt perception in medicine. *Intern. Emerg. Med.* 2014; **9**: 513–9.
2. Carley, S. *What is Gestalt?* St Emlyn's. Blog post, 2014. [Cited 10 Nov 2015.] Available from URL: http://stemlynsblog.org/gestalt-st-emlyns/
3. Sabri A, Szalas J, Holmes KS, Labib L, Mussivand T. Failed attempts and improvement strategies in peripheral intravenous catheterization. *Biomed. Mater. Eng.* 2013; **23**: 93–108.
4. Jacobson AF, Winslow EH. Variables influencing intravenous catheter insertion difficulty and failure: an analysis of 339 intravenous catheter insertions. *Heart Lung* 2005; **34**: 345–59.
5. Yen K, Riegert A, Gorelick MH. Derivation of the DIVA score: a clinical prediction rule for the identification of children with difficult intravenous access. *Pediatr. Emerg. Care* 2008; **24**: 143–7.
6. Riker MW, Kennedy C, Winfrey BS, Yen K, Dowd MD. Validation and refinement of the difficult intravenous access score: a clinical prediction rule for identifying children with difficult intravenous access. *Acad. Emerg. Med.* 2011; **18**: 1129–34.
7. Carr PJ, Glynn RW, Dineen B, Kropmans TJB. A pilot intravenous cannulation team: an Irish perspective. *Br. J. Nurs.* 2010; **19**: S19–27.
8. Cuper NJ, de Graaff JC, van Dijk AT, Verdaasdonk RM, van der Werff DB, Kalkman CJ. Predictive factors for difficult intravenous cannulation in pediatric patients at a tertiary pediatric hospital. *Paediatr. Anaesth.* 2012; **22**: 223–9.
9. Fields MJ, Piela NE, Au AK, Ku BS. Risk factors associated with difficult venous access in adult ED patients. *Am. J. Emerg. Med.* 2014; 32: 1179–82.
10. Sebbane M, Claret PG, Lefebvre S *et al.* Predicting peripheral venous access difficulty in the emergency department using body mass index and a clinical evaluation of venous accessibility. *J. Emerg. Med.* 2013; **44**: 299–305.
11. Lapostolle F, Catineau J, Garrigue B *et al.* Prospective evaluation of peripheral venous access difficulty in emergency care. *Intensive Care Med.* 2007; **33**: 1452–7.
12. Australian Medical Association. *Time-Based National Access Targets for Public Hospital Emergency Departments – 2010.* [Cited 10 Nov 2015.] Available from URL: https://ama.com.au/position-statement/time-based-national-access-targets-public-hospital-emergency-departments-2010
13. Brazil V, Mitchell R. Balancing quantity and quality in emergency medicine training for interns. *Emerg. Med. Australas.* 2013; **25**: 387–9.
14. Brazil, V. *Neat 4 Hour National Emergency Access Target.* DEMTEd, 2011. [Cited 10 Nov 2015.] Available from URL: http://demted.com/tag/neat/
15. Schuh, N. *4-Hour Rule – Feasible or Flawed?* NSW Dr. 6–7, 2012. [Cited 10 Nov 2015.] Available from URL: http://amansw.com.au/media/File/NSW_Doctor_4hour.pdf
16. Maor D, O'Sullivan M, Bonning M, Mitchell R. Four-hour access targets for emergency departments: potential negative implications for the work practices and clinical training of junior doctors. *Emerg. Med. Australas.* 2011; **23**: 782–3.
17. Witting MD. IV access difficulty: incidence and delays in an urban emergency department. *J. Emerg. Med.* 2012; **42**: 483–7.
18. Au AK, Rotte MJ, Grzybowski RJ, Ku BS, Fields JM. Decrease in central venous catheter placement due to use of ultrasound guidance for peripheral intravenous catheters. *Am. J. Emerg. Med.* 2012; **30**: 1950–4.
19. Bauman M, Braude D, Crandall C. Ultrasound-guidance vs. standard technique in difficult vascular access patients by ED technicians. *Am. J. Emerg. Med.* 2009; **27**: 135–40.
20. Chinnock B, Thornton S, Hendey GW. Predictors of success in nurse-performed ultrasound-guided cannulation. *J. Emerg. Med.* 2007; **33**: 401–5.
21. Ker K, Tansley G, Beecher D *et al.* Comparison of routes for achieving parenteral access with a focus on the management of patients with Ebola virus disease. *Cochrane Database Syst. Rev.* 2015; **2**: CD011386.
22. Fields MJ, Piela NE, Ku BS. Association between multiple IV attempts and perceived pain levels in the emergency department. *J. Vasc. Access* 2014; 15: 514–8.
23. Tuffaha HW, Rickard CM, Webster J *et al.* Cost-effectiveness analysis of clinically indicated versus routine replacement of peripheral intravenous catheters. *Appl. Health Econ. Health Policy* 2014; **12**: 51–8.
24. Castro-Sánchez E, Charani E, Drumright LN, Sevdalis N, Shah N, Holmes AH. Fragmentation of care threatens patient safety in peripheral vascular catheter management in acute care: a qualitative study. *PLoS One* 2014; **9**: e86167.
25. Carr PJ, Rippey JC, Budgeon CA, Cooke ML, Higgins N, Rickard CM. Insertion of peripheral intravenous cannulae in the Emergency Department: factors associated with first-time insertion success. *J. Vasc. Access* 2016; 17: 182–90.
26. Rickard CM, Webster J, Wallis MC *et al.* Routine versus clinically indicated replacement of peripheral intravenous catheters: a randomised controlled equivalence trial. *Lancet* 2012; **380**: 1066–74.
27. Pelaccia T, Tardif J, Triby E *et al.* How and when do expert emergency physicians generate and evaluate diagnostic hypotheses? A qualitative study using head-mounted video cued-recall interviews. *Ann. Emerg. Med.* 2014; **64**: 575–85.
28. Kalisch, D. *Australian Hospital Statistics 2012–13: Emergency Department Care.* Australian Government: Australian Institute of Health and Welfare, 2013, 1–58. [Cited 10 Nov 2015.] Available from URL: http://www.aihw.gov.

au/workarea/downloadasset.aspx?id=60129544764

Supporting information

Additional supporting information may be found in the online version of this article at the publisher's web site:

Table S1. Clinician's pre-attempt prediction of their likelihood of first attempt success.
Table S2. Objective assessment indicators and first-time insertion success.
Table S3. Clinician identified patient factors and actual PIVC insertion success rates.
Table S4. Relationship between patient size and first-time PIVC insertion success.
Figure S1. Data collected in the self-reported survey.
Figure S2. Predicted *versus* actual PIVC insertion success – by experience.