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ORIGINAL ARTICLE

Implementation of a paediatric peripheral intravenous catheter care bundle: A quality improvement initiative

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Aim: To improve paediatric peripheral intravenous catheter (PIVC) care through the implementation of care bundles.

Methods: A pre–post study using mixed methods (clinical audit, staff survey, parent interviews) in 2016 at a tertiary paediatric hospital in Brisbane was conducted to evaluate the effectiveness of a PIVC insertion and maintenance bundle to improve PIVC insertion, promote function and support practice. Participants included children with PIVC, parents and staff inserting and managing PIVCs. A mnemonic care bundle, SUCCESS PIVCS (At insertion: Skills, Understand and prepare, Consent, Clean site, Escalate, Secure, Sign and document. During management: Prompt removal, Inspect hourly, Vein patency, Clean hands and Scrub the hub), was developed and implemented via visual aids, workshops and change champions. During audit, PIVC first-attempt insertion success, PIVC failure, PIVC dwell, escalation to senior clinicians and insertion and management procedures were measured.

Results: Pre-implementation audit (n = 102) and survey (n = 117) data described high rates of PIVC failure (n = 50; 49%), difficulty obtaining equipment (n = 64; 55%) and pressure to insert (n = 50; 43%). Parent interviews (n = 15) identified lack of communication, fear, appreciation of skilled technicians and technology and care giver roles as key to improving the experience. After implementation first-attempt insertion success (45 vs. 62%; risk ratio 1.37, 95% confidence interval 1.05–1.78), first-attempt escalation to senior clinicians (junior doctor 72 vs. 41%; P = <0.001) and median PIVC dwell (40 vs. 52 h; P = 0.021) improved.

Conclusion: This multi-level care bundle demonstrated improvements in the insertion and management of PIVCs; however, PIVC failure remained high.

Key words: catheterisation; child; evidence-based medicine; hospitals; paediatric; peripheral venous device.

What is already known on this topic

1 Insertion of peripheral intravenous catheter (PIVC) is particularly difficult in vulnerable populations such as paediatrics, and failure is high.
2 Implementation of care bundles to improve central venous catheter outcomes have proven successful.
3 Strategies to improve PIVC insertion success and outcomes should be multi-dimensional due to the complexity of the task.

What this paper adds

1 This paper includes the voice of the consumer to ensure the interventions are compatible with what families need.
2 Strategies to improve PIVC insertion and management must be interdisciplinary and multi-dimensional.
3 Research is required to investigate additional interventions such as innovations in dressing and securement of PIVCs to reduce overall PIVC failure.[1,2]

Peripheral intravenous catheters (PIVCs) are ubiquitous in paediatric health care and provide an important modality to administer fluids, antibiotics and other necessary medical treatments. PIVC insertion in the paediatric patient is often unsuccessful on the first attempt[3] and is routinely cited as one of the most painful and anxiety-producing inpatient experiences.[4–6] Intravenous therapy in the health-care setting is so commonplace that it is possible health-care professionals, including nurses and medical officers, become desensitised to the frequency and general occurrence of complications and injury that results.[7,8]

Internationally, it is estimated that more than 300 million PIVCs are sold every year in the USA alone, and 60–90% of hospitalised patients require a PIVC during their hospital stay.[9,10] In Australia, PIVCs cause over 4000 cases of bloodstream infections every year, with an associated mortality of over 10%.[11] The sheer prevalence of PIVCs suggest that even the smallest improvement in PIVC outcomes will equate to significant improvement in health-care outcomes and health-care dollars saved.[8] Quality and safety agencies nationally and internationally provide recommendations to prevent intravascular device complication, including

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designated trained personnel to insert and maintain PIVCs, surveillance, hand hygiene, proper use of aseptic non-touch technique and recommendations regarding catheter site care and early removal when no longer necessary.[11,12]

The insertion of PIVC is a complex task, and up to half of the children that present to hospital who require a PIVC have difficult venous access (DiVA).[13–15] Difficulty in obtaining peripheral venous access in children is multi-faceted and compounded by reduced procedural co-operation, increased patient and parental anxiety, increased adipose tissue and departmental staff with limited paediatric experience.[15] Unfortunately, once the PIVC is inserted, up to 50% of these will fail prior to completion of treatment.[4] The cost of PIVC failure is far-reaching and often results in delays to critical treatment, prolonged hospitalisation and, most worryingly, the need to re-insert PIVC.[4,16]

Management of PIVCs is complex as various interdisciplinary clinicians are involved in their insertion and management. Care bundles were introduced by the Institute for Healthcare Improvement to support clinicians and increase the reliability of evidence-based health-care practices.[17,18] Care bundles have been implemented extensively to improve practice and reduce the incidence of commonly reported, hospital-acquired adverse events, such as ventilator-associated pneumonia,[19,20] surgical site infections,[21,22] catheter-associated urinary tract infections[23] and sepsis.[24,25] Care bundles have been successfully implemented in vascular access to prevent central line-associated bloodstream infection related to insertion[26–29] and maintenance practices[30,31] and have been effective at reducing the high rates of associated morbidity and mortality. Despite their prevalence and susceptibility to failure, less attention has been paid to the implementation of care bundles designed to prevent failure of PIVC.

The objective of this project was to develop and implement a PIVC insertion and maintenance bundle in paediatrics and evaluate its effectiveness to improve PIVC insertion (i.e. first-attempt insertion) and performance (i.e. reducing failure, improving dwell time).

Methods

Study design

A prospective, mixed methods, pre–post design[32,33] with three phases (pre-implementation, development and implementation and post-implementation) was undertaken at Queensland Children's Hospital (QCH) between February 2016 and February 2017. Ethical approval for the project was obtained from the Children's Health Queensland, Human Research Ethics Committee (HREC/16/QRCH/32).

Setting

The Queensland Children's Hospital is a 359-bed paediatric hospital in Queensland, Australia, and provides tertiary care for high acuity patients from birth to 18 years of age. Critical care areas, including emergency department, intensive care unit and operating theatres, were not included in the project for pragmatic purposes due to differing baseline insertion practices.

Phase 1 pre-implementation (February–May 2016)

To describe baseline PIVC experience and inform design and implementation of the care bundle, pre-implementation PIVC insertion and management practices were identified via three sources: (i) an online survey of staff inserting PIVC (including PIVC insertion training and resourcing), (ii) interviews with parents or carers of children who recently had a PIVC inserted and (iii) a prospective audit of PIVC clinical practice (including insertion attempts, post-insertion performance and management).

Survey

Based on previous surveys of PIVC management,[34] a short online survey, consisting of 13 multiple choice questions, was distributed to all hospital staff who insert PIVCs via email. The survey was anonymous, and participation was voluntary. The survey format consisted of a brief demographic section outlining the participants' professional group, total experience in PIVC insertion in acute care facility, total experience inserting PIVCs in paediatric patients and knowledge of PIVC insertion and escalation procedures. In order to describe the competence and confidence of staff inserting PIVCs, questions were incorporated to reflect the training and mentorship provided to the clinicians as well as the availability of equipment. Respondents were asked to rate each item on a 5-point Likert scale (Always, Frequently, Sometimes, Rarely, Never) or simple yes/no responses.

Interviews

Exploratory interviews of parents and care givers of children who had recently had a PIVC inserted were undertaken to better understand the experience of PIVC insertion and management through hospitalisation. This included exploration of suggestions for how the experience could be improved. After informed consent, parents and care givers were interviewed one on one with semi-structured questions, which were audio-recorded and transcribed verbatim. Interview data were analysed thematically, focusing on themes and patterns concerning each of the research questions.[35,36] Standard phases of thematic analysis were followed, including familiarisation, deductive code generation, searching, reviewing and defining the identified themes.[37,38] The sample size was determined by achievement of data saturation.[37,38]

Audit

A convenience sample of 102 patients (<18 years) admitted to medical and surgical wards requiring insertion of a PIVC for 24 h or greater had their PIVC details prospectively audited. The primary outcome was the proportion of PIVCs successfully inserted on the first attempt. Secondary outcomes included other aspects of PIVC insertion, including the seniority of clinicians attempting insertion, total number of attempts and PIVC insertion practices (e.g. use of guidance technology, sites). PIVC failure was determined by any unintended cessation of PIVC function prior to completion of treatment.[39] Complications of PIVC included bloodstream infection and dwell time. General PIVC management was described through use of dressing, securement and immobilisation. It is not standard practice within our paediatric institution to routinely replace PIVCs; rather, removal and replacement occurs at the completion of treatment or as clinically indicated. Demographic, clinical and device characteristics of the

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participants were also recorded. Data were collected prospectively by a trained research nurse using a standardised, paper-based collection form and were transcribed into SPSS (version 24; SPSS, IBM, New York, NY, USA).

Phase 2 development and implementation (April–August 2016)

Following discussion with a key stakeholder group, a PIVC insertion and management care bundle (SUCCESS PIVCS (At insertion: Skills, Understand and prepare, Consent, Clean site, Escalate, Secure, Sign and document. During management: Prompt removal, Inspect hourly, Vein patency, Clean hands and Scrub the hub)) mnemonic to prompt best practice (Fig. 1) was developed and then implemented.

Development of SUCCESS PIVC bundle

Following Phase 1, an interdisciplinary group of key stakeholders was convened to review the Phase 1 results and design intervention strategies. The group consisted of local vascular access specialists, anaesthetists, infection control, junior and senior medical officers, clinical researchers and nurses.

After reviewing the pre-implementation data, the key stakeholder group agreed on a 'bundle' for insertion and maintenance of PIVCs based on current local and international guidelines.[40,41] The group decided to implement a combined insertion and maintenance bundle for PIVCs in order to focus on the longevity of the device. The use of a catchy mnemonic makes the bundle easy to remember and acts as a prompt for clinicians to undertake certain tasks or behaviours.[42] SUCCESS PIVCS was developed as a checklist for the insertion and management of PIVCs, with each evidence-based

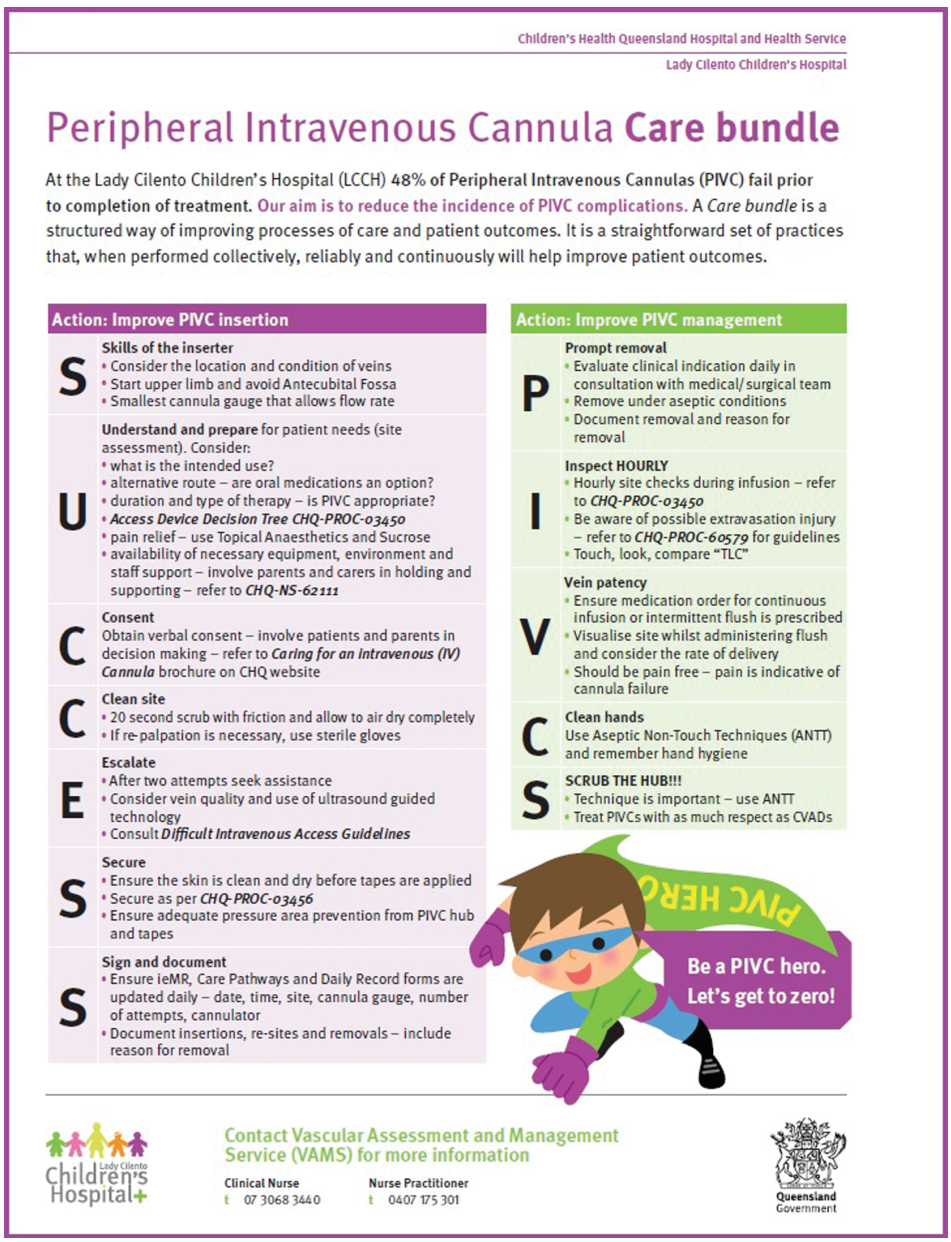

Fig. 1 SUCCESS peripheral intravenous catheter care bundle.

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Table 1 PIVC inserting clinician's responses: Practices and resources (n = 117)

		n (%)
Have you received formal PIVC insertion training?	Yes	80 (68)
Have you received training in paediatric PIVC insertion?	Yes	13 (11)
Would you like more skills and training in paediatric PIVC insertion?	Yes	59 (50)
How often do you find PIVC insertion difficult?	Always	2 (2)
	Frequently	24 (21)
	Sometimes	64 (55)
	Rarely	27 (23)
How often do you find PIVC insertion easy?	Always	2 (2)
	Frequently	24 (21)
	Sometimes	64 (55)
	Rarely	27 (23)
Have you ever declined to attempt a PIVC insertion when clinically indicated?	Yes	67 (57)
Within your practice at the Lady Cilento Children's Hospital – How often do you attempt PIVC insertion on a child with poor vein quality?	Always	7 (6)
	Frequently	63 (53)
	Sometimes	32 (27)
	Rarely	9 (8)
	Never	6 5
Are you aware of the escalation process for difficult PIVC insertion during normal working hours?	Yes	78 (67)
Are you aware of the escalation process for difficult PIVC insertion after hours and on week-ends?	Yes	61 (52)
Are you aware of the local hospital policy on PIVC insertion and maintenance?	Yes	47 (40)
Are you knowledgeable of current evidence based PIVC insertion and maintenance practices in paediatrics?	Yes – Excellent	11 (9)
	Yes – Good	38 (33)
	Yes – Average	42 (36)
	Yes – Poor	7 (6)
	No – Not at all	19 (16)
How often do you find it difficult to find equipment for PIVC insertion?	Always	5 (4)
	Frequently	14 (12)
	Sometimes	45 (39)
	Rarely	34 (29)
	Never	19 (16)
Do you think PIVC resourcing affects/impedes your confidence when inserting the PIVC?	Yes – Greatly	6 (5)
	Yes – Moderately	17 (15)
	Yes – Slightly	30 (26)
	No – Not at all	64 (55)

PIVC, peripheral intravenous catheter.

practice forming the initial letter of the acronym SUCCESS PIVCS (Fig. 1). The acronym SUCCESS formed the insertion bundle: Skill of the Inserter, Understand and prepare for patient needs, Consent, Clean site 2% chlorhexidine gluconate and 70% alcohol swab stick, Escalate, Secure with bordered polyurethane dressing, Sign and document. PIVCS formed the maintenance bundle: Prompt removal, Inspect hourly, Vein patency by intermittent flush of 0.9% sodium chloride flush, Clean hands, Scrub the hub with 2% chlorhexidine gluconate and 70% alcohol swab.

Implementation of the SUCCESS PIVC bundle

The Behaviour Change Wheel (BCW) developed by Mitchie *et al*.[43] was used as an implementation framework. This incorporates the premise that, for behaviour change to be successful, three conditions need to exist: the person performing the behaviour needs to have the physical and psychological capability (C) to perform the behaviour and the social and physical opportunity (O) and the motivation (M) to perform the behaviour (B).[30] Use of the BCW to facilitate practice change began with the identification of potential barriers and facilitators. Based on the COM-B model, the following COM steps were initiated to enable successful implementation of the intervention (B).

C – Change facilitators on each ward were identified to ensure they received intensive training on the bundle components, and they, in turn, could support this training in their clinical area. Visual materials such as the Touch, Look and Compare (TLC) Fig. S1 (Supporting Information), was adapted and used with permission from Cincinnati Children's Hospital to provide visual reinforcement of the PIVC assessment requirements.[7] This method advocated hourly checks if the patient had a continuous infusion or on each injection with intermittent intravenous medication. The PIVC site required touch to identify pain, swelling, temperature change, look for redness, bruising, swelling or fluid leakage and compared the extremity with the PIVC to the contralateral extremity to identify any change in shape or size.

O – Small group education sessions, as well as opportunistic one-on-one training sessions and real-time feedback, were provided to support learning. Visual aids were also provided to act as prompts when education was not available. PIVC insertion trolleys were standardised and provided to all clinical areas. The PIVC trolley only contained consumables necessary for PIVC insertion and were standardised to promote familiarity and ease of access to PIVC insertion equipment.

M – Education consisted of best-practice case studies demonstrating harm associated with PIVC failure.

Phase 3 post-implementation (September–January 2016)

Within Phase 3, the Phase 1 pre-implementation audit was repeated, with a further 102 paediatric patients requiring PIVC for >24 h prospectively audited daily for PIVC insertion, performance and management using the previously described processes. Opportunistic staff engagement and education strategies continued throughout the final phase.

Data analysis

At the completion of the project, audit data were thoroughly cleaned, with 10% of data checked by a second research nurse to ensure accuracy prior to exporting into IBM SPSS (version 24) and Stata 15 (Statacorp, LLC, College Station, TX, USA) for statistical analysis. Descriptive statistics, appropriate to the distribution and data characteristics, were used to report clinical characteristics of audit participants. The effectiveness of the SUCCESS PIVC implementation on the primary and secondary outcomes was analysed via hypothesis tests and/or the calculation of RR. P values at <0.05 were considered statistically significant. Missing data were not imputed.

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Table 2 Parent/care giver interviews

Theme	Participant statement
Communication	'…. Preparing people with a little bit more information would be good … just having a little handy tool about the care, about taking care of it and what things need to be done while you're there'
	'Because there are so many sick children here, having an IV is fairly ordinary. Whereas for someone who has never had one before, it's not ordinary … there probably could have been more explanation, not just assuming'
	'Maybe if there's a choice (insertion), then we should be asked rather than just told'
Apprehension and fear	'…. My initial reaction when she needs to be re-cannulated is dread'
	'My biggest worry is probably just that … what if it's hurting him and he can't tell us'
	'.. it's harder to hold them, bath them, be close to them'
	'I think the worst because the last time he had one done he crashed. Because it took four attempts to get a line in and he worked too hard by that stage screaming and he crashed. So for me, my first thought is, is that going to happen again?'
	'I was really worried when I saw there was blood in the extension tubing attached to the cannula. I felt really frightened because I thought maybe something harmful was happening to my child'
Appreciation of skilled technicians and technology	'He'd (the doctor) asked the nurse if there was a red light available to check for veins because he couldn't quite see any. He said if he couldn't get it in then they would have to get somebody back with an ultrasound to do the cannula. I thought if you can't see properly and you're not 100% sure, shy keep prodding and poking a baby…?'
	' …. Make sure they know what they're doing …'
	'They should have someone with more experience straight up when they're this little …'
Recognition of the role of the care giver	'Being well prepared before they come in … we have had experiences where they've started and then had to leave to go and get something else …'

Results

Phase 1 staff survey

The results of the staff survey are tabulated in Table 1. The overall response rate was 39% (117/300), with the majority of respondents being medical officers (80%). Over three-quarters (77%) of inserters find PIVC insertion difficult at least sometimes. Almost all (87%) PIVC inserters stated that they frequently or sometimes attempted insertion on patients with DiVA. One-third (33%) of respondents did not know who to contact for insertion assistance during working hours, and nearly half (48%) did not know who to contact for assistance after hours. When asked about the training they had received to insert PIVCs, 32% indicated they had never received any formal training, and 50% of respondents indicated they would like to receive more skills and training.

Table 3 Audit: Participant demographics and clinical characteristics pre- (n = 102) and post- (n = 102) bundle implementation

	Pre, *n* (%)	Post, *n* (%)
Age, years, mean (SD)	7.1 (6.1)	6.2 (5.6)
Gender		
Male	67 (66)	64 (63)
Ward area		
Medical/Overflow oncology	30 (29)	23 (22)
Medical	18 (18)	19 (19)
Cardiac	13 (13)	16 (16)
General surgery	14 (14)	14 (14)
Orthopaedic/Neurosurgery	11 (11)	14 (14)
Infants	11 (11)	13 (13)
Oncology and bone marrow transplant	5 (5)	3 (3)
Number of previous PIVC (current admission)		
0	12 (12)	30 (29)
1	37 (36)	35 (34)
2–4	27 (26)	30 (29)
>4	26 (25)	7 (7)
Reason for PIVC†		
Antibiotics	45 (44)	64 (62)
Other medications	38 (37)	40 (39)
Intravenous fluids	27 (26)	26 (25)
Procedure	10 (10)	5 (5)
Blood sampling	8 (8)	9 (9)
Difficult access	5 (5)	15 (15)

†More than one response per participant. PIVC, peripheral intravenous catheter; SD, standard deviation.

Phase 1: Parent interviews

Fifteen care givers participated in the interviews prior to data saturation. Four common themes emerged from these interviews:

1 Communication.
2 Apprehension and fear.
3 Appreciation of skilled technicians and technology.
4 Recognition of the role of the care giver.

Table 2 demonstrates example statements gathered during the one-on-one interviews with parents and care givers surrounding their experience of PIVC insertion within paediatrics, within each of the key themes.

Communication

Parents and care givers indicated that they wanted to be better informed and given a clear explanation of what to expect of the

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Table 4 Audit: PIVC insertion and performance pre- and post-bundle implementation

	Pre (*n* = 102)	Post (*n* = 102)	Risk ratio (95% CI) or *P* value
PIVC insertion characteristics			
First PIVC attempt success			
n (%)	46 (45)	63 (62)	1.37 (1.05–1.78)
Total number of insertion attempts			
Median (IQR)	2.0 (1.0–3.0)	1.0 (1.0–2.0)	0.022†
Insertion site, *n* (%)			
Hand	34 (33)	31 (30)	Not calculated
Ante-cubital	28 (27)	25 (25)	—
Forearm	24 (24)	29 (28)	—
Foot	9 (9)	9 (9)	—
Saphenous	6 (6)	6 (6)	—
Scalp	1 (1)	1 (1)	—
Other upper limb	0 (0)	1 (1)	—
Use of technology, *n* (%)			
No	86 (84)	77 (75)	Not calculated
Ultrasound	16 (16)	24 (24)	—
Infrared	0 (0)	1 (1)	—
Catheter gauge, *n* (%)			
20 (pink)	8 (8)	7 (7)	Not calculated
22 (blue)	60 (59)	55 (54)	—
24 (yellow)	34 (33)	39 (38)	—
Other	0 (0)	1 (1)	—
Pain relief, *n* (%)			
None	24 (24)	22 (22)	Not calculated
Positioning/Swaddling	17 (17)	19 (19)	—
Sucrose	10 (10)	16 (16)	—
Topical anaesthetic	35 (34)	41 (40)	—
Distraction	40 (39)	29 (28)	—
Oral analgesic	1 (1)	2 (2)	—
Oral/Intra-nasal sedation	1 (1)	0 (0)	—
Entonox	0 (0)	1 (1)	—
Other	18 (18)	8 (8)	—
PIVC performance			
PIVC dwell, h			
Median (IQR)	40 (22–60)	52 (25–78)	0.021†
PIVC failure			
n (%)	50 (49)	51 (50)	1.02 (0.77–1.35)
Complications, *n* (%)‡·§			
Accidental dislodgement	8 (16)	4 (8)	Not calculated
Suspected infection	1 (2)	0 (0)	—
Phlebitis	7 (14)	5 (10)	—
Blocked/Leak	7 (14)	3 (6)	—
Extravasation	0 (0)	3 (6)	—
Central access required	0 (0)	4 (8)	—
Other	4 (8)	0 (0)	—
Infiltrated	27 (54)	33 (65)	—
PIVC management			
PIVC securement, *n* (%)			
'Teddy bear' polyurethane dressing	95 (93)	95 (93)	Not calculated
Pressure-relieving foam	77 (75)	87 (85)	—
Thin brown tape	17 (17)	25 (25)	—
Bordered polyurethane dressing with border	6 (6)	8 (8)	—
Stretchy brown tape	4 (4)	6 (6)	—
Gauze	2 (2)	1 (1)	—
Standard polyurethane dressing	2 (2)	0 (0)	—

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Table 4 (Continued)

	Pre (n = 102)	Post (n = 102)	Risk ratio (95% CI) or P value
Paper tape	1 (1)	0 (0)	—
Other	15 (15)	11 (11)	—
PIVC immobilisation, n (%)			
Arm board	64 (63)	73 (72)	Not calculated
Crepe bandage	16 (16)	8 (8)	—
White elastoplast	70 (69)	84 (82)	—
Tubifast	68 (67)	76 (75)	—
Styrofoam cup	2 (2)	1 (1)	—

†Wilcoxon rank-sum test. ‡More than one response per participant. §For failed peripheral intravenous catheters (PIVCs). —, No data; CI, confidence interval; IQR, interquartile range.

insertion process, including the risks and benefits and alternative treatment options. Many care givers spoke about feelings of being inundated with verbal information, especially after feeling exhausted from the routine of caring for a sick child, and suggested that written information would be beneficial. They also reported that, if they were better informed, they could better prepare their child.

Apprehension and fear

Parents and care givers demonstrated high levels of anxiety and felt fearful and anxious when the need to insert a PIVC was proposed. Parents and carers identified that they want to be listened to, given clear instruction and treated by empathetic clinicians. Parents indicated that their anxiety would be reduced if they knew what to do and had time to prepare their child and apply topical anaesthetic and other pain-relieving measures. When discussing the care of a PIVC, parents and carers indicated that consistent management of PIVCs made them feel more confident, and those clinicians who were more responsive to patients' painful response to manipulation of PIVC made them feel less fearful.

Appreciation of skilled technicians and technology

All of the respondents acknowledged the difficulty, and sometimes urgency, involved in the insertion of a PIVC. Carers spoke about situations where it had taken several attempts to insert the catheter, their feelings of guilt and anguish when their child screamed in pain and how relieved they felt when it finally went in. Some parents spoke of instances where they had to tell the doctor to stop because they could see their child was too distressed. Parents reported finding this difficult because they trust health-care providers and assume that, if they are trying so hard to insert a PIVC, it must be necessary.

Recognition of the role of the care giver

Almost all parents and care givers agreed that they needed to be present during the catheter insertion process to support their child emotionally. Parents expressed that they wanted to be involved, to feel empowered in an otherwise vulnerable situation, and more importantly, they know their child best. Parents verbalised that clinicians need to provide them with direction on how to assist with the insertion process.

Phases 1 and 3 audit

The demographics and clinical characteristics of the audit participants in the pre- and post-implementation phases are displayed in Table 3. While admitted to general medical and surgical wards, the participants had a range of clinical indications requiring PIVC, with most clinical and demographic criteria similar between the study phases.

As described in Table 4, the implementation of the SUCCESS PIVC care bundle was associated with a significant reduction in the median number of PIVC insertion attempts (pre 2.0 vs. post 1.0; $P = 0.022$) and an increase in success of PIVC insertion on the first attempt $n = 46$ (45%) pre to $n = 63$ (62%) post (RR 1.37, 95% confidence interval 1.05–1.78). There was also a significant increase in the immediate escalation of PIVC insertion to a more senior clinician during phase 3, with a reduction in resident medical officer (RMO) as the clinician making the first PIVC insertion attempt from 72% pre to 41% post ($P = <0.001$) and an associated increase in those attempted by a more senior clinician (paediatric registrars, paediatric nurse practitioner) (28 pre vs. 59% post, $P = <0.001$; Table S1 (Supporting Information)).

There was a significant increase in mean PIVC dwell (pre 40 pre vs. post 52 h; $P = 0.021$). PIVC failure or complication rates remained at similar levels, no bloodstream infections occurred, and the majority of PIVCs failed due to infiltration (54 and 65%). The majority of children in this cohort (88 and 71%) required multiple PIVCs during their hospital admission to complete the necessary treatment. As displayed in Table 3, the proportion of patients requiring >4 PIVCs to complete treatment reduced in the post-implementation period (25 and 7%). The use of technology and pain relief remained at similar levels after the implementation of SUCCESS PIVCS.

Discussion

Reliable vascular access is critical for the effective medical treatment of many of our patients. Unfortunately, PIVC insertion and function is not a seamless procedure for many hospitalised paediatric patients. Previous studies have attempted to improve PIVC outcomes by reducing complications such as infection,[44] infiltration and extravasation.[7] This is the first study to describe and implement a PIVC insertion and maintenance bundle to improve PIVC insertion and performance. The implementation demonstrated a significant increase in first-attempt success, reduction in total number of PIVC insertion attempts and an increase in the survival time of PIVC from insertion to removal. These have substantial clinical significance as the ability to attain and maintain a

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functional PIVC for paediatric patients has positive outcomes for the patient, staff and health-care resourcing.[3,10,15]

Despite the increased vigilance and regular assessment of PIVC sites, PIVC failure did not reduce after implementation of the SUCCESS PIVC intervention (49 and 50%). In this study, the main reason for PIVC failure was infiltration, which contributed to more than half of PIVC failures. Tofani *et al*.[7] suggest that children may be more susceptible to PIVC infiltration and extravasation because of developmental and physiological factors, such as communication skills, activity level and fragile veins. Despite an intervention to improve site checks, they reported that they were unable to maintain a sustained reduction in failure caused by infiltration.

The significant increase in the number of PIVCs successfully inserted on the first attempt in this study is likely to be related to the increase in early escalation to a more experienced practitioner. This audit demonstrated an overall improvement in clinicians taking the time to thoroughly assess their patients' vasculature and escalate to a clinician more skilled in vascular access. Currently, there is no validated tool that provides direction for clinicians within inpatient facilities faced with inserting a PIVC in paediatric patients with DiVA. Previous studies in adults[45] and paediatric emergency[46] have successfully developed a tool to identify DiVA patients; however, these tools lack generalisability to the wider inpatient paediatric cohort and provide little direction for treatment escalation. Whilst the work of Hallam *et al*.[45] provides a guide for managing those patients identified as DiVA based on vascular assessment, it has been developed for use in adults and lacks data demonstrating its clinical effectiveness. The absence of clinically validated tools that provide clinicians with an escalation pathway delays referral to the most appropriately skilled clinician, delays initiation of treatment and might increase stress and anxiety related to the insertion of PIVC due to numerous failed PIVC attempts.

The staff survey data suggested there was a lack of standardisation of clinical equipment, procedures and clinical support for junior medical officers who rotate through hospitals and the paediatric environment. The clinicians surveyed suggested that these factors may impact their confidence and ability to successfully insert PIVC within the paediatric environment. Whilst care bundles provide a structured approach to reduce complications, it is important to ensure that the right equipment is available to assist in compliance with bundle components. Previous studies in PIVC insertion[47] and central venous access device care and maintenance[30] demonstrated improved reliability of care when standardised equipment was available in a dedicated procedure trolley. As part of the implementation strategy of SUCCESS PIVC, dedicated, standardised PIVC trolleys with all necessary equipment relevant to the bundle were rolled out within the hospital. In addition, a PIVC learning package and video was developed and provided to all medical officers during hospital orientation. Whilst staff were not re-surveyed after the implementation of SUCCESS PIVC, the clinical outcomes within the audit demonstrate improvements in availability, and familiarity with equipment influenced compliance with PIVC dressing and securement and reduction in total number of insertion attempts.

The voice of the consumer was used as a facilitator in the successful implementation by ensuring that the design of the intervention was what families needed.[48] Communication, fear and apprehension, appreciation of skilled technicians and technology and recognition of the role of the care giver were recurrent themes during individual interviews. This is in agreement with a recent international survey by Cooke *et al*.[49] and a qualitative study by Larsen *et al*.,[38] who found the patient experience of PIVC insertion to be painful and stressful and that patients and parents need to be involved throughout the PIVC planning. These viewpoints were incorporated within the design of the SUCCESS PIVC by encouraging thorough patient assessment, understanding the needs of the patient, preparing the environment and ensuring that the parent or care giver was fully informed of the need for vascular access and that it was the best option after other alternatives had been considered. Further understanding the parents' experience and expectations will allow clinicians to improve collaborative relationships with parents and provide a more positive experience for patients requiring PIVC.[49]

Parent and care giver interviews uncovered anxiety relating to the number of failed PIVC attempts and their frustration when escalation to more skilled practitioners was delayed. Although technology exists to improve the first-time success of PIVC insertion, this is often reliant on the skill of the inserter. Near-infrared technology improves vessel visualisation; however, it does not indicate the depth and size of the vessel.[50] Ultrasound is a promising alternative to traditional method of PIVC insertion;[15,51] however, its usefulness is reliant on staff receiving sufficient training and practical experience.[52] The lack of clinicians trained to use these technologies might be responsible for their limited use in this study.

Despite its contribution, this study has several limitations. The PIVC audit data collection was undertaken by a research nurse using the same processes pre- and post-intervention; however, participants were opportunistically identified, and therefore, only a small sample of all inpatient PIVCs was included, limiting reliability. Insufficient resources precluded assessment of every medical and surgical inpatient PIVC. However, efforts were made to collect data on a wide range of participants, following identical processes, in both study phases. Compliance with the bundle elements was not measured within the implementation phases due to resourcing. Finally, part of the implementation strategy (TLC) is potentially disruptive to the paediatric patient and time consuming for nursing staff; therefore, it is difficult to guarantee compliance with this task. Despite these limitations, this project follows a pragmatic, replicable, high-quality design, a novel intervention, and provides a basis for future practice change to improve PIVC care.

Conclusion

This project demonstrates that the implementation of a multimodal bundle of care, including education, visual aids and standardisation of equipment, improved many aspects of PIVC insertion and management. Understanding the patient and carer perspective through interviews contributed to the intervention design to improve the overall patient experience. This project used a pragmatic design to enable replication in other hospitals and provides a framework for clinicians in other paediatric health-care facilities to develop similar interventions based on local service needs. Although PIVC bundles significantly improved some aspects of care, it did not demonstrate a reduction

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in PIVC failure. This suggests that additional interventions, such as innovations in dressing and securement of PIVCs, are urgently required to achieve the 'holy grail' of SUCCESS PIVCS.

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Supporting Information

Additional Supporting Information may be found in the online version of this article at the publisher's web-site:

Figure S1. Visual prompt: Touch, Look, Compare.
Table S1. Escalation to clinician of more seniority

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