Peripheral intravenous catheter duration and failure in paediatric acute care: a prospective cohort study

Running Title: *PIVCs in paediatric acute care*

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Abstract

Objective: Children admitted to hospital commonly require peripheral intravenous catheters (PIVCs) for treatment. This study sought to address a gap in the literature about current practice in the securement and dressing of PIVCs in paediatric acute care, and to ascertain the duration and failure of these devices.

Methods: A prospective cohort study conducted at the Royal Children's Hospital in Queensland, Australia. All patients aged 0-15 years, who presented to the Emergency Department between 16 July and 16 October 2012, and had a PIVC inserted prior to emergent admission to the hospital were included.

Results: Of 458 participants, median device duration was 29 hours (IQR 13-58 hours), and ranged from less than one hour to 16 days. One quarter (113/456; 24.8%) of PIVCs were removed due to device failure, presenting as: infiltration (65/456; 14.3%); accidental dislodgement (23/456; 5.0%); blockage (12/456, 2.6%); phlebitis (7/456, 1.5%); or 'other' (6/456; 1.3%). PIVC securement and dressings were predominantly bordered polyurethane dressings and splints (n=457/458; 99.8%). PIVC placement in the antecubital fossa, in comparison to the hand, was significantly associated with an increased risk for failure (p=0.03). No other patient and device characteristics had a significant association with device failure (p>0.05). The median dwell time of PIVCs that failed was significantly longer than the PIVCs that did not fail (44.0 vs 25.5 hours; p=0.002). Less than half (53/113; 46.9%) of failed catheters were replaced with a new PIVC.

Conclusions: Observed failure rates were high for a clinically essential device, however there is no established rate of acceptability against which the results can be benchmarked against to facilitate effectiveness of practice. Many PIVCs appeared to remain in place longer than needed. Dressing and securement practice was homogenous. PIVC placement in the antecubital fossa should be minimised to reduce the risk of paediatric PIVC failure.

Keywords

Peripheral Venous Catheterization; Securement Practices; Clinical Audit; Emergency Medicine; Medical device failure; Paediatric.

Introduction

Peripheral intravenous catheters (PIVC) are one of the most ubiquitous medical devices, with many acute care paediatric patients requiring their insertion for the administration of medicines and/or fluids. Despite being a common procedure (1), PIVC placement can be difficult and time-consuming, particularly for infants and young children in emergency departments (EDs) due to smaller, less visible veins, reduced procedural cooperation, increased adiposity and parental stress (1). Multiple staff and attempts may be required,with only 40-50% of paediatric PIVC placements successful on the first attempt, and 20-30 minutes typically required to succeed (1-4). Paediatric inpatients consistently report PIVC placement as the leading source of procedure-related pain in hospital (5-7).

PIVCs are foreign objects placed within the body, with the external component requiring securement to the skin. Dressings and other securements must ensure PIVCs do not dislodge and fall out, or move out of the vein and into surrounding tissue. PIVC failure is common, with accidental dislodgement, phlebitis, infiltration, and occlusion commonly causing premature removal of the device (8-10). Effective dressings must also prevent infection by inhibiting bacteria at the skin site or the surrounding environment from entering the PIVC wound and into the bloodstream. Such infections, whilst rare, involve serious morbidity and mortality risk for patients, and increase treatment costs to the institution (11). Emergently inserted intravascular catheters, when adherence to aseptic technique cannot be ensured, are at higher risk of developing infection (12).

Whilst failure rates of up to 92% of PIVCs in hospitalised adults have been described (9, 10, 13, 14), there has been no recent investigation across the paediatric hospital population. Previous studies have been limited to either Neonatal Intensive Care Units (NICU), or paediatric units within adult hospitals, or have not adequately described PIVC dwell times and modifiable risk factors.

There are no reported benchmarks for PIVC failure rates, or PIVC lifespan, for paediatric acute care in order to compare the efficacy of interventions or care. PIVC lifespan in NICU patients has been reported at a median of 23 to 40 hours (15-17). Several studies undertaken in the paediatric wards of

predominantly adult hospitals reported longer average PIVC dwell times of 39 to 60 hours (18-20). Callaghan and colleagues (21) in 2000 undertook a prospective, non-randomised study (n=407) comparing the effect of standard gauze and tape to transparent polyurethane dressings in a tertiary paediatric hospital in Australia. They described a higher incidence of PIVC failure with polyurethane dressings compared to usual care (29% versus 19%, p=0.18), but did not provide PIVC dwell times (21). Clinical practice and international best practice recommendations have changed considerably since this study was undertaken, including the use of 2% chlorhexidine gluconate in alcohol for skin antisepsis, so its results cannot be universally applied to current practice.

Measures to reduce failure and prolong the functional duration of PIVCs are important to limit the number of PIVC resites, minimise unnecessary child discomfort and distress, and reduce the risk of infection and venous insufficiency in children with chronic disease (17). Effective dressing and securement is one such strategy. However, there is a paucity of studies in the tertiary paediatric population to measure the prevalence of failure, to identify risk factors for complications, and to inform measures to improve the functional duration of PIVCs. Our research aimed to provide preliminary data on PIVC duration and failure rates, identify any significant risk factors for PIVC failure, and to describe current dressing and securement strategies in this vulnerable group of patients.

Methods

Design

A prospective, cohort study was undertaken between 16 July and 16 October, 2012.

Setting

The study was conducted within the ED at the Royal Children's Hospital (RCH) Brisbane. The RCH is a tertiary level, specialist paediatric teaching hospital in Queensland with 168-bed capacity. It provides health services to children and young people aged 0-15 years of age. The ED services around 25,000 presentations annually, with 20-25% requiring inpatient admission.

Sample and recruitment

All patients aged 0-16 years of age, whom had a PIVC inserted in the ED at the RCH, and were admitted to an inpatient ward, were eligible for inclusion. Children were excluded from the study if they were: > 16 years of age; not admitted to the RCH; and had their PIVC inserted prior to presentation. Study participation was initiated by any member of the ED nursing or medical staff by attaching the data collection form to the patient's notes, and collecting the baseline data.

Outcome variables

The primary outcomes were: (i) PIVC dwell time; (ii) PIVC failure (occlusion, infiltration, phlebitis, dislodgement or infection); and (iii) dressing and securements used. Each of the conditions proceeding PIVC failure were defined by clinicians, as per their standard clinical decision making. No formal assessment tools were used. Secondary outcomes were demographic and clinical variables considered for potential significant association with PIVC failure including: gender; age; time of insertion; site location; cannula gauge; and reason for insertion.

Insertion and management of PIVCs

Standard Queensland Health, hospital and ED practice was used for the insertion, maintenance and removal of the PIVC (22). The hospital does not have a specialist intravenous (IV) insertion team, thus all patients had PIVCs inserted by ED medical staff (consultants, registrars, or resident medical officers), or ED nursing staff who had completed specialised PIVC insertion training and assessment. The skin was decontaminated with 2% chlorhexidine gluconate in 70% alcohol, then with an aseptic non-touch technique, BD Insyte$^{(R)}$ cannulae (Becton Dickinson; Australia) were inserted. Ultrasound and infa-red light to visualise veins during PIVC placement was not used in the ED during the study period. After insertion, all PIVCs had a three-way extension set and SmartSite® needle-free valves (Carefusion; San Diego) applied.

Standard practice in the ED for the dressing and securement of PIVCs at the study site was used, locally referred to as the 'PIVC taping protocol'. This involved the use of a bordered polyurethane dressing (BPU) (Tegaderm 1610 Paediatric IV®, 3M; Brussels) on the insertion site and catheter hub, with additional non-sterile tapes, bandages and splints used to restrict joint movement. Figure 1 displays the products and application described in the protocol.

[Insert Figure 1]

Once transferred to the ward, care was managed by ward based Registered Nurses following Queensland Health and hospital standards (22). This included routine flushing with normal saline, hourly visualisation of the insertion site, intravenous medication and/or fluid administration, with 2% chlorhexidine gluconate in 70% alcohol for needleless connector decontamination prior to use (22). Dressings were replaced weekly, or if loose or visible ooze was present. PIVCs were not routinely replaced, but could be used as long as they were clinically required and had no complications.

Data collection

As we could find no existing suitable tool, a data collection form was developed with face and content validity established via a panel of five clinical and research experts prior to study commencement. The form had two parts for data to be collected at points during admission:

- Part A. Collected in the ED: participant demographics, time and location of PIVC insertion; reason for insertion; cannula gauge; PIVC dressing and securement method; and admitting ward;
- Part B. Collected in ward: date and time of PIVC removal; reason for removal; requirement for replacement PIVC, and additional dressings or securements used.

The data collection form was completed by multiple clinical nursing or medical staff in ED and admitting wards (both PIVC inserters and assistants). Prior to commencement, a series of staff training events was held at the hospital, and information flyers were posted in the clinical areas, including telephone/email contacts for questions about the study. Data collection forms were provided on the PIVC trolleys and within the patient charting areas. Research nurses were available to assist the

clinicians during business hours throughout the study period and provided follow-up for all participants to promote data collection.

Ethical and privacy considerations

As this study met the NHMRC (23, 24) and HRCNZ (25) criteria for a quality/audit review, full ethical review and informed participant consent was not required. To permit publication, ethical approval for the study was granted by the hospital's Human Research Ethics Committee (HREC/12/QRCH/65).

Data analysis

Data were entered and analysed using PASW Statistics Version 21.0 (SPSS Inc., Chicago, IL, USA). Basic frequencies were calculated for all variables, and any extreme or obviously incorrect data were re-checked for accuracy. Continuous and categorical data were described as mean (standard deviation), median (interquartile range (IQR)), frequencies, and percentages. If outcome data did not follow normal distribution, nonparametric, bivariate statistical tests were used depending on the presence of categorical or continuous variables (Spearman's rho, Kruskal Wallis and Mann-Whitney). Time to event outcomes and categorical variables were assessed for variance using cox regression to inform the estimates using hazard ratio and 95% confidence intervals (CI). The most common variables were chosen as the reference points for comparative analyses. Statistical significance was set at $p \leq 0.05$.

Results

Participant and device characteristics

During the study period, there were 7,050 presentations to the RCH ED, with a total of 1,618 patients requiring in-patient admission to the RCH. During the study period, a total of 493 patients had a PIVC inserted whilst in the ED, and had a data collection form completed. Of these, 458 patients were eligible for the study (28.3% of patients admitted): five patients were excluded as they were aged >16

years; and 30 patients were excluded as they did not require inpatient admission. Two participants were lost-to-follow up for the final phase of data collection (part B).

Descriptive information regarding participants (n=458) and their inserted PIVCs are displayed in Table 1. Patients had a mean age of 6.1 years, but ranged from as young as one day to 15.3 years. Most PIVCs were inserted in the hand (291/458; 63.5%), and the most frequent reason for insertion was for emergent but non-resuscitative care (272/458; 59.4%). The majority of PIVCs were inserted during the afternoon or evening (326/458; 71.2%) using a 22G or 24G cannula (54.4%, 40.4% respectively).

[Insert Table 1]

PIVC Securement and Duration

PIVC securement and outcomes are described in Table 2. Almost all PIVCs were secured using the PIVC taping protocol (457 /458; 99.8%), with a splint used for immobilisation (454/458; 99.1%). During PIVC use, extra dressing reinforcement was required in only 1.7% (8/456) of participants and dressing replacement necessary in only 0.2% (1/456) of participants.

[Insert Table 2]

PIVC dwell-time

PIVC dwell-time was skewed, with a median of 29 hours (IQR 13-58 hours) and ranged from less than one hour to 16 days. Over 75% of participants had their PIVCs removed by 2.4 days (58 hours).

PIVC Failure

One quarter (113/456; 24.8%) of all PIVCs were removed due to device failure, but less than half of these were replaced with a new PIVC (53/113; 46.5%, see Table 2). Infiltration was the most common reason for device failure (65/456; 14.3%), followed by accidental dislodgement (23/456; 5.0%) or

blockage (12/456; 2.6%). Phlebitis was rare (7/456; 1.5%), and there were no PIVC-related infections.

Associations with device failure

PIVC placement in the antecubital fossa was significantly associated with an increased risk of failure, in comparison to placement in the hand (HR 1.6; 95% CI 1.1 to 2.3; *p*=0.03). No other statistically significant associations were found between baseline patient or device factors and the outcome of PIVC failure. Information on the incidence, associated hazard ratios and 95% CI are described in Table 3.

[Insert Table 3]

The median dwell time of PIVCs that failed was 44.0 hours (IQR 11.9- 67.6 hours), whereas the dwell time of PIVCs that did not fail was 25.5 hours (IQR 12.0-50.5 hours; p=0.002).

Discussion

Previous studies in adults have reported PIVC failure rates of up to 92% (9, 10, 26). Whilst our failure rate of 25% is lower, it is still of clinical concern. A failure rate of one in four for a frequently essential medical device provides considerable opportunity for improvement, particularly for vulnerable paediatric populations, as most failure should be preventable. However, research has not established what an acceptable failure rate for PIVCs is in the general, or the paediatric, acute care population. Whilst the observed median PIVC duration of 29 hours was comparable to previous reports in NICU s and paediatric units (18, 26), those that failed lasted significantly longer (median PIVC duration 44 hours). It is unclear how long it is reasonable to expect a PIVC to dwell in the paediatric acute care population.

It is recognised that best practice in dressing and securement can minimise PIVC movement within the vessel, thus preventing the irritation, occlusion/infiltration, infection and dislodgement that culminate

in device failure (27, 28). Of the PIVCs that failed, infiltration and accidental dislodgement were the leading causes of failure at 14% and 5% respectively (65 and 23/456), despite having a dressing and securement device in place. At its most basic, effective securement should prevent the PIVC from falling out, and it appears that the BPU plus splint approach used in these patients could be improved and future research should explore other potentially superior methods. Another avenue to prevent failure and maintain PIVC patency may be through better flushing strategies. The flushing of PIVCs is currently haphazard, with Australian healthcare clinicians reporting diverse, and potentially harmful, practice (29). This includes the use of smaller than recommended syringe size and varied frequency and volume of flushes (29).

The only device characteristic associated with PIVC failure was placement in the antecubital fossa, in comparison to the hand (p=0.03). Clinical characteristics were not significantly associated with PIVC failure. Device placement is potentially modifiable risk factor for PIVC failure, and clinicians should consider avoiding antecubital fossa placement PIVC where possible. A recent large adult study identified significant predictors of PIVC failure to be: female gender; hand; antecubital fossa or upper arm placement; non-IV team inserted; current infection; IV antibiotics or hydrocortisone; gauge size; younger age; and second or subsequent PIVCs (14).

Our current PIVC dressing and securement practice described in this study consisted primarily of BPU (Tegaderm 1610 Paediatric IV®, 3M; Brussels), which has been the standard care at the study site, but differs from the local adult hospitals who typically use non-bordered, standard polyurethane (SPU) dressing without additional splints or bandaging (8). BPUs retain SPUs' central polyurethane component with an added adhesive border of foam/cloth. Product manufacturers claim BPU have nearly twice the pull-out force of SPU (3M material; St Paul, Minnesota), but Simonova and colleagues (30) found in an *in vitro* study that neither SPU nor BPU significantly increased pull-out force compared to no dressing at all ($p>0.05$). They further reported that sutureless securement devices (e.g. Statlock®; Bard Medical, Covington, GA) or tissue adhesive (e.g. Histoacryl; B Braun, Australia) significantly increased the 'pull out' force compared to SPU ($p<0.01$). Existing literature

suggests that SPU dressings may even *increase* device failure, since an independent Australian paediatric study (n=407) found the incidence of PIVC failure higher with SPU dressings than with gauze and tape (29% vs 19%, p=0.18) (21).

Of our failed PIVCs, only half required reinsertion to ensure completion of required therapy. This would suggest that the PIVC was a 'redundant catheter' that could have been removed earlier in order to minimise the risk of complications. This result is in accordance with recent research by Limm and colleagues (31), where it was reported that almost half of all PIVCs inserted in the ED are unused 72 hours later. It is universally recommended to promptly remove any IV catheter that is no longer essential so as to remove the risk of serious catheter related infections (12, 32, 33). Thus, a focus on educating and/or empowering staff to remove redundant PIVCs appears to be necessary, and would reduce the risk of infection and other complications in these vulnerable patients.

PIVC failure is a common problem and millions of children each year are affected. Improved securement is likely to prevent many cases of PIVC failure. New methods for the prevention of PIVC failure are available, but at higher purchase cost and without independent clinical trial data on efficacy. Rigorous assessment of the efficacy and cost-effectiveness of any new products is urgently needed to guide decision-making.

Limitations

This study was conducted in one hospital's ED; the results may not be generalisable to other hospitals or departments, or to those using different insertion and securement methods. Secondly, follow-up and collection of some data was undertaken by research nurses, but initial recruitment, dressing reinforcement and replacement data was collected by clinical staff and may have been under-reported and participants missed. Due to a lack of data regarding PIVC insertion in the ED, we have not been able to establish the overall number of patients missed during the study. A lack of external funding necessitated the unavailability of research nurses outside of business hours. Data forms were simple, brief, and familiar to clinical staff, which should have minimised errors and missed recruitment. The

highly homogenous practice for dressings and securements meant that failure rates associated with different approaches could not be compared.

Conclusion

This study is the first to describe PIVC dressing and securement methods and failure rates in children admitted to a tertiary hospital via the ED. A failure rate of 25% is of concern, and suggests that alternative measures beyond the use of BPU with splinting and bandaging may need to be examined to improve PIVC dwell times and rates of device failure in paediatric acute care settings.

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Competing Interests

CR has received research grant funding and educational speaker fees that are unrelated to this project from PIVC manufacturer, Becton Dickinson and Company (BD), and dressing supplier Centurion Medical Products. All other authors have no competing interest, financial or otherwise, in any of the products and their associated distributors, discussed within this manuscript.

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Table 1 Characteristics of participants and devices (n=458)

Characteristic		***n***	**%**
Gender	Male	249	54.4
	Female	209	45.6
Age (years)	Less than 1	64	14.0
	1 – 4 inclusive	145	31.7
	5 - 9 inclusive	146	31.9
	10 - 15 inclusive	103	22.5
Time of insertion (hours)	00:00 – 05:59	49	10.7
	06:00 – 11:59	83	18.1
	12:00 – 17:59	169	36.9
	18:00 – 23:59	157	34.3
Insertion site	Hand	291	63.5
	Ante-cubital fossa	142	31.0
	Foot	21	4.6
	Great saphenous (leg)	1	0.2
	Other	3	0.6
Side of insertion	Right	243	53.1
	Left	215	46.9
Cannula gauge	22G (blue)	249	54.4
	24G (yellow)	185	40.4
	20G (pink)	24	5.2
Reason for insertion	Emergent	272	59.4
	Non-emergent	136	29.7
	Resuscitation	50	10.9

Table 2 Outcomes of inserted peripheral intravenous catheters (n=456)

Outcome		***n***	**%**
Time of removal (*n*=456)	00:00 – 05:59	36	7.9
	06:00 – 11:59	121	26.4
	12:00 – 17:59	210	45.9
	18:00 – 23:59	89	19.4
Re-dressing or securement required (*n*=456)	None required	447	98.0
	Extra reinforcement	8	1.7
	Dressing replaced	1	0.2
Reason for removal (*n*=456)	Completion of treatment	343	75.2
	Infiltration	65	14.3
	Accidental dislodgement	23	5.0
	Blocked	12	2.6
	Phlebitis	7	1.5
	Other	6	1.3
New PIVC required after failure (*n*=113)	Yes	53	46.9
	No	60	53.1

PIVC = Peripheral intravascular catheter.

Table 3 Participant and device associations with device failure (n=456[†])

Characteristic		Failed PIVC (n=118) n (%)	Non-failed PIVC (n=338) n (%)	Hazard Ratio (95% CI)	P values[§]
Gender	Male	63 (25)	184 (75)	1.1 (0.8, 1.6)	0.59
	Female[‡]	50 (24)	159 (76)	1.0	
Age (years)	Less than 1[‡]	14 (22)	50 (78)	1.0	
	1 – 4 inclusive	42 (29)	103 (71)	1.3 (0.7, 2.3)	0.43
	5 - 9 inclusive	38 (26)	106 (74)	1.0 (0.6,1.9)	0.88
	10 - 15 inclusive	19 (18)	84 (82)	0.8 (0.4,1.5)	0.42
Reasons for insertion	Emergent [‡]	68 (25)	203 (75)	1.0	
	Non-emergent	30 (22)	105 (78)	0.9 (0.6,1.4)	0.63
	Resuscitation	15 (30)	35 (70)	1.1 (0.6,1.9)	0.76
Insertion site	Hand[‡]	62 (21)	228 (79)	1.0	
	Antecubital fossa	43 (30)	98 (70)	1.6 (1.1,2.3)	0.03*
	Foot	6 (29)	15 (71)	2.1 (0.9,5.0)	0.08
	Great Saphenous	1 (100)	0	7.6 (1.0,55.3)	0.05
	Other	1 (33)	2 (67)	1.1 (0.2, 8.3)	0.89
Time of insertion	00:00 – 05:59	10 (20)	39 (80)	0.7 (0.3,1.3)	0.24
	06:00 – 11:59	18 (22)	64 (78)	0.6 (0.4,1.0)	0.07
	12:00 – 17:59	40 (24)	129 (76)	0.9 (0.6,1.3)	0.49
	18:00 – 23:59[‡]	45 (29)	111 (71)	1.0	
Cannula gauge	22G (blue)[‡]	60 (24)	188 (76)	1.0	
	24G (yellow)	47 (25)	137 (75)	1.2 (0.8, 1.7)	0.43
	20G (pink)	6 (25)	18 (75)	1.0 (0.5,2.2)	0.94

PIVC = Peripheral intravascular catheter; [†] missing outcome data n=2; [‡]Reference value; [§] from Cox regression

Figure 1 Demonstration of ED PIVC Taping Protocol

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