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Global Pediatric Peripheral Intravenous Catheter Practice and Performance: A Secondary Analysis of 4206 Catheters

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ABSTRACT

Purpose: To describe worldwide characteristics, performance and risk factors of peripheral intravenous catheters (PIVCs), in pediatrics.
Design: A secondary, subgroup analysis of pediatric (<18 years) data was undertaken, using a global, cross-sectional study of PIVCs. Practice characteristics included: demographic, diagnostic, utility, management, performance and resources. Multivariate regression identified complication risks factors.
Results: Data from 4206 children in 278 hospitals across 47 countries. Most PIVCs (outside of Australia, New Zealand) were inserted by nurses (71%; $n = 2950$), with dedicated teams only common in North America (23.2%; $n = 85$). Large gauges (≤18G) were mostly used in South America, Europe and Africa. Regions predominantly placed 24G (49%; $n = 2060$) except in Australia and New Zealand, who more commonly placed 22G (38.7%; $n = 192$). The most common placement was the hand (51%; $n = 2143$), however North America, Australia and New Zealand frequently utilised the antecubital fossa (24.5%, $n = 90$; 21.4%; $n = 106$). Polyurethane dressings were most used (67.1%; 2822), and many were not clean, dry and intact (17.1%; $n = 715$). Over 8% of PIVCs were idle, with the highest rates in North America (21.2%; $n = 78$).
PIVC local complication risk factors included: >2 years age (odds ratio [OR] > 1.58; 1.2–2.1); ambulance/emergency insertion (OR 1.65; 1.2–2.3); upper arm/antecubital placement (OR 1.44; 1.1–2.0); poor dressing integrity (OR 5.4; 4.2–6.9); and 24–72 h dwell (OR > 1.9; 1.3–2.6).
Conclusions: There is global inconsistency in pediatric PIVC practice, which may be causing harm.
Clinical implications: Improvements in pediatric PIVC placement, dressings, and gauge selection are needed.

Introduction

Over 50% of hospitalized children receive a peripheral intravenous catheter (PIVC) for parenteral therapy such as intravenous fluids and antibiotics (A.J. Ullman, Kleidon, Cooke, & Rickard, 2017). Pediatric PIVC placement is frequently challenging, due to procedural and physiological difficulties. <50% first insertion attempts are successful in pediatrics, with some patients requiring 10 or more attempts prior to successful PIVC placement (Cooke et al., 2018; Kleidon, Cattanach, Mihala, & Ullman, 2019).

Harm associated with inappropriate PIVC insertion and management is an under-recognised patient safety issue. Local and national studies have demonstrated, after successful insertion, pediatric PIVCs are associated with high rates of local and systemic complications, including infiltration/extravasation, occlusion and dislodgment (Ben Abdelaziz et al., 2017; Malyon et al., 2014). Bloodstream infections associated with PIVCs are rare but can be fatal (Webster, Osborne, Rickard, & Marsh, 2019); and the volume of PIVCs used entails a significant associated burden on the healthcare system. The clinical sequelae of PIVC complications and failure can be prolonged, with delays to therapy administration, traumatic repeated insertion procedures and peripheral

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vessel damage (Marsh et al., 2018). Economically, the costs of PIVC insertion and management are also high, with a recent Australian estimate suggesting annual PIVC costs of over AU$41 million in a single state of ~4.7 million people (Tuffaha et al., 2018).

While discipline-specific PIVC clinical practice guidelines exist to inform some aspects of insertion and management, their implementation and impact are unknown (Bodenham Chair et al., 2016; Infusion Nurses Society, 2016; Loveday et al., 2014). Regional variations in PIVC practice may be due to resource availability, rather than best practice. To better appreciate the current burden of PIVCs worldwide and efficiently direct opportunities for improvement, an international cross-sectional study was undertaken between 2014 and 15 (Alexandrou et al., 2015; Alexandrou et al., 2018). The study included 40,620 PIVCs in 51 countries and demonstrated significant areas of sub-optimal practice—specifically, poor placement (i.e., areas of flexion), idle dwell, non-intact dressings and absent documentation—but provided no pediatric-focused analysis or recommendations. Pediatric PIVC insertion and management practices and outcomes have traditionally differed from adults, such as routine replacement of PIVCs (Webster et al., 2019), so generalizing mixed data to pediatrics-only is ill advised. Within this secondary analysis we sought to fill this gap, aiming to describe current practice and performance of pediatric PIVCs worldwide, and examine modifiable risk factors for complications associated with their use, to focus practice improvement, evidence generation, theory building and testing in the future.

Methods

Design

The current study is a secondary subgroup analysis of the pediatric data within an international, cross-sectional study led by Alexandrou et al. (2018). In the parent study, hospitals were recruited via professional networks, social media and word of mouth. Ethics was approved centrally via Griffith University, and locally via institutional review boards and hospital committees, as required.

PIVC practice was evaluated through two separate assessments: individual participant data and hospital service data. In total, the data collection tools contained 95 variables of PIVC practice (i.e., regional, clinical, demographic, utility, management and resources characteristics) and performance (i.e., local PIVC complications). Individual participant data were captured via inspection of the participant's PIVC and medical chart, with additional information collected from parents, carers or clinical staff, if necessary. Participants were eligible for inclusion if they had a PIVC in situ on the day of data collection. No identifiable patient information was collected. A hospital service data survey provided an estimate of PIVC clinical resources at each site. After pilot testing in 13 countries (Alexandrou et al., 2015), data collection forms were translated into 15 languages, using standard techniques to ensure validity (Wild et al., 2005). An electronic database (Lime Survey® Project, Hamburg, Germany), designed specifically for the study, was used for data capture. Data was entered directly online or on paper, which was then entered on site or provided to the coordinating center in Australia for entry. Data were collected between June 12,014 and July 31, 2015.

Sample

Participants included in the parent study aged between 0 and 18 years were included in the secondary, subgroup analysis.

Variables

Variables which met our research questions for the secondary analysis were extracted. PIVC practice was described by clinical (e.g., PIVC placement, gauge, indication, inserter), utility (e.g., infusates, dwell), and management (e.g., dressing and securement) characteristics. PIVC practice was further described by hospital clinical resources, including the availability of specialists, and recommendations within local guidelines surrounding site decontamination, administration set and needleless connector changes, and PIVC insertion replacement schedules. PIVC performance was described by local complications evident during participant assessment, including: pain/tenderness on palpation, redness >1 cm from insertion site, swelling >1 cm from insertion site, purulence, itch/rash under dressing, blistering/skin tears under dressing, bruising/dried blood around PIVC, palpable hard vein cord beyond catheter tip, streak/red line along vein, induration/hardness of tissues, leaking PIVC, extravasation/infiltration, and partial/complete dislodgment.

Data collection

Data were extracted directly from the parent database and stored securely in Stata (version 13; StataCorp, College Station, TX).

Data analysis

PIVC practice (including clinical, utility and management) was reported descriptively, using categorical and continuous descriptors as appropriate considering the data distribution. The prevalence of PIVC-associated local complications was reported descriptively using absolute numbers and proportions.

As described previously, one of the study aims was to highlight PIVC practice and performance variables that can be used for practice improvement, theory building and testing for the future. Because of this, a predictive modelling approach for theory building was used (Sainani, 2014; Shmueli, 2010). Mixed-effects logistic regression model was used with hospital and region level random effects to account for clustering. Univariate analysis was performed to identify modifiable and non-modifiable risk factors that were significantly associated with PIVC local complications. Variables significant at $p < 0.2$ on univariable analysis were included in a multivariate model. Multivariate model was developed using backward stepwise variable elimination. The variables that were dropped during the previous steps were then explored by manual stepwise addition and removal iteratively until the most parsimonious model was achieved. Interactions and collinearity were investigated. The final model was validated using a random sub-sampling validation, which randomly splits the dataset into training and validation data (Green, Medley, & Browne, 2009). Next, for each of the split subsets, the model was fit to the training data, and predictive accuracy was assessed using the validation data (Green et al., 2009). Finally, the naïve estimate of the area under the ROC (Receiver operating characteristic) curve and the cross-validated estimate were compared (Green et al., 2009). The analysis was undertaken using Stata (version 13; StataCorp, College Station, TX).

Results

PIVC practice

We included 4206 children (0–18 years) admitted to hospital, who had a PIVC in 278 hospitals from 47 countries. As displayed in Table 1, worldwide, PIVCs were predominantly inserted by nurses, except for Australia and New Zealand, where 63% of pediatric PIVCs ($n = 308$) were inserted by physicians. While insertion timing was not always documented, many were inserted outside of higher staffed, business hours (weekend 10.5%, $n = 442$; evening/night 25.3%, $n = 1062$). Most were inserted for medications (72.6%; $n = 3055$) or fluids (62.7%; $n = 2636$). A variety of sizes were used, with low use of very large gauge (≤ 18G 3.1%; $n = 133$), mainly in South America, Europe and Africa. Worldwide, most PIVCs were inserted in the hand (51.1%; $n = 2143$); however, antecubital fossa placement was common in

Table 1
Demographics and characteristics by geographical region ($n = 4206$).

	Africa	Asia	Australia/New Zealand	Europe	Middle East	North America	South America	South Pacific	Total
	N = 497	***n*** = 1580	***N*** = 496	***N*** = 713	N = 90	***N*** = 367	***N*** = 434	***N*** = 28	N = 4206
Number of Hospitals	40 (14.4)	55 (19.8)	46 (16.6)	77 (27.7)	6 (2.2)	25 (9.0)	28 (10.1)	1 (0.45)	278 (100)
Age (years) Median (IQR)	2.0 (0–9)	3.0 (0–9)	6.0 (1−13)	3.0 (0−12)	5.0 (2−10)	5.0 (0–12)	2.0 (0−10)	1.5 (0–7.5)	3.0 (0–10)
Male	271 (54.8)	920 (58.5)	272 (55.0)	387 (54.7)	62 (68.9)	195 (53.1)	221 (50.9)	14 (50.0)	2342 (55.9)
Department where PIVC inserted									
General ward	277 (56.2)	1115 (70.9)	91 (18.5)	303 (42.6)	52 (57.8)	109 (30.0)	238 (56.0)	22 (78.6)	2207 (52.9)
Emergency	53 (10.8)	138 (8.8)	165 (33.5)	143 (20.1)	27 (30)	118 (32.4)	98 (23.1)	4 (14.3)	746 (17.9)
Critical care	67 (13.6)	229 (14.6)	53 (10.8)	101 (14.2)	2 (2.2)	56 (15.4)	58 (13.4)	1 (3.6)	567 (13.6)
Operation theatre	45 (9.1)	48 (3.1)	136 (27.6)	88 (12.4)	3 (3.3)	23 (6.3)	18 (4.2)	1 (3.6)	362 (8.7)
Radiology/procedure	1 (0.2)	25 (1.6)	3 (0.6)	28 (3.9)	1 (1.1)	3 (0.8)	0	0	61 (1.5)
Ambulance	0	2 (0.1)	1 (0.2)	5 (0.7)	0	4 (1.1)	2 (0.5)	0	14 (0.3)
Other	0	5 (0.3)	0	0	1(1.1)	0	0	0	6 (0.1)
Unknown	50 (10.1)	10 (0.6)	43 (8.7)	43 (6.1)	4 (4.4)	51 (14.0)	11 (2.6)	0	212 (5.1)
PIVC inserter									
Nurse	324 (65.5)	1420 (90.2)	46 (9.4)	490 (69.0)	86 (95.6)	183(49.9)	374 (86.8)	27 (96.4)	2950 (70.5)
Doctor	160 (32.3)	119 (7.6)	308 (62.7)	155 (21.8)	1 (1.1)	8 (2.2)	6 (1.4)	1 (3.6)	758 (18.1)
Vascular access team	0	10 (0.6)	3 (0.6)	1 (0.1)	0	85 (23.2)	2 (0.5)	0	101 (2.4)
Technician	1 (0.2)	17 (1.1)	4 (0.8)	2 (0.3)	0	28 (7.6)	37 (8.6)	0	89 (2.1)
Unknown	10 (2.0)	8 (0.5)	129 (26.3)	62 (8.7)	3 (3.3)	63 (177.2)	12 (2.8)	0	287 (6.9)
Other	0	1 (0.1)	1 (0.2)	0	0	0	0	0	2 (0.1)
Time of the day PIVC inserted									
Monday to Friday 0700–1700	201 (40.4)	540 (34.2)	173 (34.9)	244 (34.2)	41 (45.6)	83 (22.6)	133 (30.7)	0	1415 (33.6)
Weekend 0700–1700	56 (11.3)	192 (12.2)	21 (4.2)	66 (9.3)	6 (6.7)	65 (17.7)	36 (8.3)	0	442 (10.5)
1700–0700	140 (28.2)	297 (18.8)	110 (22.2)	194 (27.2)	32 (35.6)	136 (37.0)	149 (34.3)	4 (14.3)	1062 (25.3)
Unknown	100 (20.1)	551 (34.9)	192 (38.7)	209 (29.3)	11 (12.2)	84 (22.8)	116 (26.7)	24 (85.7)	1287 (30.6)
PIVC dwell at assessment (h) Median (IQR)	26 (12–49)	21 (6–38)	25 (7–48)	33 (16–63)	18 (5–44)	36 (17–58.5)	25 (8–49)	30 (19.5–32.5)	25 (11–49)
0–24 h	183 (36.8)	488 (30.9)	174 (35.1)	201 (28.2)	44 (48.9)	107 (29.1)	155 (35.7)	1 (3.6)	1353 (32.2)
24–48 h	100 (20.1)	278 (17.6)	67 (13.5)	114 (16.0)	15 (16.7)	82 (22.3)	79 (18.2)	3 (10.7)	738 (17.6)
48–72 h	39 (7.9)	129 (8.2)	21 (4.2)	72 (10.1)	9 (10.0)	38 (10.3)	42 (9.7)	0	350 (8.3)
>72 h	58 (11.7)	98 (6.2)	28 (5.7)	89 (12.5)	6 (6.7)	49 (13.3)	37 (8.5)	0	365 (8.7)
Unknown	117 (23.5)	587 (37.2)	206 (41.5)	237 (33.2)	16 (17.8)	92 (25.0)	121 (27.9)	24 (85.7)	1400 (33.3)
Reasons for PIVC insertion									
Medications	405 (81.5)	1152 (72.9)	356 (71.8)	512 (71.8)	53 (58.9)	219 (59.5)	334 (77.0)	24 (85.7)	3055 (72.6)
Fluids	279 (56.1)	1143 (72.3)	304 (61.3)	365 (51.2)	65 (72.2)	240 (65.2)	233 (53.7)	7 (25.0)	2636 (62.7)
Taking blood	28 (5.6)	119 (7.5)	66 (13.3)	69 (9.7)	13 (14.4)	36 (9.8)	11 (2.5)	3 (10.7)	345 (8.2)
Parenteral nutrition	18 (3.6)	101 (6.4)	8 (1.6)	10 (1.4)	0	3 (0.8)	2 (0.7)	1 (3.6)	143 (3.4)
Blood products	6 (1.21)	86 (5.4)	9 (1.8)	14 (2.0)	1 (1.1)	5 (1.4)	17 (3.9)	0	138 (3.3)
Resuscitation	7 (1.4)	15 (1.0)	15 (3.0)	18 (2.5)	1 (1.1)	4 (1.1)	6 (1.4)	0	66 (1.6)
Chemotherapy	8 (1.61)	39 (2.47)	1 (0.2)	0	0	0	2 (0.5)	0	50 (1.2)
Unknown	10 (2.0)	21 (1.33)	18 (3.7)	28 (3.9)	1 (1.1)	44 (12.0)	13 (3.0)	0	135 (3.2)
PIVC size									
14 G (orange)	0	5 (0.3)	1 (0.2)	3 (0.4)	0	0	1 (0.2)	0	10 (0.2)
16 G (grey)	1 (0.2)	2(0.1)	3 (0.6)	8 (1.1)	0	1 (0.3)	0	0	15 (0.4)
18 G (green)	14 (2.8)	21 (1.3)	12(2.4)	24 (3.4)	1 (1.1)	7 (1.9)	24 (5.5)	1 (3.6)	104 (2.5)
20 G (pink)	45 (9.1)	98 (6.2)	80 (16.1)	86 (12.1)	5 (5.6)	44 (12.0)	30 (6.9)	1 (3.6)	389 (9.3)
22 G (blue)	115 (23.1)	280 (17.7)	192 (38.7)	232 (32.5)	19 (21.1)	133 (36.1)	114 (26.3)	4 (14.3)	1089 (25.9)
24 G (yellow)	280 (56.3)	923 (58.4)	122 (24.6)	284 (39.8)	52 (57.8)	175 (47.6)	202 (46.5)	22 (78.6)	2060 (49.0)
26 G (purple)	8 (1.6)	210 (13.3)	3 (0.6)	25 (3.5)	10 (11.1)	0	0	0	256 (6.1)
Other	14 (2.8)	10 (0.6)	8 (1.6)	19 (2.7)	3 (3.3)	4 (1.1)	32 (7.4)	0	90 (2.1)
Unknown	20 (4.0)	31 (2.0)	75 (15.1)	32 (4.5)	0	4 (1.1)	31 (7.1)	0	193 (4.6)
Insertion site									
Hand	283 (56.9)	827 (52.4)	272 (55.0)	330 (46.3)	52 (57.8)	179 (48.8)	180 (42.0)	20 (71.4)	2143 (51.1)
Forearm	59 (11.9)	162 (10.3)	47 (9.5)	101 (14.2)	5 (5.6)	37 (10.1)	76 (17.7)	4 (14.3)	491 (11.7)
Antecubital fossa	36 (7.2)	99 (6.3)	106 (21.4)	99 (13.9)	10 (11.1)	90 (24.5)	34 (7.9)	2 (7.1)	476 (11.3)
Foot	45 (9.1)	197 (12.5)	41 (8.3)	66 (9.3)	17 (18.9)	34 (9.3)	47 (11.0)	2 (7.1)	449 (10.7)
Wrist	37 (7.4)	159 (10.1)	23 (4.7)	50 (7.0)	5 (5.6)	16 (4.4)	48 (11.2)	0	338 (8.1)
Upper arm	8 (1.6)	47 (3.0)	0	41 (5.8)	1 (1.1)	3 (0.8)	26 (6.1)	0	126 (3.0)
Neck/Head	19 (3.8)	61 (3.9)	2 (0.4)	20 (2.8)	0	6 (1.6)	3 (0.7)	0	111 (2.7)
Other	10 (2.0)	25 (1.6)	4 (0.8)	6 (0.8)	0	2 (0.5)	15 (3.5)	0	62 (1.5)

N (%) unless otherwise labelled; IQR = Interquartile range.

North America (24.5% of the region's PIVCs; $n = 90$) and Australia and New Zealand (21.4% of the region's PIVCs; n = 106).

Utility and management of PIVCs by geographical region are displayed in Table 2. Most PIVCs were dressed with polyurethane dressings (67.1%; 2822), but the use of non-sterile 'tape only' was common in Asia (39.2%; $n = 619$), South America (22.8%; $n = 99$) and Africa (22.3%; $n = 111$). Almost one-fifth of PIVC dressings (17.1%; $n = 715$) were not clean, dry and intact. Overall, 8.4% of PIVC ($n = 351$) were not in use on the day of assessment, with the highest frequency of idle PIVCs (i.e. those with no documented use in the previous 24 h) being

Table 2
Utility and management of PIVCs by geographical region ($n = 4026$).

	Africa	Asia	Australia/New Zealand	Europe	Middle East	North America	South America	South Pacific	Total
	N = 497	n = 1580	N = 496	N = 713	N = 90	N = 367	N = 434	N = 28	N = 4206
PIVC dressing type									
Borderless polyurethane	256 (51.5)	666 (42.2)	333 (67.1)	395 (55.4)	50 (55.6)	255 (69.3)	256 (59.0)	10 (35.7)	2221 (52.8)
Bordered polyurethane	42 (8.5)	92 (5.8)	149 (30.0)	114 (16.0)	24 (26.7)	108 (29.4)	59 (13.6)	13 (46.4)	601 (14.3)
Sterile gauze and tape	47 (9.5)	46 (2.9)	22 (4.4)	82 (11.5)	10 (11.1)	0	21 (4.8)	26 (92.9)	254 (6.0)
Chlorhexidine impregnated	0	1 (0.1)	0	5 (0.7)	0	0	3 (0.7)	0	9 (0.21)
Tape only	111 (22.3)	619 (39.2)	4 (0.8)	95 (13.3)	10 (11.1)	1 (0.3)	99 (22.8)	0	939 (22.3)
No dressing	2 (0.4)	5 (0.3)	0	13 (1.8)	0	0	2 (0.5)	0	22 (0.52)
Dressing assessment									
Clean, dry and intact	372 (74.9)	1237 (78.3)	425 (85.7)	601 (84.3)	87 (96.7)	305 (82.9)	374 (86.2)	27 (96.4)	3428 (81.5)
Loose or lifting edge	48 (9.7)	160 (10.1)	11 (2.2)	33 (4.6)	0	38 (10.3)	12 (2.8)	0	302 (7.2)
Dry, but soiled	33 (6.6)	58 (3.7)	17 (3.4)	26 (3.7)	0	8 (2.2)	24 (5.5)	0	166 (4.0)
Moist, soiled	7 (1.4)	25 (1.6)	3 (0.6)	17 (2.4)	0	7 (1.9)	10 (2.3)	1 (3.6)	70 (1.7)
Other	25 (5.0)	80 (5.1)	21 (4.2)	27 (3.8)	3 (3.3)	7 (1.9)	14 (3.2)	0	177 (4.2)
Unknown	12 (2.4)	20 (1.3)	19 (3.8)	9 (1.3)	0	3 (0.8)	0	0	63 (1.5)
PIVC securement[a]									
Splint/bandage/tubular net	182 (37.1)	272 (18.0)	252 (52.3)	312 (44.4)	30 (33.7)	97 (26.7)	88 (20.5)	25 (89.3)	1258 (30.7)
Non-sterile tape over dressing	81 (16.5)	479 (31.6)	155 (32.2)	128 (18.2)	40 (44.9)	178 (49.0)	177 (41.2)	0	1238 (30.2)
Non-sterile tape around PIVC	94 (19.1)	607 (40.1)	104 (21.6)	134 (19.1)	20 (22.5)	164 (45.2)	93 (21.6)	0	1216 (29.7)
Sterile tape around PIVC	157 (32.0)	130 (8.6)	202 (41.9)	197 (28.1)	20 (22.5)	20 (5.5)	33 (7.7)	0	759 (18.5)
Non-sterile tape around AS	20 (4.1)	183 (12.1)	64 (13.3)	71 (10.1)	12 (13.5)	57 (15.7)	100 (23.3)	1 (3.6)	508 (12.4)
Securement device	44 (9.0)	131 (8.7)	6 (1.2)	20 (2.9)	0	108 (29.8)	28 (6.5)	0	337 (8.2)
Site dressing only	77 (15.7)	35 (2.3)	31 (6.4)	76 (10.8)	21 (23.6)	22 (6.1)	54 (12.6)	2 (7.1)	318 (7.8)
No securement	38 (7.7)	131 (8.7)	8 (1.7)	46 (6.5)	0	1 (0.3)	7 (1.6)	0	231 (5.6)
Other	32 (6.5)	42 (2.8)	28 (5.8)	10 (1.4)	3 (3.4)	44 (9.4)	8 (1.9)	0	157 (3.8)
Connectors									
Extension tubing	162 (34.0)	345 (23.0)	274 (58.2)	314 (44.7)	67 (75.3)	313 (86.9)	146 (33.9)	9 (32.1)	1630 (40.2)
Needless connector	124 (26.1)	407 (27.2)	252 (53.5)	284 (40.5)	4 (4.5)	268 (74.4)	87 (20.2)	26 (92.9)	1452 (35.8)
PIVC end cap	138 (29.0)	426 (28.4)	47 (10.0)	180 (25.6)	7 (7.9)	29 (8.1)	112 (26.0)	0	939 (23.2)
Direct connection to AS	111 (23.3)	294 (19.6)	44 (9.3)	66 (9.4)	12 (13.5)	8 (2.2)	86 (20.0)	0	621 (15.3)
Stopcock/3-way tap	16 (3.4)	158 (10.5)	103 (21.9)	142 (20.2)	17 (19.1)	8 (2.2)	106 (24.6)	4 (14.3)	554 (13.7)
None	13 (2.7)	28 (1.9)	9 (1.9)	21 (3.0)	0	5 (1.4)	3 (0.7)	0	79 (2.0)
Other	10 (2.1)	77 (5.1)	4 (0.9)	5 (0.7)	0	54 (15.0)	3 (0.7)	0	153 (3.8)
PIVC fluids today[a]									
Crystalloid	298 (60.6)	1149 (76.2)	275 (56.1)	376 (55.1)	55 (61.1)	208 (58.4)	287 (67.5)	8 (28.6)	2656 (65.2)
Parenteral nutrition	26 (5.3)	79 (5.2)	11 (2.2)	14 (2.1)	1 (1.1)	14 (3.9)	1 (0.2)	1 (3.6)	147 (3.6)
Colloid	6 (1.2)	48 (3.2)	11 (2.2)	12 (1.8)	6 (6.7)	5 (1.4)	12 (2.8)	0	100 (2.5)
None	117 (23.8)	261 (17.3)	178 (36.3)	255 (37.3)	28 (31.1)	115 (32.3)	127 (29.9)	15 (53.6)	1096 (26.9)
Not documented	57 (11.6)	24 (1.6)	21 (4.3)	32 (4.7)	1 (1.1)	16 (4.5)	6 (1.4)	4 (14.3)	161 (4.0)
PIVC medications today[a]									
Antibiotics	341 (70.2)	920 (60.6)	229 (52.4)	346 (49.9)	32 (36.0)	125 (36.4)	226 (52.9)	19 (67.9)	2238 (55.6)
Electrolytes	29 (6.0)	405 (26.7)	17 (3.9)	83 (12.0)	28 (31.5)	31 (9.0)	114 (26.7)	5 (17.9)	712 (17.7)
Analgesia	86 (17.7)	79 (5.2)	91 (20.8)	170 (24.5)	12 (13.5)	34 (9.9)	104 (24.4)	3 (10.7)	579 (14.4)
Gastric protection	6 (1.2)	158 (10.4)	8 (1.8)	28 (4.0)	7 (7.9)	31 (9.0)	90 (21.1)	0	328 (8.2)
Anti-emetic	18 (3.7)	53 (3.5)	50 (11.4)	20 (2.9)	6 (6.7)	12 (3.5)	41 (9.6)	0	200 (5.0)
Sedation	9 (1.9)	29 (1.9)	56 (12.8)	31 (4.5)	5 (5.6)	17 (5.0)	15 (3.5)	0	162 (4.0)
Diuretic	6 (1.2)	37 (2.4)	5 (1.1)	5 (0.7)	0 (0.0)	5 (1.5)	12 (2.8)	0	70 (1.7)
Other	40 (8.1)	163 (10.8)	21 (4.8)	56 (8.0)	7 (7.8)	30 (8.8)	63 (14.7)	0	380 (9.5)
None	60 (12.4)	251 (16.5)	107 (24.5)	171 (24.6)	19 (21.4)	139 (40.5)	60 (14.1)	6 (21.4)	813 (20.2)
PIVC not in use (last 24 h)	23 (4.6)	62 (3.9)	67 (13.5)	90 (12.6)	7 (7.8)	78 (21.2)	21 (4.8)	3 (10.7)	351 (8.4)
Flush									
Normal saline	157 (31.6)	957 (60.6)	164 (33.1)	362 (50.8)	51 (56.7)	150 (40.8)	180 (41.5)	15 (53.6)	2036 (48.4)
Heparinised saline	42 (8.5)	88 (5.6)	0	19 (2.7)	0	29 (7.9)	3 (0.7)	0	181 (4.3)
No order	170 (34.2)	409 (25.9)	193 (38.9)	207 (29.0)	39 (43.3)	101 (27.5)	125 (28.8)	10 (35.7)	1254 (29.8)
Other	2 (0.4)	25 (1.6)	1 (0.2)	2 (0.3)	1 (1.1)	0	0	0	31 (0.7)
Flush frequency									
Every 4 h	46 (9.3)	48 (3.0)	11 (2.2)	8 (1.1)	2 (2.2)	9 (2.5)	5 (1.2)	0	129 (3.1)
Every 8 h	29 (5.8)	134 (8.5)	36 (7.2)	121 (17.0)	1 (1.1)	36 (9.8)	72 (17.0)	10 (35.7)	439 (10.4)
Every 12 h	20 (4.0)	116 (7.3)	3 (0.6)	55 (7.7)	17 (18.9)	49 (13.3)	21 (4.8)	5 (17.9)	286 (6.80)
Once daily	13 (2.6)	209 (13.2)	2 (0.4)	51 (7.2)	6 (6.7)	10 (2.7)	9 (2.1)	0	300 (7.1)
Not documented	154 (31.0)	717 (45.4)	136 (27.4)	211 (29.6)	30 (33.3)	120 (32.6)	129 (29.7)	12 (42.9)	1509 (35.9)
Other	48 (9.7)	55 (3.5)	76 (15.3)	60 (8.4)	5 (5.6)	21 (5.7)	47 (10.8)	0	312 (7.42)

AS = administration set; PIVC = peripheral intravenous catheter.
[a] More than one response provided

in North America (21.2% of the region's PIVCs; $n = 78$). Flushing was not ordered or had no documented frequency in 30% and 36% of cases (respectively).

Clinical resources providing guidelines for PIVC insertion and management are described in the Online Supplement Table. Only one-third of hospitals with pediatric patients had guidelines recommending clinically-indicated replacement of PIVCs (33%; $n = 76$). Recommendations for decontaminant cleaning solutions varied extensively worldwide and regionally; while 2% chlorhexidine (CHG) in alcohol (47.7%; $n = 122$) and alcohol only (37.5%; $n = 96$) were most common overall, these solutions were not recommended at all in the South Pacific and Middle East. Clinical Nurse Specialists to support difficult PIVC were most common in North America, Australia and New Zealand. Worldwide, most hospitals did not have Clinical Nurse Specialists available for difficult PIVC access, instead relying on escalation to physician anesthetists or intensivists (47.3%; $n = 121$).

PIVC performance

Worldwide, 11.4% of PIVCs ($n = 479$) had local complications at time of assessment (see Table 3). Pain and tenderness on palpation was the most frequently reported complication (5% of total cohort; 43.6% of complications; $n = 209$), followed by blood in the line (2.8% of total cohort; 27.6% of complications; $n = 118$), and bruising or dried blood at the insertion site (1.7% of total cohort; 14.8% of complications; $n = 71$).

Associations between PIVC practice and performance

PIVC practice factors significantly associated with local complications in the multivariate model were older age, location of insertion, PIVC position, dressing integrity and securement (see Table 4). Compared to children <2 years old, those aged 2–11 years old had significantly increased risk for PIVC local complications being reported, (OR 1.58 [95% CI 1.18–2.12]) as did those 12–18 years old (OR 2.07 [95% CI 1.49–2.88]), mostly due to self-reported pain. Pain was difficult to assess in the preverbal child, due to limited use of pediatric-focussed pain assessment scales in this large, predominantly adult-focussed, study. When the pain outcome is removed from the outcome, there were no significant differences between age groups (2–11 years: OR 1.05 (0.76–1.46), $p = 0.77$; 12–18 years: OR 1.22 (0.84–1.77), $p = 0.30$).

PIVCs inserted in the ambulance and ED had significantly higher risk of PIVC local complications (OR 1.65[95% CI 1.21–2.26]) compared to PIVCs inserted in the general ward. PIVC inserted in upper arm or antecubital fossa had higher risk for PIVC local complications than those inserted in hand and wrist (OR 1.44 [95% CI 1.06–1.97]). PIVCs with dressings that were not clean, dry and intact had significantly higher risk of having PIVC local complication (OR 5.40 [95% CI 4.20–6.92]). Having a sutureless securement device (OR 1.90 [95% CI 1.14–3.18]), non-sterile tape strips around PIVC (OR 1.49 [95% CI 1.10–2.01]), or non-sterile tape around administration set (OR 1.45 [95% CI 1.02–2.06]) significantly increased the risk of PIVC complication compared to PIVCs that did not have such securements. In the cross-validation test, the area under the curve of naïve ROC curve was 0.85 (95% CI 0.83–0.87) and 0.84 (95% CI 0.83–0.86) for randomly partitioned dataset ROC. These results were similar and suggest that there is a low degree of error in the model and has an excellent accuracy overall in this sample (Hosmer & Lemeshow, 2000).

Discussion

This secondary analysis is the largest and most comprehensive description of global pediatric PIVC practice and performance to date.

Table 3
PIVC local complications (n = 4026).

	N	%
No complications	3727	88.6
Any complication(s)[a]	479	11.4
Pain/Tenderness on palpation	209	5.0
Blood in line	118	2.8
Bruising/dried blood	71	1.7
Swelling >1 cm from insertion site	63	1.5
Redness >1 cm from insertion site	59	1.4
Leaking	33	0.8
Partial/complete dislodgment	20	0.5
Palpable hard vein cord beyond PIVC tip	17	0.4
Extravasation/infiltration	17	0.4
Streak/red line along vein	16	0.4
Itch/rash under dressing	10	0.2
Induration/hardness of tissues >1 cm	5	0.1
Other	4	0.1
Blistering/skin tears under dressing	1	<0.1

More than one complication for each observation.
cm = centimeter; PIVC = peripheral intravenous catheter.

The insertion of PIVCs is the most common invasive procedure in pediatric inpatients, and within this large dataset distinct areas in need of improvement have been identified, relevant to specific regions. Some improvements may be challenging, based on the complexity of local healthcare systems and resources. However, vast improvements in patient and healthcare outcomes are possible, as a result.

The primary areas of variation in practice that were suboptimal, included the use of very large gauge (≥18G 3.1%; $n = 133$) PIVCs in South America, Europe and Africa, and antecubital fossa placement in North America (24.5% of the region's PIVCs; $n = 90$) and Australia and New Zealand (21.4% of the region's PIVCs; $n = 106$). These practices have been demonstrated to increase PIVC dislodgment and failure in previous studies in adults (Marsh et al., 2018; Wallis et al., 2014) and pediatrics (Malyon et al., 2014), and with infrequent clinical indication (e.g., large gauge PIVC in resuscitation settings) (Webster, Larsen, Booker, Laws, & Marsh, 2018). The impact of PIVCs being inserted in the upper arm and antecubital fossa was also evident in the multivariate regression, with PIVC inserted in upper arm having a higher risk for PIVC local complications than those inserted in hand, wrist or lower arm (OR 1.48 [95% CI 1.09–2.00]). The introduction of vessel imaging devices, such as ultrasound and near infrared light, mean that routine use of antecubital fossa vessels is no longer necessary (Benkhadra et al., 2012; Egan et al., 2013). Moving away from routine placement of antecubital fossa and large gauge PIVCs in pediatrics is a simple practice change that will significantly improve patient experience.

Globally, over 8% of PIVCs were in situ for >24 h without documented use, with the highest rates in North America (21.2% of the region's PIVCs; $n = 78$). Whether these PIVCs were intentionally (i.e., in case of emergency) or unintentionally left in is unclear, and is a limitation of the study. However, idle PIVCs have been implicated in significant adverse patient outcomes, including phlebitis, intensive care admission and catheter-associated bloodstream infection (Becerra, Shirley, & Safdar, 2016). The implementation of practical solutions to prompt regular PIVC assessment and timely removal are necessary (Kleidon et al., 2019).

Guideline variation for PIVC practice was complex. In many countries, pediatric patients are frequently admitted to non-pediatric specialist hospitals. This means the PIVC guidelines that are used to support practice may not be tailored to pediatric patients. An example of this is the routine replacement of PIVCs, which has never been recommended for pediatric patients in international clinical practice guidelines due to insertion challenges (Infusion Nurses Society, 2016; Loveday et al., 2014; O'Grady et al., 2011). However, only one-third of hospitals managing pediatric patients with PIVCs had guidelines recommending clinically-indicated replacement of PIVCs (33%; $n = 76$). This may be due to pediatric patients being admitted to non-pediatric hospitals, but the recommendation are likely to be causing non-evidence-based practice variation and unnecessary catheter placements in a vulnerable group.

Skin decontamination prior to PIVC insertion has rarely been the topic of high quality randomized controlled trials. Instead, clinical practice is based on extrapolation from central venous catheter studies, where CHG has been demonstrated to be superior to other decontaminants in preventing infections (Lai et al., 2016; Mimoz et al., 2015; Yasuda et al., 2017). However, the current study demonstrates the lack of evidence specific to PIVCs, and practice appears to vary based on product availability rather than clinical indication. Recommendations for decontaminant cleaning solutions varied extensively worldwide and regionally; while 2% CHG in alcohol (47.7%; $n = 122$) and alcohol only (37.5%; $n = 96$) were most common overall, these solutions were not recommended at all in the South Pacific and Middle East, potentially due to local availability. Large studies are necessary to inform practice in this area.

Over 10% of PIVCs were associated with a local complication but had not been removed. These results agree with global estimates of >30% PIVCs failing prior to completion of therapy (Helm, Klausner,

Table 4
Risk factors for PIVC local complications ($n = 4026$).

	Univariate	*p*-Value	Multivariate	p-Value
	OR (95% CI)		OR (95% CI)	
Age category	Ref: <2 years old			
2–11 years old	1.64 (1.27–2.14)	<0.01	1.58 (1.18–2.12)	<0.01
12–18 years old	2.19 (1.65–2.92)	<0.01	2.07 (1.50–2.88)	<0.01
Where it was inserted	Ref: General ward			
Ambulance or Emergency	1.75 (1.32–2.33)	<0.01	1.65 (1.21–2.26)	<0.01
Intensive care or operating theatre	0.74 (0.54–1.02)	0.07	0.94 (0.67–1.32)	0.74
Radiology or Other	0.88 (0.31–2.56)	0.82	0.73 (0.42–1.28)	0.27
PIVC position		Ref: Hand/wrist/		
Lower arm	1.03 (0.73–1.44)	0.88	0.86 (0.59–1.25)	0.43
Upper arm (including antecubital)	1.87 (1.42–2.47)	<0.01	1.44 (1.06–1.97)	0.02
Other (foot, head, neck)	0.74 (0.53–1.03)	0.07	1.02 (0.71–1.46)	0.92
Clinical area	Ref: Surgical ward			
Medical, hematology, oncology	1.00 (0.76–1.33)	0.98	–	
Intensive care	0.76 (0.56–1.05)	0.10	–	
Other (Emergency, obstetrics)	1.66 (1.05–2.62)	0.03	–	
Non-24 Gauge[a]	1.68 (1.32–2.15)	<0.01	–	
PIVC site assessment documented in last 24 h[a]	0.76 (0.58–0.98)	0.04	–	
Dressing not clean, dry and intact[a]	5.52 (4.35–7.00)	<0.01	5.40 (4.20–6.92)	<0.01
PIVC & admin set securement	Ref: No			
Sutureless securement device	1.62 (1.01–2.59)	0.04	1.90 (1.14–3.18)	0.01
Non-sterile tape strips around PIVC	1.49 (1.13–1.97)	<0.01	1.49 (1.10–2.01)	0.01
Non-sterile tape around admin set	1.48 (1.06–2.05)	0.02	1.45 (1.02–2.06)	0.04
Connectors	Ref: No			
Needleless connector	0.74 (0.55–0.99)	0.04	–	
End cap	1.34 (1.00–1.78)	0.04	–	
Flushed every 4 h	0.37 (0.13–0.99)	0.05	–	
Dwell time	Ref: 0–24 h			
24–48 h	2.09 (1.54–2.84)	<0.01	1.87 (1.34–2.59)	<0.01
48–72 h	2.39 (1.62–3.52)	<0.01	2.14 (1.42–3.23)	<0.01
>72 h	2.04 (1.39–3.01)	<0.01	1.44 (0.94–2.19)	0.09
Not documented/Unknown	1.64 (1.21–2.20)	<0.01	1.47 (1.07–2.03)	0.02

CI=Confidence interval; PIVC=Peripheral intravenous catheter; OR = Odds ratio.
[a] Reference is opposite value.

Klemperer, Flint, & Huang, 2015; Malyon et al., 2014; Marsh, Webster, et al., 2018). PIVC complications and dysfunction are considered by many clinicians to be an acceptable part of pediatric practice (Helm et al., 2015). However, parents and children report PIVC insertion and dysfunction as one of the most stressful experiences of pediatric hospitalization (Cooke et al., 2018; Kleidon et al., 2019).

Within the multivariate model of PIVC local complication, several modifiable risks were observed, however these relationships are correlations, rather than causations. The strongest effect was PIVCs with dressings that were not clean, dry and intact having a significantly higher risk of having a local complication (OR 5.40 [95% CI 4.20–6.92]). Having a dressing that was not clean, dry and intact was common, affecting almost one-fifth of PIVC dressings (17.1%; $n = 715$) globally. The sequelae of dressings requiring non-routine changes has been demonstrated in observational studies in central venous catheters, significantly increasing risk of catheter-associated bloodstream infection (Timsit et al., 2012). Improvements in dressing integrity are possible with the introduction of additional technologies, including tissue adhesive and reinforced border dressings (Kleidon et al., 2017; Marsh, Larsen, et al., 2018; Rickard et al., 2018; A. Ullman et al., 2017). Supplementary dressing and securement products, such as sutureless securement devices (i.e., devices with clasps or adhesives to minimize movement), non-sterile tape strips around PIVC and non-sterile tape around administration set, appeared to increase the risk of local complications within the multivariate model. The causative relationship is unknown, however, it is possible that securements were retrospectively applied to PIVCs when signs and symptoms of local complications and failure were observed.

The multivariate model results should be interpreted with caution. This was not an explanatory model but a predictive model. The aim was to highlight the variables that could be used for theory building and testing in future studies. In the predictive model, variables may be included in the final model even if they are not causally related to the outcome (Sainani, 2014; Shmueli, 2010). The presence of some types of securements does not simply mean that they cause the PIVC local complications but could predict that PIVCs could develop local complications.

Limitations

The limitations of the current study mirror the primary study (Alexandrou et al., 2015). The cross-sectional design prevented follow-up of PIVCs until removal to collect outcomes following study observation, or identify the clinical rationale for data (e.g., PIVCs left idle intentionally vs unintentionally). Some useful predictors for PIVC complications that could have been included in the multivariate model were not collected: e.g., the number of PIVC insertion attempts. Despite training and clear resource manuals, there is also a possibility of misclassification bias, where the assessor did not report the complication correctly, including variation in pain assessment in preverbal children. As some regions only had small representation, inter-regional differences should be interpreted with caution.

Practice implications

In this global study, clear areas for improvement in pediatric PIVC practice have been identified. Future modifiable practice improvement areas highlighted by the study were improved placement (i.e., antecubital fossa avoidance), reduction in non-clinically indicated large gauge PIVCs, improved assessment and removal of idle PIVCs, improvements in dressing integrity. At a health services level, clinicians should develop and apply pediatric-focussed PIVC guidelines, to ensure

adult-based practices, such as routine replacement of PIVCs, are not inappropriately implemented.

Conclusion

PIVCs are a vital part of modern pediatric healthcare, but the insertion and management of these 'simple' devices is challenging. Sustainable incorporation of practice changes and systematic investment into research and innovation could achieve a drastic improvement in pediatric patient experience and clinical outcomes worldwide.

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Disclosure

These data have not been presented in any form at any forum.

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CRediT authorship contribution statement

Amanda J. Ullman: Conceptualization, Methodology, Writing - original draft, Supervision, Project administration. **Mari Takashima:** Formal analysis, Methodology, Investigation, Data curation, Writing - review & editing. **Tricia Kleidon:** Conceptualization, Methodology, Writing - review & editing. **Gillian Ray-Barruel:** Conceptualization, Methodology, Writing - review & editing. **Evan Alexandrou:** Conceptualization, Methodology, Writing - review & editing. **Claire M. Rickard:** Conceptualization, Supervision, Writing - review & editing.

Declaration of competing interest

Griffith University has received investigator-initiated grants and unrestricted donations from vascular access product manufacturers (3M, Adhezion, Angiodynamics, Becton Dickinson [BD]-Bard, BBraun, Centurion Medical Products-Medline), to support research led by AJU, unrelated to the current project.

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