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Research paper

Insertion, management, and complications associated with arterial catheters in paediatric intensive care: A clinical audit

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ABSTRACT

Introduction: Peripheral arterial catheters (PAC) are used for haemodynamic monitoring and blood sampling in paediatric critical care. Limited data are available regarding PAC insertion and management practices, and how they relate to device function and failure. This information is necessary to inform future interventional research.

Objectives: The primary objective of this study was to describe PAC insertion and management practices, and associated complications. Secondary objectives were to determine patient and clinical characteristics associated with risk of PAC successful insertion and failure.

Methods: A prospective, observational study was conducted in the anaesthetic department and paediatric intensive care unit of a tertiary paediatric facility. Data were collected on PAC insertion, PAC management and PAC removal. Standard incidence and prevalence were calculated per 1,000 device days. Risk factors for multiple insertions and PAC failure were identified using Cox regression.

Results: A total of 100 catheters in 89 children were examined capturing 472 device days. PACs were primarily inserted for blood sampling (78%) in the radial artery (78%) using ultrasound guidance (67%), with 31% inserted on first attempt. Heparin saline solution was used in 82% of devices. Median catheter dwell was 50.6 hours (IQR 24.0 − 158.0), with PAC failure occurring in 19 devices (20%), at a rate of 40.2 per 1000 catheter days (95% CI 25.7 - 63.1). Arm board immobilisation (HR 2.9; 95% CI 1.02-8.02; $p = 0.05$), higher PIM3 score (HR 1.06; 95% CI 1.03-1.09; $p < 0.01$) was associated with an increased the risk of PAC failure, and non-2% chlorhexidine antisepsis was associated with a decrease in PAC failure (HR 0.32; 95% CI 0.11-0.96; $p = 0.04$), in univariate analysis.

Conclusions: PAC insertion is challenging, and failure is common. Prospective clinical trial data is needed to identify high risk patient groups and to develop interventions which optimise practices, thereby reducing failure.

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1. Introduction

Annually, around 250,000 peripheral arterial catheters (PACs) are used across Australia to facilitate continuous haemodynamic monitoring and blood sampling in critically ill patients.[6] Typically inserted into the radial and femoral artery, axillary, brachial, and dorsalis pedis arteries are occasionally used.[2] PAC placement is mainly indicated during critical illness or during the perioperative and postoperative period. In the paediatric intensive care unit (PICU), PACs permit continuous blood pressure monitoring and facilitate regular blood sampling. Despite the clinical importance of arterial cannulation, insertion can be challenging, and device complications such as infection, skin necrosis, blockage, and thrombosis can occur.[8,12] These PAC-related adverse events are associated with significant sequelae for the patient and health service resource utilisation.[2]

In comparison to higher profile vascular access devices such as central lines, the prevalence of PAC complications relative to insertion and management practices has been scarcely investigated. A recent meta-analysis of 49 trials (30,841 PACs) found a pooled catheter-associated bloodstream infection incidence of 0.96 per 1000 catheter days[12] in critically ill adults, a similar incidence to reported central line–associated bloodstream infections.[3,20] In paediatrics however, the prevalence of PAC-associated bloodstream infection is potentially underrecognised, potentially representing a portion of healthcare-associated infections. In addition to infection, arterial cannulation can lead to mechanical and vessel complications. Arterial damage, due to PAC insertion and care, can result in significant local inflammation and may be associated with deep vein thrombosis.[2,16] Other catheter malfunctions, such as accidental dislodgement and obstruction, result in catheter failure, inaccurate monitoring, and inability to sample blood. Infants and children are particularly susceptible to vascular access complications, due to small blood vessel diameter, increasing the risk of vessel obstruction, and difficulties with immobilisation, increasing the risk of dislocation.[17] PAC failure often necessitates the insertion of a replacement PAC, which is increasingly challenging in infants undergoing repetitive procedures.[13]

PAC insertion and management is complex and multifaceted, with many interdisciplinary clinicians involved in PAC care. Evidence-based strategies have been developed to reduce preventable complications associated with PACs. These includes the use of 2% chlorhexidine gluconate (CHG) in alcohol decontamination before insertion, aseptic nontouch technique during access, minimisation of dressing disruption, CHG-impregnated dressing products, regular site assessments, and the removal of redundant devices.[10,15,21,22] But the application of these strategies to the patient is variable, and gaps between evidence and clinical practice exist. The primary objective of the study was to describe current PAC insertion (e.g., insertion location, indication, the number of attempts, ultrasound use, and catheter characteristics) and management (PAC fluid, dressing, and securement) practices. Secondary objectives were to identify the risk factors associated with first-attempt insertion success and PAC failure and to compare current practice with local guidelines.

2. Methods

2.1. Study design

A prospective single-centre observational study was conducted over 4 months from October 2017 to January 2018.

2.2. Setting and participants

PAC insertion, use, management, and related complications were audited within the anaesthetic department and PICU, at a tertiary referral paediatric facility in Queensland, Australia. The PICU has an approximate annual activity of 2000 admissions and provides multidisciplinary care including cardiothoracic, transplant, and oncology services. Children were included if they were aged 0–16 years and required a PICU admission and PAC insertion. Children were excluded if they were an external transfer with a PAC already in situ or required an emergency out-of-hours PAC insertion. The study obtained institutional human research ethics approval (HREC/17/QRCH/195) and a waiver of consent.

2.3. Data collection and measurement

The following outcome data were collected: (i) PAC dwell time; (ii) the number of PAC attempts, defined as insertion of the needle through skin, a successful insertion was defined as pulsatile blood flow noted from the PAC[8]; (iii) PAC failure, defined as PAC failure before the completion of necessary therapy; (iv) accidental dislodgement, where the body of the PAC partially or completely leaves the artery; (v) poor aspiration, where the clinician experiences difficultly aspirating blood; (vi) blockage, where the clinician is unable to flush or aspirate the PAC; and (vii) poor trace, where there is dampening of the arterial pressure waveform.

In addition to outcome variables, we collected the following insertion, management, and device variables: Insertion location; indication; ultrasound use; insertion site; device details; antiseptic solution; the number of attempts; PAC dressing and securement; PAC fluid and insertion complications (haematoma, arterial spasm)[8]; and PAC management including sampling frequency, PAC fluid, and arm board immobilisation.

Demographic and clinical variables were collected to examine associations with main outcomes. These included demographic and biometric data, primary diagnosis, mode of PICU admission, and PICU length of stay. Risk of mortality was estimated using the Paediatric Index of Mortality 3 (PIM3).[19] Data collected were developed by the investigators *a priori*, based on variables reported in previous PAC reviews and studies.[1,18]

PAC insertion data were entered onto an audit tool by the bedside clinician. Daily device checks, complication, and removal data were collected by the clinical research nurse using both clinical assessment and review of electronic medical records. Data were entered into the electronic data platform REDCap™ (Research Electronic Data CAPture, Vanderbilt University), version 6.10.6. Events were assessed during business hours, Monday to Friday, by the clinical research nurse. To reduce sampling bias, where possible, the clinical information system was used to retrieve data. Before the data collection period, the audit tool was piloted by three clinicians for acceptability and useability. Clinician feedback was incorporated into the final version of the tool. Clinicians received education about the data collection tool before the commencement of the study. Education was restricted to data collection only, and no further information on PAC insertion and care was provided.

2.4. PAC clinical practice guidelines

The local PAC guidelines, provided by the education team, were reviewed for care recommendations regarding all aspects of PAC insertion and management, including flushing solution, dressing and securement, and site checks.

2.5. Data analysis

Participant demographic and PAC characteristics are reported descriptively using percentages for categorical data and mean and standard deviation or median and interquartile range (IQR) for continuous variables depending on normality of distribution.

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Table 1
Participant characteristics (100 catheters, 89 children).

Variables	n = 100 (%)
Age (months)[a]	7.1 (0.4–79.6)
Weight (kilograms)[a]	8.4 (3.5–25.4)
PIM3[a]	0.5 (0.2–1.9)
Male	55 (55)
PICU mode of admission	
OT	58 (58)
Other hospital	23 (23)
Ward transfer	15 (15)
Emergency department	4 (4)
Primary diagnosis	
Cardiac surgical	50 (50)
Medical	26 (26)
Surgical excluding cardiac	17 (17)
Other	7 (7)
Mechanical ventilation (hrs)[a]	83.2 (6.7–163.6)
PICU LoS (days)[a]	4 (1–9)
PICU outcome	
Alive at discharged	93 (93)
Died	6 (6)
Inpatient	1 (1)

PIM3: Paediatric Index of Mortality 3; PICU: paediatric intensive care unit; OT: operating theatre; LoS: length of stay.
[a] Median (interquartile range).

Univariate and multivariate regression models were planned to investigate the association between the binary outcome variable (first-attempt success) and predictor variables. The incidences of PAC failures are reported proportionally and using incidence rates (with 95% confidence intervals [CIs]) per 1000 catheter days. Because PAC failure for each participant were time dependent, Cox proportional hazards regression model was used for time-to-event analysis, and survival data/hazard rates were reported with 95% CI adjusted for the same patient clusters. Only univariate model results were reported because of the low number of events (catheter failure) that could risk overfitting a multivariate model.[4] Data were analysed using Stata (Version 13; StataCorp, College Station, TX). An alpha value of $p < 0.05$ was considered statistically significant.

3. Results

3.1. Patient characteristics

Over the four-month study period, 174 children requiring a PAC were admitted to the PICU, of which data were collected on 100 PACs (89 children; 51%) (Supplementary material 1). Reasons for study exclusion included audit performa not completed by PICU or operating theatre (OT) staff (43; 23%), external patient transfer with a PAC in situ (15; 8%), patient missed (14; 7%), and emergency/out-of-hours PAC insertion (13; 7%). Participant demographic characteristics are outlined in Table 1. The median participant age was 7.1 months (IQR: 0.4–79.6), with the primary mode of PICU admission via the OT (58%) and surgical cardiac patients being the most common diagnostic group (50%). Overall, the median duration of mechanical ventilation was 83.2 h (IQR: 6.7–163.6), and the median PICU length of stay was 4 days (IQR: 1–9).

3.2. PAC insertion characteristics

PAC insertion characteristics are outlined in Table 2. The primary indication for PAC insertion was blood sampling (78%), with the radial artery (78%) being the most common placement site. Fifty-seven percent (n = 57) of PACs were inserted in the PICU by medical officers, the remainder (n = 42; 42%) being inserted in the OT by medical staff. The majority of PACs required two or more insertion attempts (69%) with ultrasound guidance used in 67% of insertions. Sterile gloves were used in 57% of insertions, and 2% CHG was the most common skin decontaminant. Insertion complications were observed in 6% of PAC insertions, mostly arterial spasm (4%). On univariate analysis, no patient or device variables were associated with multiple insertion attempts (Supplementary material 2).

Table 2
Peripheral arterial catheter insertion characteristics.

Variables	n = 100 (%)
PAC insertion location[a]	
PICU	42 (42)
OT	57 (57)
Emergent insertion[a]	17 (17)
Reason for insertion[b]	
Blood sampling	78 (78)
Haemodynamic monitoring	75 (75)
Intraoperative monitoring	46 (46)
Electrolyte monitoring	21 (21)
Research	5 (5)
PAC placement[a]	
Radial	78 (78)
Brachial	10 (10)
Femoral	9 (9)
Other	2 (2)
Number of insertion attempts[c]	
1	29 (29)
2 or more	69 (69)
Ultrasound-guided insertion[a]	
Yes	67 (67)
No	30 (30)
Unknown	2 (2)
Cather gauge	
20G	16 (16)
22G	71 (71)
24G	10 (10)
Unknown	2 (2)
Gloves used during insertion[a]	
Sterile	57 (57)
Clean	18 (18)
Nil	24 (24)
Aseptic solution used on insertion[a]	
2% CHG with alcohol	58 (58)
Alcohol wipe	28 (28)
0.5% CHG with alcohol	9 (9)
Other	4 (4)
PAC fluid[a]	
Heparinised saline	82 (82)
Normal saline	17 (17)
PAC dressing and securement	
Veni-Gard	42 (42)
Tegaderm (border)	35 (35)
Suture	27 (27)
Tegaderm (no border)	16 (16)
Integrated dressing and securement	3 (3)
Other	6 (6)
Additional products securing PAC	
Nil	61 (61)
Hypafix™ (BSN medical, Essity)	18 (18)
Foam	17 (17)
Nonsterile tape	6 (6)
Gauze	2 (2)
Arm board immobilisation	21 (21)
Insertion complications	
None	94 (94)
Haematoma	2 (2)
Arterial spasm	4 (4)

PAC: peripheral arterial catheter; PICU: paediatric intensive care unit; OT: operating theatre; CHG: chlorhexidine gluconate.
[a] 1 missing.
[b] Multiple responses chosen per participant.
[c] 2 missing.

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Table 3
Peripheral arterial catheter outcomes (100 catheters, 472.1 catheter days).

Variables	N = 100 (%)	IR per 1000 catheter days (95% CI)
Multiple insertion attempts[a]	69 (69)	
PAC dwell (hours)[b]	50.6 (24.0–158.0)	
All-cause failure	19 (20.0)	40.25 (25.67–63.10)
Failure reason[c]		
Poor trace	10 (10.53)	21.18 (11.40–39.37)
Blocked	6 (6.32)	12.71 (5.71–28.29)
Accidental dislodgement	4 (4.21)	8.47 (3.18–22.57)
Poor aspiration	3 (3.16)	6.35 (2.05–19.70)
Other	1 (1.05)	2.12 (0.30–15.04)

PAC: peripheral arterial catheters; IR: Incidence rate.
[a] 2 missing.
[b] Median (interquartile range).
[c] Multiple responses for each participant.

Table 4
Associations between peripheral arterial catheter failure and patient and device characteristics.

Variables	19 failures; N = 100 peripheral arterial catheters (PAC)			
	Failed PAC (n = 19)	PAC completed therapy (n = 71)	HR (95% CI)	P value
Age	0.1 (0.0–0.7)	1.6 (0.2–7.7)	0.95 (0.81–1.10)	0.48
Weight	3.5 (3.1–6.7)	13.8 (4.0–29.6)	0.99 (0.94–1.04)	0.68
PIM3[b]	1.4 (0.5–3.0)	0.4 (0.2–1.5)	1.06 (1.03–1.09)	<0.01
Sex (ref = male)	9 (18.0)	41 (82.0)		
Female	10 (22.2)	32 (77.8)	1.25 (0.48–3.26)	0.64
Site[a] (ref = radial)	15 (20.3)	59 (79.7)		
Other	4 (20.0)	16 (80.0)	0.47 (0.17–1.35)	0.16
Size[b] (ref-22G)	13 (19.4)	54 (80.6)		
Other	6 (24.0)	19 (76.0)	1.41 (0.53–3.77)	0.49
Diagnosis (ref = cardiac/neuro surgical)	8 (14.0)	49 (86.0)		
Medical and other	8 (14.0)	11 (29.0)	1.87 (0.75–4.65)	0.18
Catheter length (ref = other)	10 (19.6)	41 (80.4)		
4–5 cm	9 (20.5)	35 (79.5)	0.78 (0.34–1.81)	0.56
Heparinised fluid[a] (ref = heparin)	16 (20.8)	61 (79.2)		
Other	3 (17.7)	14 (82.4)	2.54 (0.81–7394)	0.11
Tegaderm bordered (ref = no)	13 (21.0)	49 (79.0)		
Yes	6 (18.2)	27 (81.8)	1.37 (0.53–3.55)	0.52
Veni-Gard (ref = no)	10 (18.2)	45 (81.8)		
Yes	9 (22.5)	31 (77.5)	1.04 (0.44–2.48)	0.93
Suture used (ref = no)	14 (20.0)	56 (80.0)		
Yes	5 (20.0)	20 (80.0)	0.59 (0.25–1.40)	0.23
Inserted in[a] (ref = OT)	5 (9.3)	49 (90.7)		
ICU	14 (35.0)	26 (65.0)	1.98 (0.73–5.40)	0.18
Immobilised with arm board[c] (ref = no)	7 (11.1)	56 (88.9)		
Yes	9 (45.0)	11 (55.0)	2.83 (1.05–7.63)	0.04
Aseptic solution used at insertion[a]: (ref = 2% CHG)	16 (28.6)	40 (71.4)		
Other solution (0.5% CHG with alcohol. Alcohol wipe, and other)	3 (7.9)	35 (92.1)	0.32 (0.11–0.96)	0.04
Insertion side[a] (ref = right)	14 (24.6)	43 (75.4)		
Left	5 (13.5)	32 (86.5)	0.73 (0.24–2.17)	0.57
Glove used at insertion[a] (ref = no)	3 (13.0)	20 (87.0)		
Yes	16 (22.5)	55 (77.5)	1.38 (0.45–4.20)	0.57
Ultrasound used for insertion[b]: (ref = no)	4 (13.8)	25 (86.2)		
Yes	14 (22.2)	49 (77.8)	0.75 (0.26–2.22)	0.61
No of access (mode) (ref = 0 times)	5 (20)	20 (80)		
5 or more times	10 (19)	44 (81)	1.11 (0.41–3.04)	0.84

Hazard ratios (HRs) and 95% confidence intervals (CIs) are shown.
OT: operating theatre; median (IQR) shown; frequencies and column percentages shown, unless otherwise noted. HR adjusted for the same patient cluster.
[a] 1 missing.
[b] 3 missing.
[c] 12 missing.

3.3. PAC management and utility

On daily checks, 405 (62%) PACs had been accessed up to six times in the preceding 24-h period, predominately for blood sampling purposes (65%). As described in Table 1, heparin sodium (1000 IU/L in 0.9% sodium chloride, 500 ml IV infusion) was the most common infusate, used in 82% of transducer systems. Local unit policy is a continuous infusion of 1 ml per hour increasing to 2 ml/h in older children, is at the discretion of the treating medical officer. Arm board immobilisation was observed in 19% of daily checks. Ooze at site was the most common site complication observed (14%), followed by local blanching (1.4%).

3.4. PAC complications and failure

Table 3 outlines PAC outcomes. Overall, 20% of PACs failed before therapy completion, with an incidence rate (IR) of 40.2 per 1000 catheter days (95% CI: 25.7–63.1). A total of 14 catheters required

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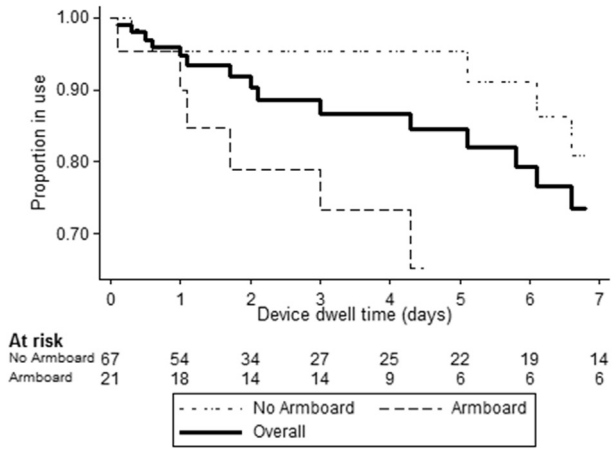

Fig. 1. Kaplan–Meier curve of peripheral arterial catheter failure.

reinsertion. Poor trace had the highest complication rate (21.2 per 1000 catheter days; 95% CI: 11.4–39.4) followed by PAC blockage (12.7 per 1000 catheter days; 95% CI: 5.7–28.3). Median dwell time for PACs that failed was 3.0 days (1.0–6.6) compared with PACs that completed therapy (1.0–6.5; $p = 0.8$). The majority of PAC failures were observed in the first seven days (15 PACs; 79%). Table 4 describes associations between PAC failure and patient and device characteristics. On visual inspection, younger children, who weigh less and have a higher severity of illness score, appear to be more likely to experience PAC failure; however, this was not confirmed on univariate analysis. On univariate analysis, higher PIM3 scores (hazard ratio [HR]: 1.06; 95% CI: 1.03–1.09; $p < 0.01$) and use of arm board immobilisation were associated with an increased the risk of PAC failure (HR: 2.83; 95% CI: 1.05–7.63; $p = 0.04$). Use of antiseptic solution other than 2% CHG was associated with a decreased risk of PAC failure (HR: 0.32; 95% CI: 0.11–0.96; $p = 0.04$). However, mean PIM3 scores were higher in the 2% chlorhexidine group (2.58 ± 4.77 versus other 0.70 ± 1.21), with 67% (39 PACs) of PACs inserted using 2% CHG placed in the PICU compared with 7% (3 PACs) of PACs using other solutions. The Kaplan–Meier curve (Fig. 1) demonstrates a consistent risk of PAC failure over time.

3.5. PAC guidelines

Overall, there was moderate adherence to local PAC guidelines (Supplementary material 3). PAC guidelines recommended the radial artery as the preferred site of placement; 87% of audited PACs were placed in the radial artery. After cannula placement, the guidelines recommend the use of arm board immobilisation, which were observed to be used in 19% of PACs. To secure PACs, local guidelines recommended the use of border polyurethane dressings; however, these were only used in 35% of insertions. In accordance with the guidelines, heparin saline solution (1000 IU/L in 0.9% sodium chloride) was used in 66% of PAC transducer systems.

4. Discussion

The aim of this study was to describe PAC insertion and management practices in a large paediatric critical care unit and to identify risk factors for PAC failure to guide further interventional research. This study demonstrates that although PAC insertion is a common procedure, 69% arterial cannulation procedures required multiple insertion attempts. In addition, despite the reliance of PACs in the PICU and a short median dwell time, we observed that 20% of PACs were associated with dysfunction before the completion of treatment. The majority of catheters which failed (74%) required reinsertion, and risk of failure was associated with greater severity of illness score. Furthermore, this study identified that arm board immobilisation is associated with PAC failure; however, further investigation is required to determine whether there is likely no benefit from the use of arm board immobilisation in the context of PAC failure.

Ultrasound guidance (USG) insertion was used in 67% of PAC insertions; however, we still observed a high multiple insertion attempt rate. A possible explanation for this finding is that inserters may be experts in the landmark-based approach but developing skills in ultrasound-based methods. Furthermore, children in the PICU are often complex with multiple comorbidities with small vessels. A recent study investigating the benefits of USG for placement of PACs demonstrated ultrasound use was associated with an improved first-attempt success rate (28% compared with 11%, $p = 0.001$) and fewer insertion attempts (3.1 ± 2.6 attempts compared with 6.9 ± 4.2 attempts, $p < 0.001$).[8] Ultrasound proficiency is fast becoming an important skill for vascular access clinicians to improve first-attempt success and reduce the current waste in consumables and staff time to repeatedly attempt catheter insertion.

Overall, we found one in five PACs fail before treatment completion. This rate is comparable to adult studies.[13] Our findings are in support of previous evidence suggesting 10–33% of children requiring arterial catheterisation will experience a device-related complication.[7,9] A retrospective analysis of 10,000 PACs reported catheter-related infections and inflammation (61%) as the most prevalent PAC complications in paediatrics.[9] However, we did not observe a similar rate of infectious complications, but a longer observation period would have been required to capture events. We observed mechanical complications such as poor trace (10%) and blockage (6%) to be the most frequent device complications. This result may be explained by the evolution of vascular catheter materials, with developments in catheters material purported to reduce the incidence of catheter failure and associated complications. A recent retrospective study of 229 PACs lends support to our findings. Habel et al[7] found a bloodstream infection rate of 0% but reported 59% of PACs in paediatric critical care experienced an episode of line malfunction (defined as nonfunctional, e.g., no waveform or blood return or blanching). Traditionally, paediatric vascular access studies have focused on high cost complications such as bloodstream infection. Our findings demonstrate that mechanical complications are much more frequent and lead to catheter failure and reinsertion procedures. Given the high incidence of PAC complications and failure, it is important to identify risk factors associated to prevent catheter failure.

We explored risk factors for PAC failure to identify patients at higher risk. We observed arm board immobilisation (limb splinting) to be associated with an increased risk of PAC failure ($p = 0.04$). This was an unexpected finding, and owing to the sample size, we were not able to perform multivariate modelling; therefore, this finding should be considered with the limitations and context of the study. Arm boards may be a marker for a mobile patient or PAC site placement. A single randomised controlled trial (RCT) in neonates found joint immobilisation with limb splints did not improve the functional duration of peripheral intravenous cannulae.[5] In the PICU, limb immobilisation is primarily a nursing decision. Nurses may perceive this strategy for securement as advantageous in cases where the patient is highly mobile or lightly sedated, at increased risk of accidental or intentional dislodgement. Furthermore, they may use it in areas of greatest flexion to help secure the catheter. In our study, 78% of PACs were inserted into the radial artery, with the local guideline recommending limb immobilisation. However, on daily checks, only 20% of PACs were observed to have limb

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immobilisation. Variation in care and limited adherence to local guidelines were evident; however we did not explore the clinically relevant reasons behind this practice decisions.

Existing evidence examines risk factors in the context of complications and not failure. Our findings indicate increasing critical illness severity is associated with PAC device failure. Use of antiseptic solution other than 2% CHG was also associated with a decrease in PAC failure; however, children receiving 2% CHG had greater severity of illness scores and were more likely to have their PAC inserter in PICU than those receiving other solutions used predominately in the OT. Patient and clinical variables associated with PAC complications include patients of a younger age (5 months–2 years).[9] Surprisingly, we did not observe these variables to be predictors of PAC failure. However, this may be explained by the small sample size and inability to perform multiple regression analysis. Insertion-related variables reported in current literature as associated with PAC complications include PAC placement after prolonged admission (10 + days)[9] and insertion attempts at multiple sites.[7] Overall, 69% of PACs in the study required multiple insertion attempts; however, this was not significantly associated with catheter failure in univariate analysis. One retrospective study found the presence of more than one practitioner during insertion was also an independent risk factor associated with failure; however, this may be indicative of procedural difficulty or inserter experience.[7] Further investigation into the potentially modifiable risk factors associated with PAC failure is needed. Future innovations could focus on ways to minimise PAC failure due to failed limb immobilisation.

Evidence-based recommendations regarding the insertion and care of PAC devices are lacking, indicating a need for a RCTs. Despite this, we observed several practices which may contribute to first-attempt PAC insertion and a reduction in PAC failure rates such as use of technology, skin decontaminant, and transducer fluid. The majority of insertions used 2% CHG in alcohol (58%) for skin decontamination. A recent RCT[11] demonstrated 2% CHG in alcohol led to a significantly lower incidence of PAC-related infections (0.28 vs 1.77 per 1000 catheter days) than povidone iodine in alcohol. In addition to skin decontaminant, choice of PAC flushing solution aligned with local guidelines. We observed 82% of PAC transducer systems to be maintained with heparin saline. However, within current evidence, there is uncertainty regarding the most appropriate infusate to maintain PAC patency and functionality. A systematic review of seven studies (606 adult participants) found insufficient evidence to support the inclusion of heparin to PAC maintenance solution,[14] with no meta-analyses performed because of trials' clinical and statistical heterogeneity. Overall, evidence concerning best-practice PAC care is lacking, and consequently, clinicians have limited evidence to incorporate into local guidelines. High-quality data generated from rigorous clinical trials are needed to inform practice and reduce the high incidence of catheter failure.

5. Limitations

This study has a number of limitations. First, the study was undertaken at a single Australian site, limiting generalisability. Second, we did not characterise patient comorbidities and operator factors in detail, increasing the risk of confounding. A multivariate analysis was not possible because of the small sample size and the low number of events (catheter failure) that could risk overfitting a multivariate model.[4] In addition, the accuracy of insertion variables may be compromised because they relied on bedside clinicians. A strength of the study was that daily checks were performed by a research nurse, improving the accuracy of data collection.

6. Conclusion

PACs are widely used in paediatric anaesthesia and critical care, yet this study has identified 20% of catheters fail before therapy completion. This is a considerable patient safety issue because catheter failure often necessitates a reinsertion procedure which contributes to risk and increases demand on healthcare resources. Future research is needed to identify modifiable risk factors of PAC failure and interventions which reduce the impact of these variables. These strategies could include USG PAC insertion training, dressing and securement devices, and PAC fluid maintenance recommendations. Improvements in PAC insertion and management will have a major impact on the health of children requiring PAC for complex PICU care, providing safe and reliable vascular access to facilitate necessary monitoring, without complications.

Authors' contributions

Dr Ullman and Dr Long conceptualised study, designed the data collection instruments, drafted the initial manuscript, and reviewed and revised the final manuscript. Ms Schults designed the data collection instruments, performed the data collection, drafted the initial manuscript, and reviewed and revised the final manuscript. Ms Pearson designed the data collection instruments, performed the data collection, and reviewed and revised the final manuscript. Ms Takashima carried out the analyses and reviewed and revised the manuscript. Dr Schlapbach, Ms Baveas, and Dr Macfarlane provided clinical expertise in the design of the data collection instrument and reviewed and revised the final manuscript. All authors approved the final manuscript as submitted and agreed to be accountable for all aspects of the work.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.aucc.2019.05.003.

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