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# Peripheral intravenous catheter failure: A secondary analysis of risks from 11,830 catheters

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A R T I C L E I N F O

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A B S T R A C T

*Background:* Peripheral intravenous catheters are an essential medical device which are prone to complications and failure.
*Objectives:* Identify patient, provider and device risk factors associated with all-cause peripheral intravenous catheter failure as well as individual complications: phlebitis, infiltration/occlusion, and dislodgement to improve patient outcomes.
*Design:* Secondary analysis of twelve prospective studies performed between 2008 and 2020.
*Settings:* Australian metropolitan and regional hospitals including one paediatric hospital.
*Participants:* Participants were from medical, surgical, haematology, and oncology units.
*Methods:* Multilevel mixed-effects parametric survival regression was used to identify factors associated with all-cause peripheral intravenous catheter failure, phlebitis, occlusion/infiltration, and dislodgement. We studied patient (e.g., age, gender), device (e.g., gauge), and provider (e.g., inserting clinician) variables. Stepwise regression involved clinically and $p<0.20$ significant variables entered into the multivariable model. Results were expressed as hazard ratios (HRs) and 95% confidence intervals (CI); $p<0.01$ was considered statistically significant.
*Results:* Of 11,830 peripheral intravenous catheters (8,200 participants) failure occurred in 36% ($n$ = 4,263). Occlusion/infiltration incidence was 23% ($n$ = 2,767), phlebitis 12% ($n$ = 1,421), and dislodgement 7% ($n$ = 779) of catheters. Patient factors significantly associated with failure and complications were: female gender (phlebitis; (HR 1.98, 95% CI 1.72–2.27), (infiltration/occlusion; HR 1.45, 95% CI 1.33–1.58), (failure; HR 1.36, 95% CI 1.26–1.46); and each year increase in age (phlebitis; 0.99 HR, 95% CI 0.98–0.99), (failure; 0.99 HR, 95% CI 0.99–0.99). The strongest provider risk factor was intravenous antibiotics (infiltration/occlusion; HR 1.40, 95% CI 1.27–1.53), (phlebitis; HR 1.36, 95% CI 1.18–1.56), (failure; HR 1.26, 95% CI 1.17–1.36). Catheters inserted by vascular access teams were less likely to dislodge (HR 0.53, 95% CI 0.42–0.67). Device risk factors most associated with all-cause failure were wrist/hand (HR 1.34, 95% CI 1.23–1.46), antecubital fossa peripheral intravenous catheters (HR 1.29, 95% CI 1.16–1.44) and 22/24 gauge (HR 1.27, 95% CI 1.12–1.45) catheters.

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*Conclusion:* Factors identified, including the protective aspect of vascular access team insertion, and high catheter failure associated with intravenous antibiotic administration, will allow targeted updates of peripheral intravenous catheter guidelines and models of care.



**What is already known**

- Peripheral intravenous catheters are the most common invasive medical devices in hospitalized patients, but frequently develop complications and fail before the completion of treatment.
- Although previous research has identified some risk factors for peripheral intravenous catheter failure, there are limitations to this research, such as small study sizes or retrospective designs

**What this paper adds**

- Infiltration/occlusion are the most commonly occurring complications for peripheral intravenous catheters and are significantly associated with the insertion site in the wrist/hand or antecubital fossa, and with smaller gauge.
- Peripheral intravenous catheters inserted by vascular access teams are associated with decreased catheter dislodgement compared to general nurse/doctor insertions
- Intravenous antibiotic administration is associated with increased all-cause peripheral intravenous catheter failure, occlusion/infiltration, and phlebitis

## 1. Background

Peripheral intravenous catheters are an essential medical device in hospitals to facilitate patients' short-term intravenous treatment. (Marsh et al., 2017) They are the most frequently used of all in-dwelling devices and most patients will have at least one placed during their hospital admission. (Zingg and Pittet, 2009; Chen et al., 2020) However, these vital devices are prone to complications and failure prior to the completion of treatment; this has been reported to be as high as 67%, (Chico-Padron et al., 2011; Marsh et al., 2015; Enes et al., 2016) making it a common and expensive problem in healthcare. (Helm et al., 2015) The replacement of a failed peripheral intravenous catheter is often painful for the patient, (Cooke et al., 2018; Larsen et al., 2017) can delay time critical intravenous treatment, and lead to an increase in length of hospital stay. (Helm et al., 2015; Royer, 2003) In addition, repeated peripheral intravenous catheter replacements can result in venous access depletion for patients, needle-phobia, hospital avoidance, and an increased likelihood of requiring a central venous access device, which is a more costly device with a higher risk for significant complications. (Chopra et al., 2013; Hawes, 2007)

The most frequently reported peripheral intravenous catheter complications are phlebitis (irritation or inflammation of the vein wall), occlusion (blockage), infiltration (intravenous fluids moving into surrounding tissue), dislodgement, and infection (local and systemic). (Bolton, 2010; Rickard et al., 2012; Marsh et al., 2020; Indarwati et al., 2020; Webster et al., 2008) Treating the sequalae of peripheral intravenous catheter complications can be time-consuming for health professionals (frequently nurses), and often necessitates peripheral intravenous catheter replacement to continue treatment which results in increased fear and procedural anxiety related to hospitalisation. (Helm et al., 2015; Alexandrou et al., 2018; Kleidon et al., 2019) Catheter insertion is often performed by nurses in addition to their usual workloads, and estimated in 2010 to cost healthcare providers $69.30 (AUD) or $51.92 (USD) per episode. (Palefski and Stoddard, 2001; Marsh et al., 2020; Tuffaha et al., 2014) With over two billion peripheral intravenous catheters purchased each year, current high failure rates suggest substantial financial and environmental waste. (Rickard and Ray-Barruel, 2017)

Although previous research have listed variables associated with peripheral intravenous catheter failure, such as catheter gauge, insertion near a joint, or catheter placement in extremes of age (both the young and elderly), there were limitations to this research, such as retrospective data collection or small study sizes. (Indarwati et al., 2020; Abolfotouh et al., 2014; Cicolini et al., 2009; Fields et al., 2012; Singh et al., 2008; Ben Abdelaziz et al., 2017) A lack of high-quality evidence has created challenges identifying variables to focus improved peripheral intravenous catheter care. Therefore, using a published and validated framework, (Chopra et al., 2012) we sought to define modifiable and non-modifiable patient-, provider-, and device (catheter) characteristics associated with peripheral intravenous catheter failure. In doing so, we hope to provide stakeholders with targeted evidence to inform local and international policies and guidelines and inform models of care for peripheral intravenous catheter insertion and maintenance.

## 2. Methods

### 2.1. Design

Secondary analysis of twelve prospective studies conducted between 2008 and 2020. The combined dataset included 8197 participants with 11,830 peripheral intravenous catheters.

### 2.2. Types of studies and participants

Data included in this analysis were from our research network (Alliance for Vascular Access Teaching and Research, AVATAR, www.avatargroup.org.au). These were comprised of ten randomized controlled trials (RCTs) (Marsh et al., 2015; Rickard et al., 2012; Rickard et al., 2010; Keogh et al., 2016; Rickard et al., 2018; Marsh et al., 2018; Marsh et al., 2018; T.M. Kleidon et al., 2020; T.M. Kleidon et al., 2020; Keogh et al., 2020) and two prospective observational studies. (N. Marsh et al., 2018; Larsen et al., 2020) Included studies explored peripheral intravenous catheter replacement frequency, dressing/securement efficacy, catheter flushing practices, insertion models, and observation of peripheral intravenous catheter management (Supplementary Table 1). Notably, these studies did not include long peripheral intravenous catheters or midline catheters (Gorski et al., 2021), they tested interventions that were variations of current practice and not premarket/investigational products, thus data collected reflects the range of standard hospital practices and were suitable for the aim of this analysis.

Studies were carried out in two Australian states (Queensland and Tasmania) in two large metropolitan hospitals, two regional hospitals, and one paediatric speciality hospital. Participants were adult and paediatric patients from medical, surgical, haematology, oncology, and the general hospital setting. Although patients and hospitals varied, all data were prospectively collected using standardised terminology.

Each included study obtained human research ethics committee (HREC) approval prior to commencement from the appropriate health service. Approval to conduct this secondary data analysis was obtained from study lead authors and Griffith University human research ethics committee (GU Ref No 2019/817).

### 2.3. Data collection

At recruitment, using either a purpose-built Microsoft Access database or the electronic data platform Research Electronic Data Capture (REDCap) hosted on Griffith University servers, research nurses (ReNs) collected basic patient demographic details (e.g. gender, admitting diagnosis, comorbidities) and catheter characteristics data (e.g. insertion gauge, insertion site). Across all studies, ReNs assessed the peripheral intravenous catheter insertion site at least second daily and at catheter removal for signs of peripheral intravenous catheter complications (e.g. pain, redness, oedema). To ensure protocol adherence, project managers trained and supervised ReNs, and audited study data quality. For each individual study, data was extensively cleaned for data analysis. For this research project a data manager exported and combined individual study databases into a single de-identified database for secondary analysis.

### 2.4. Outcome definitions

For data analysis, all-cause peripheral intravenous catheter failure was defined as unplanned removal of the catheter before completion of intravenous therapy. We used a composite variable consisting of: occlusion (catheter will not flush or leaks when flushed), infiltration (movement of intravenous therapy into surrounding tissues), phlebitis (from clinical record or observed as two or more of pain or tenderness of the maximum 10, redness, swelling, palpable cord, vein streak or purulence, or patient reported as too painful to tolerate), dislodgement (partial or complete dislodgment of the catheter from the vein), and local or peripheral intravenous catheter-related bloodstream infection (O'Grady et al., 2011) to define failure.

### 2.5. Variables

Patient-, provider-, and device characteristics previously identified in literature and consistently collected using standardised definitions in all included studies were abstracted. Peripheral intravenous catheter dwell time was calculated by subtracting the date/time of catheter removal from the date/time of catheter insertion. Patient variables such as admitting diagnosis and comorbidities (none, one, or $\geq$ two) were collected as documented in medical notes. The Fitzpatrick scale was used to determine patients skin type. (Fitzpatrick, 1988) Provider characteristics such as department of insertion (e.g., emergency department, ward), designation of inserting clinician (e.g., physician, nurse), and number of insertion attempts were collected from direct observation by the research nurse or medical chart documentation. Intravenous antibiotics were considered when any antibiotic was directly administered through the study catheter. Peripheral intravenous catheter characteristics such as insertion site and catheter gauge were collected by direct observation by the research nurse.

### 2.6. Data analysis

The demographic and clinical characteristics of participants were descriptively reported, using categorical and continuous descriptors appropriate to their distribution. Peripheral intravenous catheter failure and complications (infiltration/occlusion, phlebitis, dislodgement) were time-to-event outcomes, therefore associations were reported using hazard ratios (HRs) and 95% confidence intervals (CIs). Multilevel mixed-effects parametric survival regression models were used with study and participants set as random effects to explore the associations between risk factors and peripheral intravenous catheter all-cause failure. This approach was also used to examine associated factors for individual complications that resulted in peripheral intravenous catheter failure: 1. phlebitis; 2. infiltration/occlusion (catheter will not flush or leaks and/or movement of intravenous therapy into surrounding tissue); and 3. catheter dislodgement. (N. Marsh et al., 2020) We did not examine associations for infection complications due to low prevalence, making examination unfeasible. Imputation for missing data was deemed not appropriate due to its non-random nature. Variables clinically relevant and significant at $p<0.20$ level on univariable analyses were subjected to multivariable regression (Budtz-Jorgensen et al., 2007). Correlations between variables were checked and covariate interactions were explored. Manual mixed (forward and backward) approach was used for variable selection for the final multivariable model guided by the changes in effect sizes, and Akaike's and Bayesian Information Criterion (to assess model parsimony and goodness-of-fit). Inserting clinician variable was re-categorised as vascular access team and other clinicians to reflect common insertion workforce models (generalist inserter versus vascular access teams) utilised in hospitals (N. Marsh et al., 2020). Age and gender were included in the model as *a priori* selected variables identified in previous studies. (N. Marsh et al., 2018) Final models were checked using the global proportional-hazards assumption test and the visual inspection of the cumulative hazard of Cox–Snell residual plot. The analysis was undertaken using Stata (version 15; StataCorp, College Station, TX). Both clinical and statistical significance ($p<0.01$) using the effect size and 95% CI were considered when interpreting the results.

## 3. Results

### 3.1. Participant characteristics

Table 1 describes the baseline characteristics of patients. Participants were predominantly male ($n$ = 4856, 59%) with a median age of 58 (inter-quartile range [IQR] 31) years: 59 years (IQR 27) for adults ($\geq$18 years) ($n$ = 7807) and 6 years (IQR 9.7) ($n$ = 390) for children. More than half of study participants had two or more comorbidities ($n$ = 4619, 56%). Most patients had a surgical diagnosis ($n$ = 5190, 63%) followed by a medical diagnosis ($n$ = 2503; 31%) and one-fifth of participants ($n$ = 1535, 19%) had an infection at recruitment. Most participants ($n$ = 2525, 68%) had white skin and good skin integrity ($n$ = 2280, 47%).

### 3.2. Peripheral intravenous catheter characteristics

The majority of peripheral intravenous catheters in this study were inserted in a medical/surgical ward ($n$ = 8300, 71%), with just over one-third inserted by a vascular access team member ($n$ = 4475, 38%). The most frequently selected size was 20 gauge (g) ($n$ = 5726, 49%) and the most common insertion site was the forearm ($n$ = 5960, 50%). Multiple insertion attempts (2 or more) were necessary for 43% ($n$ = 2268) of patients. See Table 2.

### 3.3. Peripheral intravenous catheter failure and complications

All-cause peripheral intravenous catheter failure occurred in 36% ($n$ = 4263) of catheters at a failure rate of 127 per 1000 catheter-days (95% confidence interval [CI] 123–131). Peripheral intravenous catheter failure occurred as a result of multiple individual catheter complications with the most common being infiltration/occlusion ($n$ = 2767, 23%), followed by phlebitis ($n$ = 1421,

**Table 1**
Patient characteristics at baseline.

| Variable (n)* | Frequency (%) | peripheral intravenous catheter failure and complications, n (%) | | | |
|---|---|---|---|---|---|
| | | All-cause peripheral intravenous catheter failure $n = 3175$ | Infiltration/occlusion $n = 2156$ | Phlebitis $n = 1235$ | Dislodgement $n = 717$ |
| Age - years (8197) | 58 (31)[a] | 59 (30)[a] | 60 (30)[a] | 55(30)[a] | 59 (29)[a] |
| Male gender (8197) | 4856 (59) | 1791 (56) | 1210 (56) | 626 (51) | 454 (63) |
| Comorbidities (8195): | | | | | |
| none | 1819 (22) | 641 (20)[b] | 413 (19)[b] | 267 (22)[c] | 163 (23)[b] |
| one | 1757 (21) | 654 (21) | 426 (20) | 293 (24) | 132 (18) |
| two or more | 4619 (56) | 1878 (59) | 1315 (61) | 674 (55) | 420 (59) |
| Diagnosis (8195): | | | | | |
| medical | 2503 (31) | 955 (30)[b] | 616 (29)[b] | 423 (34)[c] | 208 (29)[b] |
| surgical | 5190 (63) | 2026 (64) | 1414 (66) | 735 (60) | 465 (65) |
| cancer care | 370 (5) | 158 (5) | 109 (5) | 59 (5) | 35 (5) |
| obstetrics | 106 (1) | 12 (<1) | 5 (<1) | 4 (<1) | 3 (<1) |
| other | 26 (<1) | 22 (<1) | 10 (<1) | 13 (1) | 4 (1) |
| Wound (8195) | 2125 (26) | 834 (26) [b] | 524 (24) [b] | 348 (28) [c] | 189 (26)[b] |
| Infection (8145) | 1535 (19) | 725 (23) | 544 (25) | 314 (25) | 124 (17) |
| Skin integrity (4827): | | | | | |
| good | 2280 (47) | 744 (43) | 421 (41) | 359 (49) | 158 (40) |
| fair | 1859 (39) | 721 (42) | 463 (44) | 280 (39) | 153 (39) |
| poor | 688 (14) | 260 (15) | 161 (15) | 88 (12) | 81 (21) |
| Skin type (3724): | | | | | |
| pale white | 408 (11) | 162 (12) | 103 (13) | 63 (10) | 54 (16) |
| white | 2525 (68) | 923 (68) | 526 (67) | 444 (71) | 191 (62) |
| light brown | 545 (15) | 169 (13) | 99 (13) | 73 (12) | 45 (15) |
| moderate brown | 160 (4) | 64 (5) | 37 (5) | 27 (4) | 11 (4) |
| dark brown | 65 (2) | 23 (2) | 17 (2) | 12 (2) | 2 (1) |
| deep brown | 21 (<1) | 8 (<1) | 3 (<1) | 3 (<1) | 6 (2) |

[a] median (inter-quartile range).
[b] two missing.
[c] one missing.
* number of patients for which the variable was collected.

**Table 2**
Patient characteristics at baseline.

| Variable (n) | Frequency (%) | Peripheral intravenous catheter failure and complications, n (%) | | | |
|---|---|---|---|---|---|
| | | All cause peripheral intravenous catheter failure $n = 4263$ | Infiltration/occlusion $n = 2767$ | Phlebitis $n = 1421$ | Dislodgment $n = 779$ |
| Insertion department (11,830): | | | | | |
| ward | 8300 (71) | 3100 (73) | 2053 (74) | 1042 (73) | 546 (70) |
| ED | 1322 (11) | 463 (11) | 300 (11) | 145 (10) | 86 (11) |
| proc/rad | 1612 (14) | 516 (12) | 319 (12) | 165 (12) | 101 (14) |
| other | 421 (4) | 129 (3) | 61 (2) | 54 (4) | 34 (4) |
| unknown | 175 (1) | 55 (1) | 34 (1) | 15 (1) | 12 (2) |
| Inserted by (11,830): | | | | | |
| physician | 2546 (21) | 868 (20) | 500 (18) | 304 (21) | 163 (21) |
| nurse | 796 (7) | 247 (6) | 154 (6) | 82 (6) | 61 (8) |
| Vascular access team | 4475 (38) | 1623 (38) | 1109 (40) | 616 (43) | 240 (31) |
| unspecified* | 4013 (34) | 1525 (36) | 1004 (37) | 419 (29) | 315 (40) |
| Insertion site (11,830): | | | | | |
| upper arm | 311 (3) | 114 (3) | 81 (3) | 37 (3) | 24 (3) |
| cubital fossa | 1671 (14) | 609 (14) | 371 (13) | 185 (13) | 130 (17) |
| forearm | 5960 (50) | 2101 (49) | 1428 (52) | 744 (52) | 320 (41) |
| wrist | 955 (8) | 313 (7) | 178 (6) | 126 (9) | 65 (8) |
| hand | 2813 (24) | 1078 (25) | 681 (25) | 312 (22) | 227 (29) |
| foot/leg | 38 (<1) | 21 (<1) | 13 (<1) | 7 (<1) | 8 (1) |
| other | 32 (<1) | 7 (<1) | 5 (<1) | 3 (<1) | 0 (0) |
| unknown | 50 (<1) | 20 (<1) | 10 (<1) | 7 (<1) | 5 (1) |
| Peripheral intravenous catheter size (11,830): | | | | | |
| 14/16/18 g | 1654 (14) | 526 (12) | 311 (11) | 174 (12) | 113 (15) |
| 20 g | 5726 (49) | 2082 (49) | 1425 (52) | 673 (47) | 334 (43) |
| 22 g | 4201 (36) | 1541 (36) | 968 (35) | 541 (38) | 300 (39) |
| 24 g | 63 (1) | 31 (1) | 23 (1) | 13 (1) | 7 (1) |
| unknown/other | 186 (2) | 83 (2) | 40 (1) | 20 (1) | 25 (3) |
| Dominant side (5134): | 2636 (51) | 930 (54) | 516 (54) | 410 (55) | 184 (52) |
| Insertion attempt (5324): | | | | | |
| one | 3056 (57) | 1050 (57) | 607 (60) | 453 (59) | 227 (60) |
| Two | 618 (12) | 221 (12) | 119 (12) | 96 (12) | 53 (14) |
| three or more | 1650 (31) | 559 (31) | 286 (28) | 222 (29) | 98 (26) |

ED = emergency department; Proc = procedure room; rad = radiology department; *unspecified clinician but not from a vascular access team; *g* = gauge.

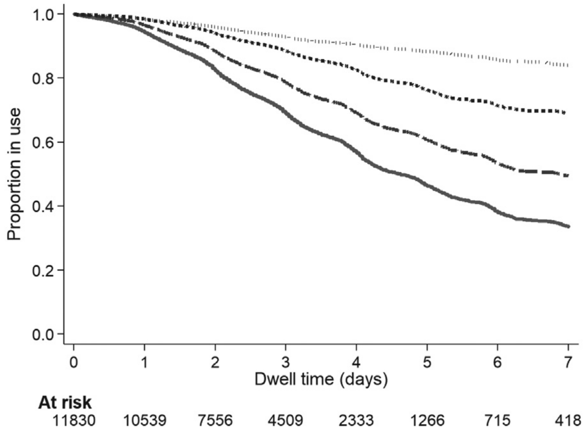


**Fig. 1.** Kaplan-Meier Survival Curve for all-cause device failure, occlusion/infiltration, phlebitis, and dislodgement.
From the top: Dislodgement (dotted line), phlebitis (short dashed line), occlusion/infiltration (long dashed line), overall failure (solid line).

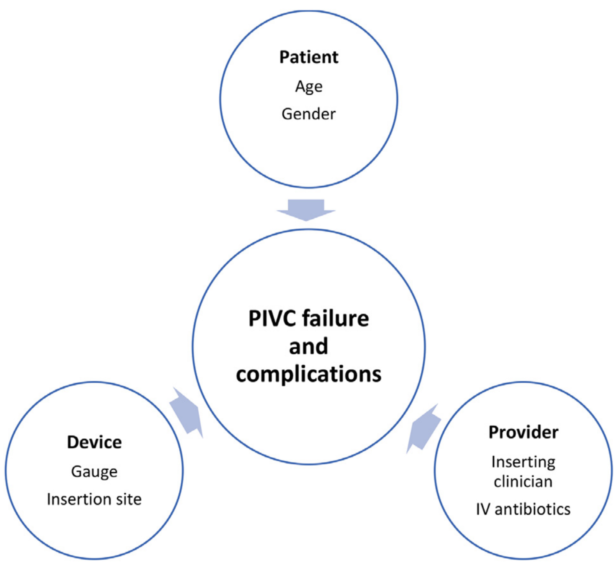


**Fig. 2.** Variables included in multivariable analysis for all-cause PIVC failure, occlusion/infiltration, phlebitis and dislodgement.

12%), and catheter dislodgement ($n$ = 779, 7%). Fig. 1 shows the Kaplan-Meier survival estimate for all-cause peripheral intravenous catheter failure, occlusion/infiltration, phlebitis, and dislodgement, for the first 150 h of catheter dwell ($n$ = 11,267 catheters). The results of the univariable analyses for this study are presented in Supplementary Table 2.

### *3.4. Multivariable analyses*

Patient-, provider-, and device characteristics included in the multivariable analyses are presented in Fig. 2 and Table 3.

### *3.5. Patient risk factors*

Female gender was significantly associated with phlebitis (HR 1.98, 95% CI 1.72–2.27), infiltration/occlusion (HR 1.45, 95% CI 1.33–1.58), and all-cause peripheral intravenous catheter failure (HR 1.36, 95% CI 1.26–1.46). Each year increase in patient's age was significantly associated with a 1% lower risk of all-cause peripheral intravenous catheter failure (HR 0.99, 95% CI 0.99–0.99) and less phlebitis (HR 0.99, 95% CI 0.98–0.99). See Table 3.

### *3.6. Provider risk factors*

Catheters inserted by a vascular access team had a significant association with decreased dislodgement (HR 0.53, 95% CI 0.42–0.67). Antibiotic administration was significantly associated with infiltration/occlusion (HR 1.40, 95% CI 1.27–1.53), phlebitis (HR 1.36, 95% CI 1.18–1.56), and all-cause failure (HR 1.26, 95% CI 1.17–1.36).

### *3.7. Device risk factors*

Placement of a peripheral intravenous catheter in the wrist/hand (HR 1.34, 95% CI 1.23–1.46) or antecubital fossa (HR 1.29, 95% CI 1.16–1.44) compared with forearm insertions, and device sizes 22/24 g (HR 1.27, 95% CI 1.12–1.45) compared to 14 to 18 g catheters were significantly associated with failure (table 3). Infiltration/occlusion was significantly associated with 20 g (HR 1.23, 95% CI 1.06–1.42) and 22/24 g (HR 1.30, 95% CI 1.11–1.52). Complications were significantly associated with peripheral intravenous catheters in the wrist/hand (dislodgement HR 1.83, 95% CI 1.52–2.21; infiltration/occlusion HR 1.24 95%CI 1.12–1.37), and antecubital fossa (dislodgement HR 1.74, 95% CI 1.37–2.21; infiltration/occlusion HR 1.20 95%CI 1.05–1.38).

## 4. Discussion

Peripheral intravenous catheters are a ubiquitous but necessary invasive clinical device, however they carry risk. Ideally, peripheral intravenous catheters should remain complication-free for the duration of therapy, yet the findings of this secondary analysis are that more than one in three (36%) failed before the completion of treatment. The most frequently reported peripheral intravenous catheter complication was infiltration/occlusion (23%), which is consistent with the results of studies from North America and Asia. (Ascoli et al., 2012; Murayama et al., 2017; Xu et al., 2017) Phlebitis was observed in 12% of catheters. Although phlebitis is often considered an ambiguous term, with over 71 different scales used in studies to define its presence, (Ray-Barruel et al., 2014) this secondary analysis consistently applied clinicians' determination or a definition of two or more signs or symptoms present at the insertion site, providing the largest ever, and most consistently reported, incidence of phlebitis. However, it is no longer enough to simply identify the incidence of failure and complications, we need to understand the patient, device, and provider factors that place our most vulnerable patient populations at risk of healthcare associated harm as a result of their peripheral intravenous catheter.

This study identified patient factors, such as female gender, as a consistent variable associated with failure, infiltration/occlusion, and phlebitis. This association has been reported in other studies, (Abolfotouh et al., 2014; Dillon et al., 2008; Hirschmann et al., 2001) and it has been suggested it may be related to the smaller calibre of female vessels compared to males. (N. Marsh et al., 2018; Dillon et al., 2008) However, female gender remained significant in modelling after adjustment for catheter gauge. Although gender has been identified as influencing the effectiveness of medical devices, likely due to different hormonal and adipose tissue distribution, the United States of America's Food and Drug Administration have identified an under-representation of women in clinical trials testing medical devices. (U.S. Department of Health and Human Services, 2014) This makes it difficult to determine the efficacy of devices for women, (Fox-Rawlings et al., 2018) and highlights a need for manufacturers to consider gender when designing and testing peripheral intravenous catheters.

Age was another significant patient factor associated with a 1% decrease in the risk of phlebitis with each year increase in age, perhaps due to the inclusion of acutely unwell young

**Table 3**
Multilevel mixed-effects parametric survival regression of peripheral intravenous catheter all-cause failure and complications (infiltration/occlusion, phlebitis, and dislodgement).

| | Hazard Ratios (95% CI) by failure and complications ($n$ = 11,552) | | | |
|---|---|---|---|---|
| | All cause failure | Infiltration/occlusion | Phlebitis+ | Dislodgement+ |
| Patient | | | | |
| Age (1 y increase) | 0.99 (0.99–0.99)* | ^ | 0.99 (0.98–0.99)** | ^ |
| Female gender (ref.: male) | 1.36 (1.26–1.46)** | 1.45 (1.33–1.58)** | 1.98 (1.72–2.27)** | ^ |
| Provider | | | | |
| Inserted by vascular access team(ref: all other inserters) | ^ | ^ | ^ | 0.53 (0.42–0.67)** |
| Intravenous antibiotic | 1.26 (1.17–1.36)** | 1.40 (1.27–1.53)* | 1.36 (1.18–1.56)** | ^ |
| Device | | | | |
| Location (ref.: forearm)#: | | | | |
| upper arm | ^ | ^ | ^ | ^ |
| antecubital fossa | 1.29 (1.16–1.44)** | 1.20 (1.05–1.38)* | ^ | 1.74 (1.37–2.21)** |
| wrist/hand | 1.34 (1.23–1.46)** | 1.24 (1.12–1.37)** | ^ | 1.83 (1.52–2.21)** |
| Device size (ref.: 14–18 g): | | | | |
| 20 g | ^ | 1.23 (1.06–1.42)** | ^ | ^ |
| 22/24 g | 1.27 (1.12–1.45)** | 1.30 (1.11–1.52)** | ^ | ^ |

CI = confidence interval.
^ not significant * $p < 0.01$.
** $p < 0.001$.
# foot/leg insertion removed due to small numbers; $g$ = gauge.
+ adjusted for age, gender, comorbidity, location, vascular access team, procedure/radiology insertion, gauge, and intravenous antibiotics during treatment (comorbidity and procedure/radiology insertion are not shown as they were not significant).

children (over 5 kgs and up to 18 years of age) in the cohort. A sensitivity analysis of adult patients showed minimal impact on the overall results. This may be related to dampened inflammatory response or structural changes in the vein wall associated with ageing. (Schelper, 2003) Regardless of the cause, these results highlight a need for vigilant observation of female and younger patients for signs of peripheral intravenous catheter complications and failure, and the targeting of new clinical innovations to prevent phlebitis in these groups.

The site of insertion, specifically at the point of flexion (antecubital fossa, hand/wrist) compared to insertion in the forearm, was a characteristic significantly associated with all-cause failure, infiltration/occlusion, and catheter dislodgement. This is likely due to joint motion loosening the catheter dressing or securement, and causing catheter movement in the vein, creating irritation, catheter kinking, and/or mechanical occlusion. In addition, peripheral intravenous catheter movement can cause the catheter tip to pierce the vessel wall leading to infiltration, inflammation, thrombus formation, occlusion, and/or complete dislodgement. (Helm et al., 2015; Hadaway, 2007) These results are similar to studies reporting higher peripheral intravenous catheter failure rates when catheters were placed over joints. (Cicolini et al., 2009; do Rego Furtado, 2011) Peripheral intravenous catheter insertion in the forearm reduces failure and complications, however many inserters find it challenging if there are no visible or palpable veins, reverting to hand/wrist or antecubital fossa placement. This further highlights a need for vascular access teams to be the dominant model of insertion, complemented by improved education and training for all inserters, including the use of technology such as ultrasound to increase the number of successful, forearm placed peripheral intravenous catheters, and therefore reduce catheter failure. (Lian et al., 2017)

Infiltration/occlusion and all-cause failure were also significantly associated with catheter sizes 22 g and 24 g compared to 14–18 g catheters. This may be related to the amount of catheter residing within the vein. Although studies included in this analysis did not report the length of the catheter, it is likely that 22 g and 24 g catheters were shorter (2.5 cm and 1.9 cm respectively) than catheters ≥20 g (3 cm). A recent prospective observational study of ultrasound inserted peripheral intravenous catheters ($n$ = 86) in an emergency department found that 100% of catheters failed when less than 30% was residing in the vein, compared to no failure when greater than 65% of catheter length in the vein. (Pandurangadu et al., 2018) This may be a result of greater catheter length in the vein decreasing catheter movement known to irritate the vessel wall and lead to complications such as phlebitis (N. Marsh et al., 2020), or the complete dislodgement of the catheter out of the vein. Over the last few years long peripheral intravenous catheters (≥4.0 cm) have increased in popularity, particularly for patients with difficult vascular access. (Bahl et al., 2020; E. Alexandrou et al., 2018) The potential benefit of longer catheters needs to be explored in high quality RCTs (e.g. standard versus long peripheral intravenous catheters) to help guide clinicians and inform international guidelines which currently recommend the use of the smallest gauge possible, but make no recommendations about ideal catheter length. (Gorski et al., 2021; Loveday et al., 2014)

Different models of peripheral intravenous catheter insertion are used by healthcare care providers. (N. Marsh et al., 2020) Some rely on vascular access or intravenous therapy teams to place and monitor catheters, (Carr et al., 2010) these teams are made up of nurses who have advanced vascular assessment and technical skills related to peripheral intravenous catheters. (N. Marsh et al., 2020; N. Marsh et al., 2018) Other models depend on bedside clinicians (nurses and doctors) for peripheral intravenous catheter insertion, often with various levels of insertion skill. (Carr et al., 2018) Our study found almost 50% decrease in the risk of catheter dislodgement associated with vascular access team-inserted catheters. These findings are in keeping with results from small observational studies that have reported the advanced insertion skills of vascular access teams improve first-time insertion success and decrease complications. (Palefski and Stoddard, 2001; Carr et al., 2010; da Silva et al., 2010) In addition to direct benefits of vascular access team-inserted peripheral intravenous catheters, our study shows significant association of many factors that vascular access team can ensure happen, such as preferment for forearm insertion, rather than areas of flexion. Vascular access team inserters have advanced assessment and technical skills including appropriate gauge and insertion site selection. (Wallis et al., 2014) Our study provides high-quality evidence to support healthcare providers, planners, and policy makers to develop guidelines recommending a vascular access team insertion model.

Intravenous antibiotic administration was the other provider risk factor significantly associated with all-cause failure, infiltration/occlusion, and phlebitis. Due to varying study processes regarding intravenous antibiotic data collection, *individual* antimicrobials could not be differentiated, however anecdotally there was a large variety of types (and doses) administered. Despite this, the findings of our study are consistent with previous research that reported high rates of phlebitis and failure with the use of *any* intravenous antibiotics. (Salgueiro-Oliveira et al., 2012; Roszell and Jones, 2010) Current recommendations for appropriate vascular access device selection for infusions and medications state peripheral intravenous catheters should not be used for infusions with extremes of pH and osmolarity. (Gorski et al., 2021; Gorski et al., 2015) However, commonly used intravenous antibiotics, such as vancomycin (pH 2.5–4.5), (Burridge and S., 2017) that have a known association with device failure, continue to be administered through a peripheral intravenous catheter. (Bruniera et al., 2015; Lanbeck et al., 2002) Moreover, the association between intravenous antibiotic administrations and all-cause failure, infiltration/occlusion, and phlebitis, may also be influenced by infusion rate and drug dilution. (LaRue and Peterson, 2011) To circumvent vessel irritation, inserters should be cognisant of whether the catheterised blood vessel is large enough with sufficient blood flow for antibiotic administration, and that medications are diluted according to manufacturer instruction (and not infused too rapidly). (McCallum and Higgins, 2012) A failed peripheral intravenous catheter can lead to delayed or missed doses of antibiotics placing the patient at risk of harm from antibiotic resistance and act as an obstruction to eradication of infection. (Patel et al., 2019) While the use of a central venous access device to alleviate the problems arising from multiple failed peripheral intravenous catheters is widely recognised, it is yet unclear the role that other devices such as long peripheral intravenous catheters (>4.5 cm in adults) and midlines (long peripheral catheters placed in a large vessel of the upper arm with the tip at the level of axillary fold) may have upon catheter complications and failure. (Alexandrou et al., 2011)

A major strength of this secondary analysis is that data were derived from high-quality studies that prospectively collected the same variables, using the same definitions, strengthening the reliability of the reported outcomes. It is the largest study undertaken on this topic to date, comprising well over 10,000 peripheral intravenous catheters with more than adequate statistical power to investigate and detect important risk factor associations. While inclusion of a larger cohort of paediatric patients would have been ideal data was collected in multiple hospital departments across both adult and paediatric settings enhancing the generalisability of our results. Although limited to an Australian population, the incidence of complications was similar to recent systematic reviews of adult and paediatric studies which reported a global infiltration/occlusion incidence of 22% in adults and 19% in paediatrics, and a 6% and 8% dislodgement occurrence, respectively. (N. Marsh et al., 2020; Indarwati et al., 2020) This demonstrates that peripheral intravenous catheter complications and failure are a substantial and international problem.

Peripheral intravenous catheters are an essential device for the delivery of healthcare. (Chen et al., 2020) The high peripheral intravenous catheter complication and failure incidence reported in this study highlight an urgent need for investment to improve insertion, and RCTs to test interventions designed to target the identified risk factors so as to improve both insertion and post insertion care.

## 5. Conclusion

The results of this study support vascular access teams for peripheral intravenous catheter insertion, complemented by other highly skilled inserters, choosing insertion in the forearm rather than points of flexion, gauge and length that adequately enters the vein, and heightened monitoring of females, younger patients, and patients receiving intravenous antibiotics. In addition, our results show that intravenous antibiotic administration through a peripheral intravenous catheter has increased association with failure, phlebitis and infiltration/occlusion. More high-quality research is needed to explore the potential benefit of other types of peripheral catheters such as the midline catheter. The risk factors identified can influence product development, policy/guideline development, education and training, and workforce models to improve insertion and post-insertion practices.

## Declaration of Competing Interest

NM reports, Griffith University has received on her behalf, speaker fees from 3M, investigator-initiated research grants from Becton Dickinson and Cardinal Health, and a consultancy payment from Becton Dickinson for clinical feedback related to catheter placement and maintenance (unrelated to the current project).

EL's employer, Griffith University, received, on her behalf, an investigator-initiated grant-in-aid from Cardinal Health (formerly Medtronic) (unrelated to the current project) and an educational scholarship (conference attendance) from Angiodynamics (unrelated to the current project).

TK reports investigator-initiated research grants and speaker fees provided to her employer Griffith University from 3M Medical, Becton Dickinson, Medical Specialties Australia and Smiths Medical, and a consultancy payment provided to Griffith University from Access Scientific for consultancy work (unrelated to the current project).

SK reports speaker fees provided to QUT and research consultancy monies via Griffith University from BD Medical.

AJU reports investigator-initiated research grants and speaker fees provided to Griffith University from vascular access product manufacturers (3M Medical, Becton Dickinson-Bard, and Cardinal Health) (unrelated to the current project).

CMR's (Griffith University) employer has received, on her behalf investigator-initiated research or educational grants from: Becton Dickinson-Bard, Cardinal Health, and consultancy payments for educational lectures/expert advice from 3M Medical and Becton Dickinson-Bard (unrelated to the current project).

MT, GM, and VC have nothing to declare.

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Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.ijnurstu.2021.104095.

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