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Inherent and modifiable risk factors for peripheral venous catheter failure during cancer treatment: a prospective cohort study.

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ABSTRACT

Purpose:

To identify modifiable and non-modifiable risk factors for peripheral intravenous catheter (PIV) failure among patients requiring intravenous treatment for oncology and haematology conditions.

Methods:

A single centre prospective cohort study was conducted between October 2017 and February 2019. Adult in-patients requiring a PIV for therapy were prospectively recruited from two cancer units at a tertiary hospital in Queensland, Australia. The primary outcome was a composite of complications leading to PIV failure (local- and bloodstream- infection; occlusion; infiltration/extravasation; leakage; dislodgement; and/or phlebitis). Secondary outcomes were: (i) PIV dwell-time; (ii) insertion- and (iii) failure of- a CVAD; (iv) adverse events; (v) length of hospital stay. Outcomes were investigated using Bayesian multivariable linear regression modelling, and survival analysis.

Results:

Of 200 participants, 396 PIVs were included. PIV failure incidence was 34.9%; the most common failure type was occlusion/infiltration (n=74, 18.7%), then dislodgement (n=33, 8.3%), and phlebitis (n=30, 7.6%). While several patient and treatment risk factors were significant in univariable modelling, in the final multivariable model, only the use of non-sterile tape (external to the primary dressing) was significantly associated with decreased PIV dislodgement (Hazard Ratio 0.06, 95% Confidence Interval 0.01, 0.48; p=0.008).

Conclusion:

PIV failure rates among patients receiving treatment for cancer is high; the sequelae of which may include delayed treatment and infection. Larger studies on risk factors and interventions to prevent PIV failure in this population are needed; however, the use of secondary securements (such as non-sterile tape) to provide further securement to the primary PIV dressing is particularly important.

Registration:

Study methods were registered prospectively with the Australian New Zealand Clinical Trials Registry on the 27th March 2017 (ACTRN12617000438358); https://www.anzctr.org.au/Trial/Registration/TrialReview.aspx?id=372191&isReview=true

Keywords:

Peripheral Venous; Vascular Access; Oncology; Haematology.

Introduction:

Patients receiving treatment for cancer (both solid tumours and haematological malignancies) are highly dependent upon intravenous (IV) infusions such as chemotherapies and antibiotics [1]. Within this setting, Central Venous Access Devices (CVADs) are recommended for long-term and vesicant treatments (i.e. infusates harmful to peripheral vasculature), and Peripheral Intravenous (PIV) catheters for short-term and non-vesicant treatments [2]. Studies have highlighted drawbacks of PIV use in cancer treatment (compared with CVADs), including the frequency and pain associated with frequent venepuncture; inability to draw blood (a regular requirement during treatment); and subsequent vein exhaustion [3, 4]. Despite this, CVAD use is, in some cases, impractical for reasons such as recency of bloodstream infection (BSI) [5] or short-term IV treatment; and PIVs remain a necessary tool in cancer care. Little evidence exists, however, to establish the prevalence- and characteristics- of PIV use specifically in the cancer setting, despite studies highlighting this as a key area of concern [1, 6]. Moreover, recent studies have identified alarmingly high rates of PIV failure (resulting from occlusion, infiltration, dislodgement, phlebitis, and infection) in medical and surgical-care populations (33-69%) [7, 8]. However, similar outcome rates have yet to be confirmed in cancer-specific populations as, traditionally, PIV studies in cancer populations have focussed upon the incidence and treatment of vesicant extravasation injuries, specifically [9, 10]; to date there have been no prospective studies which have reported the incidence of *all-cause* PIV failure.

There are inherent differences in the population of patients with cancer which would lead clinicians to believe the rate and characteristics of PIV failure would differ to medical and surgical populations (e.g. regular administration of vesicant therapies; limbs affected by lymphoedema; and long-term treatment requirements) [11]. The aim of this prospective observational cohort study was to investigate the use and outcomes of PIV (and subsequent use- and failure- of CVAD) among cancer care inpatients from hospital admission through to discharge, and to determine both inherent and modifiable risk factors for PIV failure.

Methods:

Study design and setting:

We conducted a single centre prospective, observational cohort study at a large teaching and referral hospital in Queensland, Australia (approximately 3000 inpatient admissions per year for cancer). Participants were prospectively enrolled between 20th October 2017, and 3rd February 2019 from two haematology (including bone marrow transplant (BMT)), and oncology (medical, radiation) in-patient units. Study methods were registered prospectively with the Australian New Zealand Clinical Trials Registry on the 27th March 2017 (ACTRN12617000438358).

Ethical Approvals:

Human Research Ethics Committee (HREC) approval was obtained from the Royal Brisbane and Women's Hospital (HREC/17/RBWH/7); and Griffith University (NRS/2017/154).

Participants:

All adult patients (≥18 years) admitted to a haematology/bone-marrow transplant or oncology (medical, radiation) units at the recruiting hospital were eligible for participation if they (i) were able to provide informed consent; and (ii) had a PIV inserted within the previous 48 hours (first PIV this admission). Exclusion criteria were: (i) patients receiving end-of-life care; (ii) those from a non-English speaking background without a suitable interpreter. Patients with previous enrolment in the study were also excluded, as patient may present with the same inherent risk factors each admission, potentially influencing findings. The Research Nurses (ReNs) reviewed admission lists for the recruiting wards three times weekly (Monday, Wednesday, Friday), and further screened for the presence of a PIV, before liaising with the treating nurse/team for patient appropriateness to participate. Eligible patients were provided with a participant information sheet and consent form; signed informed consent was required prior to enrolment.

PIV insertion procedures:

Standard PIV insertion and maintenance policies and procedures were in place throughout the duration of the project and applied to both the haematology/bone-marrow transplant and oncology (medical, radiation) units. Skin preparation was 2% chlorhexidine gluconate (CHG) in alcohol 70% for skin preparation (SoluPrep™; 3M, St Paul, USA); and PIVs were BD Insyte™ Autoguard™ blood control catheters (Becton Dickinson, Utah, USA). PIVs were recommended to be dressed with a bordered polyurethane dressing, Tegaderm™ 1635 (3M, St Paul, USA), however small variations in selected dressings were common in these units. Due to the nature of the study, compliance was not monitored or enforced.

Outcomes:

The primary outcome was all-cause PIV failure; a composite measure of any one of the following five events: infection (suspected- or laboratory confirmed- local or bloodstream infection [12]); occlusion (device will not infuse)[13]; infiltration (infusate leaking into the interstitial tissue; if with vesicant, this was considered *extravasation*)[14]; leakage (external); dislodgement (complete or partial removal from the vein); or phlebitis (defined as pain alone (≥2/10); or ≥2 signs/symptoms of (i) pain/tenderness, (ii) erythema, (iii) swelling and/or (iv) palpable cord.)[15].

Secondary outcomes were (i) PIV dwell time; (ii) insertion- and (iii) failure of- a CVAD; (iv) adverse events (including BSI and mortality); and (v) length of hospital stay.

Data sources/Measurement:

All data was entered on the Research Electronic Data Capture (REDCap) web-based platform (Vanderbilt University)[16], hosted on a secure internal server (Griffith University).

Participant characteristics: Upon enrolment, the ReN collected baseline data including: age; gender; height; weight; skin integrity (good, fair, poor)[17]; dominant hand; number of co-morbidities (0, 1, 2, 3, >3); primary admitting diagnosis and treatment duration; presence and type of current infections or wounds; blood type; and history of PIV and/or CVAD insertion.

Device characteristics: Data were collected for every PIV inserted during the patients' admission including: inserter; place of insertion (e.g. ward, emergency); PIV size/gauge; anatomical location; insertion side; number of insertion attempts required; insertion pain experienced (11-point Likert scale, 0 (no pain) to 10 (worst pain); primary PIV dressing and additional securements; and the patients' hydration status at device insertion. Three-times weekly, the ReN further collected data with a standardized tool including: IV treatments administered; administration set attachments; primary dressing and additional securement changes; and phlebitis assessment (requiring both a visual assessment and insertion site palpation). Signs and symptoms of phlebitis included: pain and/or tenderness (each, collected on an 11-point Likert scale, 0 (no pain) to 10 (worst pain)); erythema , swelling , palpable cord, or vein streak (each, in cm); purulence (with- or without- ulceration); warmth/heat, skin hardness, or itch (any, at the insertion site).

Device and patient outcomes: Data collected included reason for device removal (including complications); signs and symptoms of phlebitis; and dwell time. Discharged patients were contacted by phone to establish outcomes (within 72 hours). Data relating to subsequent CVAD details was collected including: type; gauge; insertion side; inserting clinician; and reason for removal (including complications). Patient outcomes (mortality, infection), occurring between enrolment and 48 hours after patient removal (from study), were entered once available. Infection outcomes (catheter associated local- and bloodstream- infection) were determined by a qualified Infectious Diseases physician.

Study size:

The sample size was determined by calculating the number of anticipated failure events, to ensure a minimum of ten events per variable (twenty possible risk factors) used in model development [18]; this practice is recommended for observational studies in cancer research employing multivariable modelling. Based on previous studies conducted locally, a 40% PIV failure rate was anticipated [15, 19], with an average of 2.5 devices per participant (pp) predicted (n=500 PIVs, 200 failure events).

Statistical methods:

Data were exported into Stata Statistical Software [20] for analysis. Continuous data are presented as means (and standard deviations), or medians (and inter-quartile ranges), where appropriate; categorical data is presented as frequency (percentage). Incidence rates for failure per 1000 catheters days was calculated using Poisson regression with the natural logarithm of days-at-risk included in the model as an offset. Failure was coded into three failure types including: (i) dislodgement (partial, complete); (ii) infiltration/occlusion/extravasation; and (iii) phlebitis. The association between patient characteristics and failure was investigated using univariable and multivariable Cox regression models. Effect estimates are presented as Hazard Ratio (HR) with 95% Confidence Interval (CI). The best multivariable model was selected based on the Bayesian information criterion (BIC). The best model for a fixed number of explanatory variables was identified as the model with the lowest BIC value. When adding another explanatory variable to the model, the new model was defined to be superior if the BIC decreased by 2 units or more when determining the best multivariable model. P-value <0.05 was considered statistically significant. Kaplan-Meier curves were used to evaluate time-to-PIV failure for the three failure types. Data was censored either when the device was removed or at five days, whichever occurred first. No data were imputed; where missing data exists, altered sample sizes are provided.

Results:

Participants:

Overall, n=280 eligible patients were considered for inclusion (n=79 met exclusion criteria) with a total of n=201 enrolled (Figure 1). One participant subsequently withdrew all consent, leaving a final sample of n=200 included in the analysis.

[Insert Figure 1: Participant flow diagram]

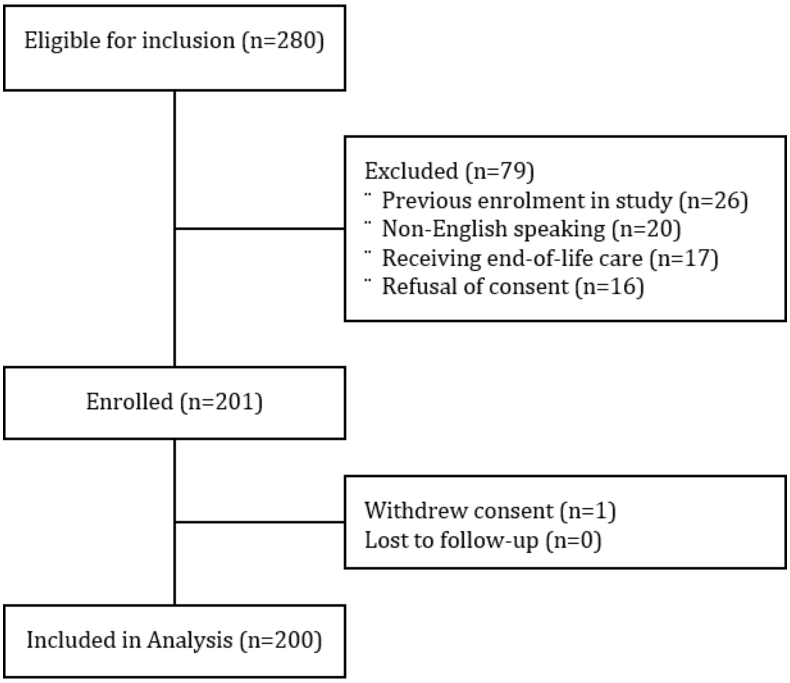


Figure 1. Participant Flow Diagram[21]

Descriptive data:

Participants had a median age of 64 years (IQR, 54;71), and the majority were male (n=132, 66%) (Table 1). Most participants were being treated for a haematological malignancy (n=123, 62%), and 60% (n=119) had two or more underlying co-morbidities. The presence of a wound was uncommon (n=20, 10%), however there was a high prevalence of patients with current infections (n=84, 42%). Length of hospital stay (follow-up time from study entry) was a median of 5 days (IQR, 3;10).

[Insert Table 1. Participant (non-modifiable) characteristics by failure mode]

On average, participants required 2 PIVs each during their hospital admission, with a total of n=396 PIVs analysed (957 PIV days) (Table 2). These PIVs were most commonly a 22-gauge catheter (n=194/362, 54%), inserted by a ward nurse (n=263/375, 70%), into the forearm (n=191/385, 50%); ultrasound was seldom used (n=6/396, 2%). Secondary dressing use was common, with 46% (n=136/293) of PIVs dressed with at least one piece of non-sterile tape (outside of the primary dressing), with or without additional elasticised tubular bandaging, used on 45% (n=131/293) of PIVs.

CVADs were placed following PIV removal for n=19 (9.5%) participants (total n=34 CVADs); these were most commonly Peripherally Inserted Central Catheters (n=24/34, 71%).

[Insert Table 2. Peripheral Intravenous Catheter (PIV, modifiable) characteristics by failure mode]

Outcome data:

PIV failure occurred in 34.9% of all PIVs (130.7/1000 catheter days, 95%CI 109.7, 155.7). The most common failure type was occlusion/infiltration (n=74, 18.7%; 7.4/1000 catheter days, 95%CI 61.6, 97.1), followed by dislodgement (n=33, 8.3%; 34.5/1000 catheter days, 95%CI 24.5, 48.5), and phlebitis (n=30, 7.6%; 31.4/1000 catheter days, 95%CI 21.9, 44.9); there were no cases of extravasation. The median dwell time was 2.3 days (IQR 1.1-3.2); a Kaplan-Meier survival analysis (risk of PIV failure by dwell time) was plotted to five days (Figure 2). The need for subsequent PIV insertions was high, with 55% (n=109) of participants requiring a second device; with a further 22% (n=44) and 10% (n=20) requiring third, and fourth PIVs, respectively. A further 12% (n=23) or participants required five or more PIVs during their admission.

[Insert Figure 2: Kaplan-Meier curve of (a) dislodgement, (b) occlusion/infiltration, (c) phlebitis.]

Univariable Modelling:

In univariable Cox regression analysis (Table 3) the 20g gauge PIVs (HR 2.38, 95%CI 1.01;5.63, p=0.049); was significantly associated ($p<0.05$) with an increase in PIV failure by dislodgement. Three or more attempts at PIV insertion was also significantly associated with an increased risk of occlusion/infiltration/leakage (HR 2.13, 95%CI 1.05;4.32; p=0.037). PIVs were significantly less likely to present with phlebitis with: each increase in age (by decade) (HR 0.78, 95%CI 0.61;0.99, p=0.043); if the patient had three or more comorbidities (HR 0.36, 95%CI 0.13;0.98, p=0.045); and if the patient was receiving IV antibiotics (HR 0.25, 95%CI 0.08;0.73, p=0.011). The administration of IV fluids was significantly associated with a reduced risk of PIV dislodgement (HR 0.29 , 95%CI 0.13;0.62, p=0.002), occlusion/infiltration (HR 0.45, 95%CI 0.26;0.77, p=0.003) and phlebitis (HR 0.31, 95%CI 0.14;0.71, p=0.005); and the use of secondary non-sterile adhesive tape was significantly associated with reduced risk of PIV dislodgement (HR 0.04, 95%CI 0.01;0.31, p=0.002) and occlusion/infiltration (HR 0.46, 95%CI 0.25;0.84, p=0.012).

[Insert Table 3 – Cox Univariable Regression by failure mode]

Multivariable Modelling:

Multivariable modelling demonstrated the use of secondary application of non-sterile tape to the primary dressing was significantly associated with less PIV failure by dislodgement (HR 0.06, 95%CI 0.01;0.48, p=0.008) (Table 4).

[Insert Table 4: Cox Multivariable Regression by failure mode]

Adverse Events:

There was one case of confirmed PIV-related BSI[12] (*Proteus mirabilis*). The patient, who was febrile and displaying symptoms of delirium Day 4 PIV dwell (102 hours) had a recent history of local PIV infection (*Staphylococcus aureus*); and presented with a tender PIV site (3/10), with erythema (1cm length) and purulence at the insertion site.

There were two confirmed catheter local infections (n=1 *Enterobacter cloacae*; n=2 unconfirmed organism):

- *Case 1* was admitted to the emergency department five days post-discharge with fevers and PIV site local infection (purulence); five-day admission requiring IV antibiotics (piperacillin tazobactam; vancomycin). The patient was subsequently discharged home on oral antibiotics (ciprofloxacin, flucloxacillin).
- Case 2 developed signs and symptoms of local infection Day 1 (24 hours) of PIV dwell (erythema <0.5cm; swelling/induration <0.5cm; purulence); the infection resolved post-removal without intervention.

Mortality occurred in 4% (n=16/200) of the population; no cases were related to vascular access devices.

Discussion:

This observational study confirmed an unacceptably high PIV failure rate among patients receiving treatment for cancer (34.9%). This failure rate was comparable to other prospective studies, which found similar rates (and higher) in medical and surgical populations [8, 19, 22]. PIVs most commonly failed from complications associated with occlusion or infiltration (n=74, 18.7%). To date, PIV research has overwhelmingly focused upon extravasation injuries among patients with cancer [9, 10, 23, 24], however, there were no cases of extravasation reported in our study. We postulate this may be a result of a low incidence of chemotherapy administration (n=19, 5%); and a high proportion of CVAD use (within this local population) (70%) based on a point-prevalence audit conducted in this population [25]. PIVs were instead more likely to be placed for the administration of hydrocolloid fluids (n=221, 56%); antibiotics (n=138, 35%) and/or blood products (n=54, 14%).

In univariable modelling several non-modifiable patient and treatment-related factors were associated with a reduction in PIV failure by phlebitis (increase in age; ≥ 3 comorbidities; and IV antibiotics). Increase in age related to a decrease in phlebitis was similarly found in a large multivariate analysis (HR 0.99; 95%CI 0.98;0.99, p<0.001) [26]. However, while our study found ≥ 3 comorbidities and the use of IV antibiotics reduced the risk of phlebitis, this contradicts evidence from other studies which found higher rates of phlebitis with the use of several IV antibiotics [27] and a higher rate of phlebitis among patients with comorbidities such as diabetes mellitus [28, 29]; these factors were not significant in multivariable modelling. Occlusion/infiltration and dislodgement were associated with modifiable (PIV-related) risk factors such as 20g PIVs (dislodgement), and ≥ 3 attempts at PIV insertion (occlusion/infiltration). In contrast, 20g PIVs have previously demonstrated *lower* incidence of dislodgment compared to 22g (HR 1.29; 95%CI 1.02, 1.61, p. 0,03) [26]. The administration of IV fluids was associated with less failure from all three failure modes; the nature of this association is not clear as the mode of administration (e.g. flush or slow infusion) was not collected; IV fluids alone have not previously been shown as protective in risk factor studies.

Multivariable modelling identified a single protective factor for the prevention of PIV dislodgment alone; the application of non-sterile tape, secondary to the primary dressing (HR 0.06, 95%CI 0.01, 0.48, p=0.008). This finding is consistent with previous studies which similarly demonstrated the benefits of using secondary tapes and securements, to prevent PIV failure [19, 30]. A large RCT which recently compared novel dressing and securement methods to prevent PIV failure, such as tissue adhesive and external securement devices, found that while simple (un-bordered) polyurethane dressings preformed equally to these novel options, the use of additional non-sterile tapes and secondary securements (e.g. bandaging) was common, and may have influenced results [15]. Consequently, we agree with recommendations [15, 31] for the development of improved secondary dressings and securements to decrease PIV failure, specifically dislodgement.

Regrettably, multiple (≥2) insertion attempts prior to PIV placement was common (26%) and in univariable modelling was associated with occlusion and infiltration (≥3 attempts, HR 2.13, 95%CI 1.05, 4.32; p=0.037). Improved technology (e.g. ultrasound guidance) to prevent multiple needlesticks, particularly prior to the administration of chemotherapy, is recommended to ensure best-possible outcomes for patients [32]. However, in our study, ultrasound was seldom used (n=6/396) which likely contributed to the incidence of multiple insertion attempts, given there is strong evidence of its efficacy, with a recent systematic review (n=1660) finding insertion success significantly higher with ultrasound use (81%) than without (70%) (95%CI 1.37-4.52, p=0.003) [33].

It was also observed that 76% of participants (n=151) had *previously* required a CVAD for treatment (any admission); this was unsurprising due to the chronic nature of cancer, and the regular administration of vesicant and irritant infusates [1]. However, in our study, patients who *commenced* treatment with PIVs rarely had CVAD placement following PIV failure (n=19, 10%), despite 22% (n=44) of participants requiring three or more PIVs during their admission. Improved device selection (based on expected treatments and duration) may reduce the number of patients requiring multiple PIVs during their stay; alternative options may include long-dwell or midline catheters [34], where CVADs are deemed inappropriate due to risks of thrombosis and/or infection[35]. This further supports the need for wide implementation of ultrasound technologies, to enable the insertion of devices unsuitable for blind puncture insertion[36]. Furthermore, as antibiotic use was common (n=138, 35%), oral alternatives may be considered; recent evidence suggests IV antibiotic administration may be substituted for oral delivery, with equivalent efficacy, in low-risk patients with neutropenia and fever [37]. Improvements such as these are necessary, to reduce PIV failure, as the sequalae of PIV complications is not merely limited to the need for PIV re-insertion; it can result in further negative outcomes such as venous depletion, and morbidity/mortality associated with critical complications (e.g. catheter-related BSI)[38]. Moreover, the resulting pain, discomfort and anxiety associated with PIV re-insertion can be severe, particularly for patients requiring multiple re-insertion attempts [39, 40].

Due to recent advancements in treatments, increased awareness, and early cancer detection methods (particularly for solid tumours)[41], the estimated number of cancer survivors is expected to grow (approximately 30%, 2016 to 2026) [42]. As a result, a growing number of oncology and haematology patients are likely to require long-term therapy, to maintain interruption of disease progression and for treatment of secondary chronic illnesses [43]. It is imperative that improvements are made for PIV insertion, care/maintenance, and removal among patients with cancer to ensure long-term Vessel Health and Preservation [44], and ensure compliance with the *Access Device Standards of Practice for Oncology Nursing* [45].

Limitations:

This study had several limitations. First, the sample size was smaller than required, based on the 10-events per-variable rule; fewer PIV (2 per person) were studied than expected (2.5 per person). This may have influenced final results as risk factors identified as significant in the univariable model may have been significant in the multivariable model, if a larger sample was studied. Second, this observational cohort study was conducted in cancer units (only) at a single tertiary hospital in Australia; the findings may not be externally valid to other clinical settings (disciplines, hospitals). Third, reasons for CVAD insertion were not assessed, therefore their insertion may relate to treatment needs rather than as a result of PIV failure. Despite these limitations, this was the first-ever observational cohort study designed to determine risk factors for PIV failure in a cancer cohort; and findings can now inform future research and priorities in this area.

Conclusions:

In conclusion, this study highlighted a high rate of PIV failure in an oncology and haematology population. This confirms findings from other patient cohorts (e.g. medical, surgical), demonstrating similar associations between PIV failure and risk factors, with the strongest association found between the use of non-sterile tape securement and significantly reduced PIV dislodgement.

Table 1. Participant (non-modifiable) characteristics by failure mode

Variable	Failure Type			
	Total	Dislodgement	Occlusion/ Infiltration/Leakage	Phlebitis
Group Size	**n=200**	**n=17**	**n=39**	**n=16**
Age (years)[a]	64 (54,71)	65 (59,74)	65 (55,71)	62 (45,69)
Male gender	132 (66)	9 (53)	23 (59)	9 (56)
Body Mass Index[a]	28 (24,32)	28 (24,32)	25 (21,28)	26 (22,28)
Skin Integrity				
- Good	83 (42)	4 (24)	12 (31)	8 (50)
- Fair	77 (39)	8 (47)	21 (54)	6 (38)
- Poor	40 (20)	5 (29)	6 (15)	2 (13)
Comorbidities				
- Zero	46 (23)	0 (0)	12 (31)	6 (38)
- One	35 (18)	6 (35)	3 (8)	3 (19)
- Two	36 (18)	3 (18)	5 (13)	3 (19)
- Three+	83 (42)	8 (47)	19 (49)	4 (25)
Discipline				
- Haematology	123 (62)	11 (65)	24 (62)	8 (50)
- Oncology	77 (39)	6 (35)	15 (39)	8 (50)
Current infection	84 (42)	11 (65)	16 (41)	5 (31)
Blood type (n=155)				
- O+	66 (43)	5 (38)	10 (32)	5 (36)
- A+	46 (30)	3 (23)	11 (36)	4 (29)
- Other	43 (28)	5 (38)	10 (32)	5 (36)
Wound present	20 (10)	2 (12)	3 (8)	3 (19)
History of CVAD	151 (76)	4 (24)	7 (18)	5 (31)
Hospital stay length	5 (3, 10)	6 (4,12)	5 (3,10)	6 (4,19)

n=200 participants unless otherwise noted; [a]median (inter-quartile range)

Table 2. Peripheral Intravenous Catheter (PIV) modifiable characteristics by failure mode

Variable	Failure Type			
	Total	**Dislodgement**	**Occlusion/ Infiltration/Leakage**	**Phlebitis**
Group Size	**n=396**	**n=33**	**n=74**	**n=30**
Inserted by (n=375)				
- Nurse	263 (70)	21 (68)	48 (71)	17 (61)
- Doctor	92 (25)	8 (26)	17 (22)	10 (36)
- Other	20 (5)	2 (7)	3 (4)	1 (4)
Size/gauge (n=362)				
- 16 / 18g	15 (4)	0 (0)	2 (3)	3 (11)
- 20g	145 (40)	17 (61)	32 (47)	11 (39)
- 22g	194 (54)	10 (36)	33 (49)	14 (50)
- Other	8 (2)	1 (4)	1 (2)	0 (0)
Device location – position on arm (n=385)				
- Upper arm	5 (1)	0 (0)	0 (0)	1 (3)
- Antecubital fossa	101 (26)	11 (34)	19 (27)	6 (20)
- Forearm	191 (50)	12 (38)	37 (52)	14 (47)
- Wrist	53 (14)	3 (9)	11 (16)	5 (17)
- Hand	35 (9)	6 (19)	4 (6)	4 (13)
Multiple attempts (n=367)				
- One	271 (74)	19 (63)	45 (71)	20 (69)
- Two	53 (14)	7 (23)	5 (8)	6 (21)
- Three or more	43 (12)	4 (13)	13 (21)	3 (10)
Hydration status (n=396)				
- Nil by mouth	24 (6)	2 (6)	2 (3)	3 (10)
- Altered fluid intake	74 (19)	7 (21)	16 (22)	9 (30)
- None of the above	298 (75)	24 (73)	56 (76)	18 (60)
Administration set in place (n=293)	211 (72)	11 (65)	33 (73)	9 (56)
Medications administered (n=396)				
- IV fluids	221 (56)	13 (39)	36 (49)	13 (43)

- IV antibiotics	138 (35)	12 (36)	25 (34)	6 (20)
- Blood products	54 (14)	2 (6)	8 (11)	4 (13)
- Chemotherapy	19 (5)	0 (0)	3 (4)	2 (7)
- Antivirals / antifungals	1 (0)	1 (3)	0 (0)	0 (0)
Secondary dressings (n=293)				
- Non-sterile tape	136 (46)	4 (12)	18 (24)	9 (30)
- Elasticised tubular bandage	131 (45)	6 (18)	26 (35)	8 (27)
- No additional dressing/s	87 (30)	5 (15)	10 (14)	1 (3)
- Other	31 (11)	3 (9)	3 (4)	3 (10)

[a]>100% where multiple options could be selected; [a]median (inter-quartile range);

Table 3 – Cox Univariable Regression by failure mode

Variable	Hazard Ratio (95% CI) p-value		
	Failure Type		
	Dislodgement	Occlusion/ Infiltration/Leakage	Phlebitis
Age (per decade)	^	^	0.78 (0.61, 0.99) p=0.043[a]
Comorbidities (ref. none)			
- Three+	^	^	0.36 (0.13, 0.98) p=0.045[a]
Inserted by (ref. nurse)			
- Doctor	^	^	2.30 (0.96, 5.40) p=0.061[b]
Size/gauge (ref. 22g)			
- 20 (Pink)	2.38 (1.01, 5.63) p=0.049[a]	^	^
Multiple attempts (ref. no)			
- Two	2.26 (0.88, 5.80) p=0.089[b]	^	^
- Three or more	^	2.13 (1.05, 4.32) p=0.037[a]	^
Medications administered (ref.no)			
- IV fluids	0.29 (0.13, 0.62) p=0.002[a]	0.45 (0.26, 0.77) p=0.003[a]	0.31 (0.14, 0.71) p=0.005[a]
- IV antibiotics	^	0.60 (0.33, 1.06) p=0.079[b]	0.25 (0.08, 0.73) p=0.011[a]
- Blood products	^	^	^
- Chemotherapy	^	^	^
Secondary dressings applied (ref. no)			
- Non-sterile tape	0.04 (0.01, 0.31) p=0.002[a]	0.46 (0.25, 0.84) p=0.012[a]	0.45 (0.19, 1.09) p=0.077[b]
- Elasticised tubular bandage	0.46 (0.19, 1.14) p=0.093[b]	^	^

- No additional dressing/s	^	0.48 (0.22, 1.07) p=0.072[b]	0.14 (0.02, 1.03) p=0.054[b]
- Other	^	^	^

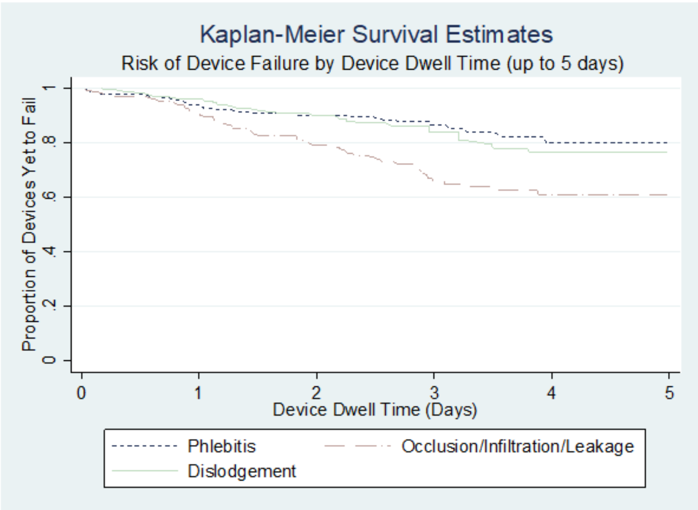
[a]p<0.05; [b]p<0.1; ^ p>1.0 (not presented); ref=reference

Table 4 – Cox Multivariable Regression by failure mode

Variable	**Hazard Ratio (95% CI) p-value**		
	Failure Type		
	Dislodgement	**Occlusion/ Infiltration/Leakage**	**Phlebitis**
Hospital stay length	1.00 (0.94, 1.06) p=0.983	1.01 (0.97, 1.05) p=0.613	1.03 (0.99, 1.07) p=0.100
Current infection	^	^	0.45 (0.15, 1.37) p=0.162
Non-sterile tape	0.06 (0.01, 0.48) p=0.008[a]	^	^

[a]p<0.05; ^no included in multivariable modelling

<u>Figure 2. Kaplan-Meier curve of (a) dislodgement, (b) occlusion/infiltration, (c) phlebitis.</u>



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