DOI: 10.1097/JPN.0000000000000589

J Perinat Neonat Nurs • Volume 000 Number 000, 1–8 • Copyright © 2022 Wolters Kluwer Health, Inc. All rights reserved.

Neonatal Vascular Access Practice and Complications

An Observational Study of 1,375 Catheter Days

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This project was funded by the Royal Brisbane and Women's Hospital Foundation.

Thank you to the neonates, parents, caregivers, and clinicians who generously participated in this study.

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

Disclosure: The authors have disclosed that they have no significant relationships with, or financial interest in, any commercial companies pertaining to this article.

Each author has indicated that he or she has met the journal's requirements for Authorship.

ABSTRACT

Vascular access devices play vital roles within neonatal care. We aimed to identify neonatal vascular access device insertion and management practices, and describe the incidence and risk factors for complication development. This is a prospective cohort study of neonates requiring vascular access devices over 3 months in an Australian quaternary-referral neonatal intensive care unit. In addition to describing current practices, primary outcomes were device failure, complications, and skin complications. Results are reported using descriptive statistics and with risk factors calculated via Cox proportional hazards regression. A total of 104 neonates required 302 vascular access devices, over 1375 catheter days. Peripheral intravenous catheters (PIVCs) were most used ($n = 186$; 62%), followed by umbilical venous catheters ($n = 52$; 17%). Insertion attempts were often undocumented; but for those recorded, 5% of devices ($n = 15$) required 4 attempts or more. Device failure occurred in 28% ($n = 82$), at an incidence rate of 62.5 per 1000 catheter days (95% confidence interval [CI] 49.7-75.9). Failure was most frequent in PIVCs (37%; $n = 68$), peripheral arterial catheters (33%; $n = 2$), and peripherally

Supplemental digital content is available for this article. Direct URL citations appear in the printed text and are provided in the HTML and PDF versions of this article on the journal's Web site (www.jpnnjournal.com).

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Submitted for publication: April 23, 2020; accepted for publication: April 22, 2021.

inserted central catheters (20%; $n = 6$). Infiltration and extravasation were the most frequent cause of PIVC failure (12%; $n = 35$). A birth weight less than 1500 g was associated with a significant decrease in PIVC failure (hazard ratio 0.58; 95% CI 0.34-0.99).

Key Words: extravasation, infection, neonates, skin complications, vascular access

Vascular access devices (VADs) play a vital role within neonatal care, providing a route for the administration of medications, fluids, and nutrition. Hospitalized neonates have a variety of vascular access needs, ranging from short duration, peripherally compatible infusates, to long duration and complex therapies. Clinicians select VADs based on these indications, with a range of devices available, including umbilical venous catheters (UVCs), peripheral intravenous catheters (PIVCs), and peripherally inserted central catheters (PICCs).

The support and management of many neonatal conditions rely upon stable vascular access.[1] However, VAD use is not without risk, with complications including infections, thrombosis, occlusion, and extravasation resulting in device failure and significant patient harm.[1] Internationally, observational studies in neonates have found more than 50% of PIVCs,[1] and 35% of PICCs[2] developed VAD-related complications leading to device failure. Preterm and sick neonates are especially vulnerable to catheter-associated bloodstream infections (CABSIs), due to an immature immune system, underdeveloped skin barrier, and exposure to invasive diagnostic and therapeutic procedures.[3,4]

VAD insertion and management is complex and multifaceted, with many interdisciplinary clinicians involved in their care. Evidence-based VAD insertion and management strategies, including site antisepsis and dressings, have been developed to reduce the preventable causes of VAD failure and complication; however, evidence in the neonatal population is scant.[5] Approaches to VAD management in neonates frequently vary among clinicians, with practice often based on anecdotal evidence, or recommendations for adults and older children.[4,5] This study aimed to improve VAD-related outcomes for neonates by identifying current insertion and management of VADs in neonatal care. It also aimed to describe the incidence and risk factors for VAD complications to potentially inform innovation, practice, and policy development.

MATERIALS AND METHODS

Study design, setting, and participants

A prospective observational study of neonatal VADs was conducted over 3 months (September 7 to December 7, 2018). Ethics approval was provided from the hospital (HREC/18/QRBW/196) and Griffith University (NRS/2018/462). The study was carried out in a 70-bed tertiary referral neonatal unit, at the Royal Brisbane and Women's Hospital, Brisbane, Australia. All neonates receiving care, who required a VAD, were eligible to participate. VADs included peripheral (PIVCs, peripheral arterial catheters [PACs]) and central (PICCs, UVCs, umbilical arterial catheters [UACs], nontunneled percutaneous central VADs) devices. Written, informed consent was obtained from parents/legal guardians of eligible neonates.

Outcomes

To describe current VAD insertion and management practice, and incidence of VAD-associated complications, demographic, clinical, and device-related characteristics were collected prospectively by clinical and research staff. Outcomes and definitions of the study were in accordance with international benchmarks, reported in Supplementary Table 1 (available at: http://links.lww.com/JPNN/A19).[6–12]

Data collection

The primary and secondary outcomes were incorporated into a secure, web-based data collection tool (Research Electronic Data Capture). The data collection tool was originally designed and trialed within the study site by Marsh et al[13] and in pediatrics by Ullman et al.[14] The data collection instruments were piloted for interrater reliability and feasibility prior to use.[15] Education and familiarization with the data collection tools were provided to clinical and research staff, to ensure consistency and clarify processes.

Data were collected prospectively by the bedside nurse (daily), with follow-up by a dedicated research nurse (every second day; Monday to Friday), until the neonate was discharged, or for one additional visit after the VAD was removed.

Demographic and clinical characteristics potentially increasing or decreasing VAD-associated complications were also prospectively collected, including prematurity, weight, overall skin integrity, and nutrition status.[1–3,16] Data were not collected on policy-driven practices, such as skin decontamination for PICC insertion (ie, with 10% povidone-iodine solution applied over the whole limb followed by 2% chlorhexidine in 70% alcohol) and device brands (ie, PIVCs and PACs: BD Insyte [Becton Dickinson; New Jersey] PIVCs, UVC, and UAC: Argyle Umbilical Vessel Catheter [Covidien; Dublin, Ireland] and PICC: Premicath [Vygon; Écouen, France]).

Statistical methods

The demographic and clinical characteristics of the participants and their VAD management are descriptively reported, using categorical and continuous descriptors appropriate to their distribution. The incidence of VAD and skin complications per patient is reported proportionally and using incidence rates (with 95% confidence intervals [CI] per 1000 catheter days). As VAD and skin complication development were time dependent, Cox proportional hazards regression models were used for time-to-event analysis with shared frailty model to account for the random effects, and survival data/hazard rates reported with 95% CI. The model building was performed to generate hypothesis for future studies. Only PIVCs were included in the regression modeling due to the low numbers of other VAD types. For the PIVC failure outcome, the variables significant at $P < .20$ on univariable analysis were subjected to multivariable regression. Variable selection for the final multivariable model was performed using the manual stepwise removal/addition method and by clinical judgment. The final model was selected by assessing the Akaike and Bayesian information criterion and was checked for the global proportional-hazards assumption test. Only univariate model results were reported due to low number of skin complications that could risk overfitting a multivariate model.[17] The analysis was undertaken using Stata (version 13; StataCorp, College Station, Texas).

RESULTS

Over the 3-month study period, there were 408 admissions to the neonatal unit. After screening, 29 admissions were missed due to research nurse availability, 7 were excluded due to lack of translation services to enable informed consent, 6 were excluded due to unavailability of guardians to provide consent, and 2 guardians declined participation. This resulted in 140 participants, with 302 VADs (median 1 VAD per participant; interquartile range [IQR] 1-3) being studied for 1375 catheter days.

Participant and device characteristics

Within the 140 participants, there were a range of birth weights, and admission conditions, with prematurity ($n = 86$; 61%) and respiratory failure ($n = 73$; 52%) most common (see Table 1). Median length of stay was 13 days (IQR 5-35). PIVCs were the most commonly used VAD ($n = 186$; 62%), followed by UVCs ($n = 52$; 17%) (see Table 2). While the number of insertion attempts was often undocumented ($n = 180$; 60%), for those documented, the median was 3 attempts (IQR 2-3), with 5% of all VADs ($n = 15$) requiring 4 attempts or more.

Table 1. Participant demographic and clinical characteristics ($n = 140$)

Characteristic	Median (IQR)
Length of stay, d	13 (5-35)
Birth gestation, wk	33.8 (30.4-37.4)
Birth weight, g	2006 (1352-2956)
	n **(%)**
Birth weight groups, g	
ELBW (<1000 g)	17 (12)
VLBW (1001-1500 g)	29 (21)
Larger (>1501 g)	94 (67)
Admission source	
Inborn	130 (93)
Outborn	10 (7)
Sex	
Male	68 (49)
Female	72 (51)
Condition on admission[a]	
Prematurity	86 (61)
Respiratory failure	73 (52)
Hypoglycemia	25 (18)
Infection	10 (7)
Low birth weight	9 (6)
Neurological injury	4 (3)
Other	9 (6)
Infection at time of admission	
Suspected infection	78 (56)
Respiratory	20 (14)
Positive blood culture	1 (<1)
Other	2 (1)
Nonvascular access devices at recruitment[a]	
Endotracheal tube	25 (18)
Urinary catheter	2 (1)
Drain	2 (1)

Abbreviations: ELBW, extremely low birth weight; IQR, interquartile range; VLBW, very low birth weight.
[a]More than 1 answer provided.

Utility and management characteristics

Almost all devices (90%; $n = 271$) were in continuous or high use (>9 medications or therapies per day), with antibiotics ($n = 172$; 60%) and fluids ($n = 122$; 40%) most commonly infused. Parenteral nutrition was only administered via a central device (UVC or PICC). Primary VAD securements were primarily sterile, such as reinforced skin closures; however, the use of nonsterile fabric adhesive was common for additional securement of PIVCs ($n = 131$, 70%). UVCs had the poorest dressing integrity, with 13% ($n = 7$) not clean, dry, and intact at assessment.

Device outcomes

Overall, 28% ($n = 86$) of VADs failed prior to completion of therapy, at an incidence rate of 62.6 per 1000 catheter days (95% CI 50.3-76.7) (see Table 3). Failure was most common in PIVC (37%; $n = 68$), PAC (33%;

Table 2. **Vascular access device and management characteristics (*n* = 302)**

	PIVC *n* (%) 186 (62)	PAC *n* (%) 3 (1)	UAC *n* (%) 36 (12)	UVC *n* (%) 52 (17)	PICC *n* (%) 25 (8)	Total *n* (%) 302 (100)
Indication						
Medications/fluids	184 (98)	0	1 (2)	52 (100)	25 (100)	262 (87)
Monitoring	0	2 (67)	6 (17)	0	0	8 (3)
Blood sampling	0	1 (33)	29 (81)	0	0	30 (10)
Future procedure	2 (2)	0	0	0	0	2 (1)
Inserted by						
Consultant	2 (1)	1 (33)	7 (19)	9 (17)	8 (32)	27 (9)
Fellow/registrar	82 (44)	2 (67)	22 (61)	36 (69)	13 (52)	140 (46)
Nurse/NP	10 (5)	0	5 (14)	5 (10)	4 (16)	24 (8)
Undocumented	92 (49)	0	2 (6)	2 (4)	0	111 (36)
Size						
20G	1 (1)	0	...	...	...	1 (<1)
24G	185 (99)	3 (100)	...	...	...	188 (62)
1Fr					4 (16)	4 (1)
2Fr					21 (84)	21 (7)
3.5Fr	...	...	21 (58)	31 (60)	...	52 (17)
5Fr	...	...	6 (17)	11 (21)	...	17 (6)
Undocumented	0	0	9 (25)	10 (19)	0	44 (14)
Insertion attempts						
Median (IQR)	3 (2-4)	2 (2-2)	2 (2-3.5)	3 (2-3)	2 (2-3)	3 (2-3)
1	40 (21)	1 (33)	5 (14)	10 (19)	5 (20)	61 (20)
2	12 (6)	2 (67)	3 (8)	2 (4)	11 (44)	30 (10)
3	12 (6)	0	0	3 (6)	2 (8)	17 (6)
≥4	10 (4)	0	1 (3)	1 (2)	2 (8)	14 (5)
Undocumented	112 (60)	0	27 (75)	36 (69)	5 (20)	180 (60)
Lumens						
Single	186 (100)	3 (100)	36 (100)	2 (4)	25 (100)	252 (84)
Multiple	...	...	...	50 (96)	0	50 (16)
Location						
Dorsal venous arch	135 (73)	...	...	...	...	135 (44)
Cephalic	23 (12)	...	...	...	...	23 (8)
Median cubital	10 (5)	...	...	...	8 (32)	18 (6)
Saphenous	4 (2)	...	...	...	1 (4)	5 (2)
Accessory cephalic	2 (1)	...	...	...	...	2 (1)
Scalp	1 (<1)	...	...	...	...	1 (<1)
Basilic	...	...	...	...	6 (24)	6 (2)
Axillary	...	...	...	...	1 (4)	1 (<1)
Radial	...	1 (33)	...	...	...	1 (1)
Umbilical	...	...	36 (100)	52 (100)	...	88 (29)
Undocumented	11 (6)	2 (67)	0	0	9 (36)	22 (7)
Inserted at						
Intensive care	139 (75)	3 (100)	35 (97)	50 (96)	25 (100)	252 (83)
Special care	35 (19)	0	0	1 (2)	0	36 (12)
Another facility	11 (6)	0	1 (3)	1 (2)	0	13 (4)
Undocumented	1 (<1)	0	0	0	0	1 (<1)
Frequency of use						
Continuous or high[a]	160 (86)	3 (100)	33 (92)	50 (96)	25 (100)	271 (90)
Low to moderate[b]	26 (14)	0	3 (8)	2 (4)	0	31 (10)
Infusates[c]						
Antibiotics	127 (68)	0	0	41 (79)	4 (16)	172 (60)
Fluids	66 (35)	0	0	34 (65)	22 (88)	122 (40)
Parenteral nutrition	0	0	0	23 (44)	23 (92)	46 (15)
Heparin saline	0	3 (100)	33 (100)	0	0	36 (12)
Opioids/sedatives	5 (3)	0	0	1 (2)	2 (8)	13 (4)

(*continues*)

Table 2. **Vascular access device and management characteristics (*n* = 302) (*Continued*)**

	PIVC *n* (%) 186 (62)	PAC *n* (%) 3 (1)	UAC *n* (%) 36 (12)	UVC *n* (%) 52 (17)	PICC *n* (%) 25 (8)	Total *n* (%) 302 (100)
Inotropes	1 (1)	0	0	1 (2)	2 (8)	11 (4)
Caffeine	5 (3)	0	0	4 (8)	0	9 (3)
Blood products	5 (3)	0	0	0	0	5 (2)
Paracetamol	2 (1)	0	0	1 (2)	0	3 (1)
Insulin	0	0	0	1 (2)	3 (12)	4 (1)
Steroids	4 (2)	0	0	0	0	4 (1)
Other	4 (2)	0	0	0	1 (4)	5 (2)
Primary securement[c]						
Sterile securements	168 (90)	3 (100)	35 (97)	49 (94)	24 (96)	279 (92)
Sutures	0	0	32 (89)	43 (83)	0	75 (25)
Non-sterile tape	9 (5)	0	0	0	0	9 (3)
Additional securement[c]						
None	11 (6)	0	33 (92)	45 (86)	0	89 (29)
Bandage	1 (1)	2 (66)	0	0	23 (92)	26 (9)
Splint	172 (92)	3 (100)	1 (3)	1 (<1)	25 (100)	102 (33)
Nonsterile, fabric adhesive	131 (70)	1 (33)	0	1 (<1)	0	133 (44)
Hydrocolloid	1 (1)	0	2 (6)	5 (10)	0	8 (3)
Sterile strips	3 (2)	0	1 (3)	2 (1)	0	6 (2)
Dressings[c]						
Polyurethane	186 (100)	3 (100)	4 (9)	4 (8)	24 (96)	221 (73)
Hydrocolloid	...	...	32 (91)	41 (79)	1 (4)	74 (24)
Nonsterile, fabric adhesive	0	0	0	2 (4)	0	2 (1)
Other	0	0	0	5 (10)	2 (8)	2 (1)
Dressing not clean, dry and intact	1 (<1)	1 (33)	5 (14)	7 (13)	1 (4)	15 (5)
Insertion documented	85 (46)	3 (100)	36 (100)	52 (100)	25 (100)	201 (67)
Insertion site visible	85 (46)	3 (100)	36 (100)	52 (100)	0	176 (58)

Abbreviations: IQR, interquartile range; PAC, peripheral arterial catheter; PICC, peripherally inserted central catheter; PIVC, peripheral intravenous catheter; UAC, umbilical arterial catheter; UVC, umbilical venous catheter.
[a]Continuous or high (>9 medications or therapies per day)
[b]Medium use (3-8 medications or therapies per day) or low use (<2 medications or therapies per day).
[c]More than 1 answer provided.

n = 2), and PICC (20%; n = 6). The most common reason for failure was infiltration/extravasation (12%; n = 35) mainly for PIVCs (18% PIVCs infiltrated/extravasated; n = 34). The most common complication necessitating premature PICC removal was suspected infection (12%; n = 3), with 4 PICCs having CABSI confirmed (16%). Four CABSIs were identified, 3 due to coagulase-negative *Staphylococcus* (*S. capitis*, *S. haemolyticus*, and *S. epidermidis*). A single *Escherichia coli* CABSI was identified. No catheter breakage, venous thrombosis, or local site infections were identified. Comparative device dwells are displayed in Figure 1.

VAD-associated skin complications were evident in 24% of the devices (n = 72), at an incidence rate of 52.3 per 1000 catheter days (95% CI 41.2-65.5). Skin complications occurred at numerous time points of VAD dwell, with bruising noted more on insertion (n = 13; 4%) compared with contact dermatitis (n = 4; 1%) and pressure injury (n = 2; <1%) on removal. There were no reports of skin tear, tension blister, epidermal stripping, chemical burn, allergic dermatitis, or maceration.

Risk factors for PIVC failure

In multivariate models, a birth weight less than 1500 g was associated with a significant decrease in PIVC failure (hazard ratio [HR] 0.58; 95% CI 0.34-0.99) (see Table 4). Female sex (HR 2.01; 95% CI 1.03-3.91) and having no suspected infection at admission (HR 1.89; 95% CI 1.07-3.35) were associated with a significant increase in PIVC failure.

DISCUSSION

Reliable vascular access is a fundamental component of neonatal care provision, and vascular access should be provided without patient harm. This study is the first systematic description of the practices and outcomes across the range of VADs currently being used

Table 3. **VAD outcomes and complications (*n* = 302)**

	PIVC *n* (%) 186 (62)	**PAC** *n* (%) 3 (1)	**UAC** *n* (%) 36 (12)	**UVC** *n* (%) 52 (17)	**PICC** *n* (%) 25 (8)	**Total** *n* (%) 302 (100)
VAD failure	68 (37)	2 (33)	4 (11)	6 (12)	6 (20)	86 (28)
Incidence rate (per 1000 catheter days; 95% CI)	121.7 (95.9-154.3)	132.4 (33.1-529.6)	24.1 (9.0-64.2)	23.3 (18.6-49.9)	15.9 (5.8-34.3)	62.6 (50.3-76.7)
Device complications[a]						
Infiltration/extravasation	43 (23)	0	0	0	1 (1)	44 (15)
Occlusion	28 (15)	0	2 (6)	0	0	30 (10)
Phlebitis	6 (3)	0	0	0	0	6 (2)
Dislodgement/migration (partial)	Total: 1 (<1)	0	0	Partial: 2 (4)	Partial: 1 (4)	Total: 1 (<1) Partial: 3 (1)
CABSI	0	0	0	0	4 (16)	4 (1)
Low tip position	0	0	0	4 (8)	0	4 (1)
Peripheral tissue ischemia	2 (1)	0	1 (3)	0	0	3 (1)
Lost trace	N/A	2 (66)	1 (3)	N/A	N/A	3 (1)
VAD-associated skin complications	66 (35)	1 (33)	0	1 (2)	4 (16)	72 (24)
Incidence rate (per 1000 catheter days; 95% CI)	118.0 (92.5-147.8)	66 (1.7-319.5)	0	4 (0.09-21.4)	10.6 (2.8-26.9)	52.3 (41.2-65.5)
Skin complication types[a]						
Extravasation	43 (23)	0	0	0	1 (4)	44 (15)
Erythema	4 (2)	0	0	1 (2)	0	5 (2)
Pressure injury	2 (1)					2 (<1)
Compartment syndrome	3 (2)	0	0	0	1 (4)	4 (1)
Bruising	11 (6)	1 (3)	0	0	1 (4)	13 (4)
Contact dermatitis	3 (2)	0	0	0	1 (4)	4 (1)
Total dwell days	559	15	166	258	377	1375
Dwell time (days) Median (IQR)	2.3 (1.5-3.9)	1.7 (0.9-12.5)	3.8 (1.8-5.9)	4.9 (2.7-6.8)	11.8 (7.9-14.3)	3 (1.7-5.6)

Abbreviations: CI, confidence interval; CABSI, catheter-associated bloodstream infection; IQR, interquartile range; PAC, peripheral arterial catheter; PICC, peripherally inserted central catheter; PIVC, peripheral intravenous catheter; UAC, umbilical arterial catheter; UVC, umbilical venous catheter; VAD, vascular access device.

[a]More than 1 complication could apply.

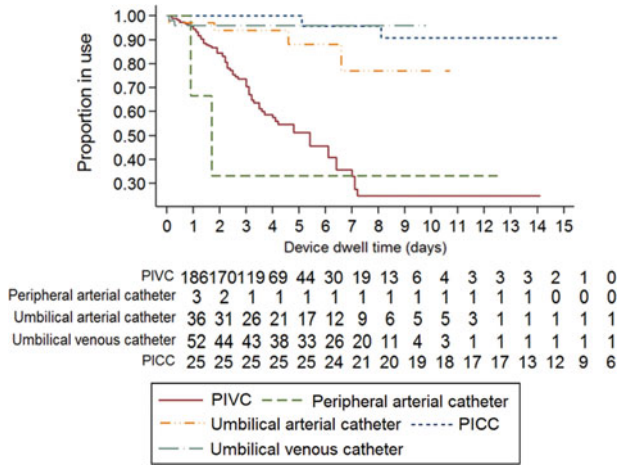

Figure 1. Kaplan-Meier of device dwell. This figure is available in color online (www.jpnnjournal.com).

in neonatal care. We have demonstrated the commonality of these devices, but also the challenges in inserting them successfully (median 3 attempts per device [IQR 2-3]), and maintaining their function (28% failure prior to completion of therapy [$n = 85$]). This will provide a platform for future improvement in neonatal vascular access insertion and management.

The prevention of CABSI remains an international health priority. Four CABSIs were identified within the current project, all associated with PICCs (IR 10.6 per 1000 PICC days; 95% CI 2.9-26.9), at a higher rate than previously benchmarked.[2,16] The causative agents were similar to a recent Australian retrospective study,[16] with all CABSIs developing in neonates born less than 1000 g. Whether this high CABSI rate is reflective of longitudinal outcomes is unclear, however innovations further reduce neonatal CABSI are warranted.

Other than infection, VAD failure was primarily due to infiltration or extravasation of the device, impacting 12% total cohort and causing 42% of VAD failure, at a similar rate to previous international studies.[1] These complications resulted in several episodes of significant harm, with 3 neonates experiencing compartment syndrome. The sequelae of infiltration and extravasation can be dire for neonates, due to the volume of medications being infused, in comparison to the surface area, and skin immaturity.[18] Innovation to reduce infiltrations and extravasation should focus on the appropriate device selection (ie, prohibiting infusion of vesicant medications into the peripheral vasculature), device placement (ie, away from areas of flexion), vessel purchase (ie, the length of the device within the vessel), and catheter stabilization (via securement and dressing).

Counterintuitively, there was a reduced rate of PIVC failure for neonates less than 1500 g (HR 0.58 [0.34-0.99]). This result is supported by the findings of

Table 4. **Univariate and multivariate risk factors for PIVC failure ($n = 186$; 495 catheter days)[a]**

Variables	No failure ($n = 118$) n (%)	Failure ($n = 68$) n (%)	Univariable			Multivariable		
			HR	95% CI	*P* level	HR	95% CI	*P* level
Birth weight (ref: ≥1500 g)	70 (68)	33 (32)	Ref					
Birth weight <1500 g	48 (58)	35 (42)	0.62	0.35-1.08	.09	0.58	0.34-0.99	.047
Sex (ref: male)	58 (82)	13 (18)	Ref			Ref		
Female	60 (52)	55 (48)	2.01	1.03-3.91	.04	2.21	1.15-4.24	.02
Reason of admission: Hypoglycemia (ref: no)	92 (63)	53 (37)	Ref					
Hypoglycemia: yes	26 (63)	15 (37)	0.50	0.25-1.01	.05	[b]		
Suspected infection (ref: yes)	90 (65)	49 (35)	ref					
No	28 (60)	19 (40)	2.03	1.14-3.66	.02	1.89	1.07-3.35	.03
Inserted by (ref: other than registrar)	48 (61)	31 (39)	ref					
Inserted by registrar	70 (65)	37 (35)	0.69	0.41-1.16	.17	[b]		
Inserted in intensive care	85 (61)	54 (39)				[b]		
Inserted elsewhere	33 (70)	14 (30)	1.56	0.83-2.96	.17			
Medications administered at any time of during the trial (other than blood, antibiotics, inotropes)	53 (76)	17 (24)	Ref					
Blood, antibiotics, inotropes administered	65 (56)	51 (44)	1.66	0.91-3.03	.10	[b]		

Abbreviations: CI, confidence interval; HR, hazard ratio; PIVC, peripheral intravenous catheter; ref, referent.
[a]The final model was adjusted for the time interaction with weight.
[b]Not part of the multivariable model, as the results did not reach significance.

Legemaat et al,[1] who also found an increased risk in PIVC failure for neonates greater than 1500 g ($P < .001$). They hypothesized that this was due to larger neonates having PIVCs inserted by clinicians with less experience. The true cause of this phenomenon warrants further investigation.

Empirical evidence to support clinical decision-making surrounding umbilical catheters securement is limited,[19] with this being difficult to apply adhesives due to immature and degrading tissue, and the angle of the device. This may explain some of the dressing performance challenges for umbilical catheters (both venous and arterial), with 13% not clean, dry, and intact on assessment. Umbilical securements not meeting these criteria are unlikely to function adequately to prevent local or systemic infection and device migration, with a previous adult study demonstrating increased risk of infection with disrupted dressings.[20]

This study has limitations. It was based in a single, Australian site, so generalizability outside of this setting is unknown. However, we have provided a clear description of the study population and methods, including a priori definition of study outcomes. Second, due to resource limitations not all neonates were able to participate in the study; however, the population is representative of the general Australian neonatal community.[21] Overall, we have provided a reliable platform for research and practice development across the scope of VADs used in neonatal care.

CONCLUSION

Despite commonality and importance of VAD use, harm associated with VAD in neonates is a substantial and significant problem. We have provided accurate, reliable data to guide future interventional studies and evidence implementation.

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