Original Article

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Catheter failure in the administration of hyperosmotic drugs through a peripheral vein and vascular selection: A retrospective cohort study

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SUMMARY This study aimed to determine whether the placement of a peripheral intravenous catheter (PIVC) in the cephalic vein of the forearm could prevent PIVC failure in patients receiving hyperosmotic drugs through the peripheral vein. This retrospective cohort study included patients aged ≥ 20 years who had received infusion therapy *via* a PIVC in our institution between July and November 2017. Patients were divided into groups according to PIVC insertion into the cephalic, basilic, and medial veins. PIVCs used to administer drugs with osmotic pressure ratios > 2.0 were included. The primary outcome was survival time to catheter failure. Catheter failure was defined as accidental and unplanned catheter removal. We set the cephalic vein and other veins, including the medial and basilic veins, in the forearm as cohort groups. We used the Kaplan-Meier survival curves to compare the time until catheter failure in the cohort groups. The Cox proportional hazard models were fitted, and the hazard ratios were calculated. A total of 46 catheters with hyperosmotic agents were included in the analysis. Catheter failure was observed in 25 (54.3%) cases. Time to catheter failure in patients receiving high-dose drugs *via* the cephalic vein was significantly longer than that in the other two groups ($p < 0.01$). Thus, the cephalic vein, which has a high blood flow, is the ideal site of PIVC insertion in patients receiving high drug concentrations to prevent catheter failure.

Keywords peripheral intravenous catheter, ultrasonography, blood flow, complication, adverse events

1. Introduction

Most patients require at least one peripheral vascular device when intravenous fluids and medications are being administered. The most commonly used one is the peripheral intravenous catheter (PIVC). Recent studies reported that more than 70% of patients in acute care hospitals require PIVCs (*1-3*). Notably, more than 25% of PIVCs are removed prematurely, which is known as catheter failure (*3-5*). In Japan, the prevalence of catheter removal due to catheter failure among inpatients in a university hospital was 18.8% (*6*). Catheter failure is associated with symptoms such as erythema, swelling, induration, bleeding, pain, and insufficient dripping (*7,8*). These symptoms negatively affect patients' comfort and treatment, thus preventing the continuation of infusion therapy (*1,9*). In such cases, catheters need to be replaced, resulting in an increase in labor, cost, and patient discomfort (*10*). Therefore, it is important for patients and healthcare providers to prevent PIVC failure. Risk factors of various PIVC complications are known; however, healthcare providers cannot effectively prevent these complications.

In a previous study that suggested that mechanical irritation was an important factor in catheter failure, the effectiveness of care protocols was investigated, including an ultrasonographic "pre-scan" for selecting a large-diameter vein before catheterization, a "post-scan" to confirm the position of the tip of the catheter after catheterization with ultrasonography, and the use of a flexible polyurethane catheter to reduce the mechanical irritation that contributes to the incidence of catheter failure (*11-15*). Consequently, the relative risk reduction in interventions for catheter failure was 0.60 (95% confidence interval [CI]: 0.47-0.71). In the intervention group, it was difficult to completely prevent catheter failure. Despite a reduction in the mechanical stimuli that contributed to catheter failure, complications related to chemical irritation from pharmaceuticals could not be avoided. An effective method to prevent pharmaceutical chemical stimulation, especially from drugs administered at high concentrations, has not been established (*16-18*). High concentrations of drugs are administered *via* central veins with abundant blood flow. Moreover, the administration of drugs at an osmotic pressure more than twice as that of physiological saline increases the risk of catheter failure and ulceration, even in the dosage range permitted for administration into the peripheral veins (*19*). However, the volume of the main blood flow distribution in the forearm is unknown as previous studies limited their investigation to the veins in the upper arms (*20,21*). Therefore, it remains unclear whether catheterization in the peripheral vein with an abundant blood flow will prevent catheter failure. A previous study suggested that blood flow in the peripheral veins in the forearm is more abundant in the cephalic veins than in the other forearm veins (*22*) and indicated that the cephalic vein might be a better choice for preventing catheter failure when patients are administered drugs at a high osmotic pressure.

This study aimed to determine whether the placement of the PIVC in the cephalic vein in the forearm could reduce the probability of PIVC failure in patients administered high osmotic pressure drugs through the peripheral veins.

2. Materials and Methods

2.1. Design and setting

This retrospective cohort study included patients aged 20 years who were hospitalized and had received infusion therapy *via* a PIVC placed by the nurses at our institution between July and November 2017. The detailed study protocol has been published elsewhere (*19*). Patients were recruited from a medical department with high PIVC usage based on previous studies (*12,23*). PIVCs used to administer drugs with osmotic pressure ratios > 2.0 were included in the study. Patients receiving chemotherapy and those with poor cognitive ability were excluded. Study procedures were explained to the physicians and nurses working at the ward at the beginning of the study period. Upon admission, patients who were scheduled to receive a PIVC as part of their treatment were provided a written briefing of the study. Moreover, permission for patient intervention was obtained from the attending physician. Written informed consent was obtained from all residents or their representations. The study was performed in accordance with the principles of the Declaration of Helsinki. The study protocol was approved by the Ethics Committee of our institution (#2019009NI).

2.2. Data collection

2.2.1. Outcome

The outcome measure was survival time to catheter failure. Catheter failure was defined as the accidental or unplanned removal of catheters based on standard nursing practice for using PIVCs in our hospital in accordance with the Centers for Disease Control and Prevention guidelines (*24*). Information regarding catheter failure was obtained from a medical chart and interviews. Data on catheter insertion and removal and time were collected from the patients' medical charts. The researcher made direct observations at least twice a day and interviewed nurses and patients (*25*). The researcher also collected data on the dwelling time.

2.2.2. Catheterized vein

The researchers photographed and recorded the site where the catheter was inserted. They identified the major veins based on the anatomical location of the insertion. This study excluded cases of dorsal hand veins and upper arm implantation. The veins of the forearm were divided into three categories: cephalic, basilic, and medial veins.

2.2.3. Other variables

The following data were collected by reviewing the patients' medical charts: patient characteristics such as age, sex, and body mass index (BMI); comorbidities (presence of organ tumors); medical history (diabetes); previous treatments (history of steroid use, chemotherapeutic solutions, immunosuppressive solutions, anticoagulants, and radiation therapy); blood examination results including C-reactive protein (CRP), albumin, and platelet levels; antibiotic medications administered at baseline; and the total time of locking. Nurse-related information such as the experience of catheterization was also collected (*26*). The following data were collected through macroscopic observation: characteristics of the site for catheterization (anatomical insertion site, dominant vein, success of first catheterization attempt, times for catheterization), PIVC type (catheter material and size), and the characteristics of the target vein (diameter and depth) (*12*).

2.3. Data analysis

We compared time to PIVC failure based on catheter insertion in the cephalic, medial, and basilic veins in the forearm. We used the Kaplan-Meier survival curves to compare the time until catheter failure between the cohort groups. The log-rank test was used to compare the catheter survival rates among the groups. Cox proportional hazard models were fitted, and the hazard ratios (HRs) were calculated. Age (reference: 1 year), sex (reference: male), BMI (unit = 0.1), blood vessel diameter (unit = 0.1 mm), blood vessel depth (unit = 0.1 mm), experience of the nurse, Alb (unit = 0.1 g/dL) and CRP (unit = 0.1 mg/dL) levels, and the use of antibacterial agents were added to the model as control variables. The problem of the Hosmer-Lemeshow test used in logistic regression analysis to evaluate the fitness of the model was clarified in this study. Data were analyzed using Stata version 14 (StataCorp, USA).

3. Results

A total of 46 catheters used to administer hyperosmotic agents were included in the analysis. Catheter failure was observed in 25 (54.3%) cases. Patient characteristics are shown in Table 1. The median age of the patients was 72 years (57-82 years), and 62.5% of the patients were male.

Figure 1 shows the Kaplan-Meier survival curves to compare the time until catheter failure among the three cohort groups. Multivariate Cox proportional hazards models were fitted to identify independent predictors of complications, including the type of the catheterized vein, catheter size, and first insertion attempts (Table 2).

Four additional cases of concomitant use of fat emulsion were excluded from the analysis. The results were similarly significant for the vascular sites ($p < 0.05$), indicating the robustness of the results.

4. Discussion

4.1. Short summary

PIVC insertion into the cephalic vein significantly reduced the hazard of catheter failure in case of high-concentration drugs. Catheter placement in the cephalic vein was associated with a longer survival time to catheter failure when using highly osmotic agents, even when morphological features of blood vessels (vessel diameter and depth) were introduced as covariates.

4.2. Outcome interpretation

The use of high-concentration drugs may cause ulceration and catheter failure (*27-29*). To prevent this, comprehensive care, such as the care-bundle

Table 1. Baseline characteristics of subjects

Items	Cephalic vein	*n* = 26	Basilic vein	*n* = 10	Medial vein	*n* = 10	Total	*n* = 46
Age, years	64.9	(17.2)	64.7	(19.6)	73.6	(16.9)	66.7	(17.6)
Sex, male	15	(57.7%)	5	(50.0%)	4	(40.0%)	24	(52.2)
Body mass index	23.5	(3.8)	24.7	(3.7)	24.4	(4.8)	23.9	(4.0)
Diameter of vein (mm)	2.8	(0.8)	2.7	(0.8)	2.4	(0.6)	2.7	(0.8)
Depth of vein (mm)	2.5	(0.9)	2.2	(0.7)	2.3	(1.1)	2.41	(0.9)
Using oversized catheters	16	(61.5)	8	(80.0)	8	(80.0)	32	(69.6)
Level of nurse's experience in PIVC insertion								
Beginner	7	(26.9%)	5	(50.0%)	7	(70.0%)	11	(23.9)
Intermediate	13	(50.0%)	2	(20.0%)	1	(10.0%)	26	(56.5)
Expert	4	(15.4%)	3	(30.0%)	2	(20.0%)	9	(19.6)
Albumin (g/dL)	3.3	(0.7)	3.5	(0.5)	0	(0.0%)	3.3	(0.7)
C-reactive protein (mg/dL)	2.4	(2.8)	3.6	(4.2)	3.0	(0.7)	3.0	(3.8)
Antibacterial drugs	18	(69.2%)	6	(60.0%)	3.6	(5.5)	27	(58.7)
Multiple puncture attempts	19	(73.1%)	2	(20.0%)	8	(80.0%)	29	(63.0)
Catheter failure	11	(42.3%)	4	(40.0%)	7	(70.0%)	22	(47.8)

The variables are presented as the mean (standard deviation) or *n* (%). Level of nurse's experience: beginner, 0-100 PIVCs; intermediate, 101-800 PIVCs; expert, > 801 PIVCs. Abbreviation: PIVC, peripheral intravenous catheter.

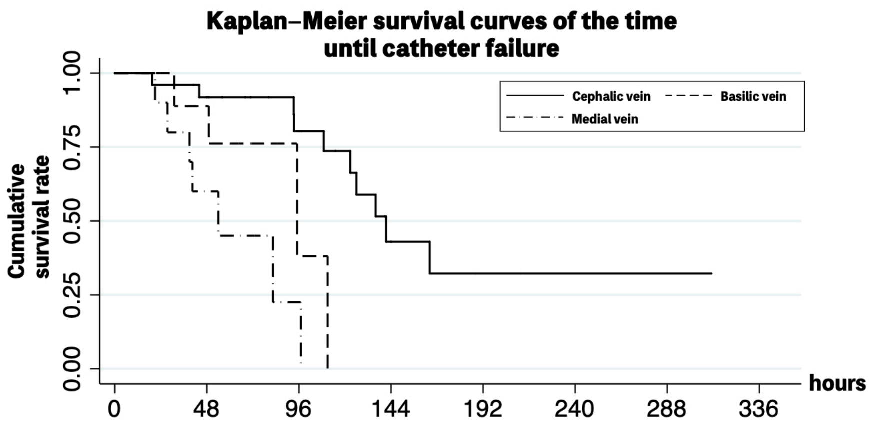

Figure 1. Kaplan-Meier survival curves of the time until catheter failure.

Table 2. Multivariate Cox proportional hazard model

n = 46	Adjusted HR	95% CI	*p*-value
Catheterized vein (compared with the cephalic vein)			
Basilic vein	3.15	0.82-11.4	0.09
Medial vein	7.73	2.16-28.1	0.01
Using oversized catheters	1.09	0.35-3.43	0.88
First punctuator attempts	1.46	0.51-4.17	0.48

Note: Hosmer-Lemeshow test; $p = 0.603$. Abbreviations: HR, hazard ratio; CI, confidence interval.

approach has been proposed (*19,30*). Furthermore, many interventions were limited to those that prevent catheter deviation and those that aimed to reduce mechanical stimulation (*19,31-33*). Although the properties of the chemical solutions have been a related factor, there are some aspects that the nurse cannot change in clinical practice, such as the drug composition (*34*). Moreover, the method of drug use is different across countries and clinical settings, and it is difficult to propose an improvement plan that can be applied universally. However, the action of the drug solution and its chemical properties are less likely to cause local tissue damage if sufficient dilution is performed. Blood dilution is important for any drug, and this study shows the importance of selecting blood flow-rich sites as a possible preventive strategy of catheter failure.

4.3. Internal validity

The concern of this study was the outcome evaluation challenges. In the present study, the assessment of catheter failure was performed by nurses in one ward, and the nurse's ability may have affected the incident rate of catheter failure. However, all cases of the catheter and non-catheter failure extractions were photographed and symptomatically identified by the researchers. Therefore, certain criteria were met, and the variability was considered minimal.

4.4. External validity and clinical implementation

This study has some limitations. There was an external validity issue with the target population. The patients were from urban areas hospitalized in an acute care university hospital with an average age of approximately 65 years. Therefore, the results of this study may not be applicable to more elderly patients (*i.e.*, > 80 years old) or those with vascular-related diseases because many patients had gastroenterology as their primary disease and did not have any vascular-related conditions.

4.5. Further research

It is necessary to examine the functional factors of the blood vessels related to catheter failure and ulceration, especially when using a high concentration of drugs. Finally, it is possible to find a sound basis for evaluating the peripheral vein blood flow and catheter management.

In conclusion, catheter placement in the cephalic vein was associated with a longer survival time to catheter failure when using highly osmotic agents, even when morphological features of blood vessels (vessel diameter and depth) were introduced as covariates. Therefore, it is necessary to consider not only the morphological but also the functional characteristics of the vessel when selecting a site for catheter placement.

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Conflict of Interest: The authors have no conflicts of interest to disclose.

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