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The impact of flushing with pre-filled saline syringes on the incidence of peripheral venous catheter failure: A quasi-experimental study

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Abstract

Background: Short peripheral venous catheters are one of the most frequently used devices in hospitals. Peripheral venous catheter failure, defined as the unscheduled dysfunction of peripheral venous catheter, is common and frequently entails a new invasive procedure. Flushing the catheter maintains patency and could prolong peripheral venous catheter dwell time. The introduction of pre-filled saline flushing syringes as compared to manually filled saline flushing syringes could facilitate the frequency of catheter flushing, and subsequently it could reduce peripheral venous catheter failure rate.

Objective: To demonstrate differences in overall peripheral venous catheter failure rates before and after the introduction of pre-filled saline flushing syringes and to assess the risk factors for peripheral venous catheter failure.

Methods: Quasi-experimental design, before-and-after intervention study. Intervention: introduction of pre-filled saline syringes for flushing. Multicenter study conducted in medical and surgical wards of three European hospitals during a 9-month period (4 months pre-intervention, 5 months intervention). A multivariate Cox proportional model was used to identify factors associated with the occurrence of peripheral venous catheter failure.

Results: Data from 3853 peripheral venous catheters in 1915 patients were analyzed. Compared to pre-intervention period, a significant decrease in peripheral venous catheter failure rate was observed in the intervention period (57% vs 43.4%, $p < 0.001$). Independent factors associated with peripheral venous catheter failure were as follows: Charlson score ≥ 4 (hazard ratio: 1.648; 95% confidence interval: 1.069–2.527), days of hospital stay ≥ 10 (hazard ratio: 1.468; 95% confidence interval: 1.172–1.837), and catheter "D" (hazard ratio: 1.758; 95% confidence interval: 1.058–2.919).

Conclusion: The use of pre-filled saline syringes significantly reduced peripheral venous catheter failure and increased catheter dwell time. Thus, it is important to reinforce the use of the pre-filled syringes for flushing to reduce the incidence of peripheral venous catheters' failure.

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Introduction

Short peripheral venous catheters (PVCs) are one of the most commonly used devices in hospitals. According to the recent point prevalence study of nosocomial infections conducted in Europe,[1] almost 50% of hospitalized patients had a PVC inserted. Its use has expanded significantly in recent years because of the increase of medical procedures among hospitalized patients. Despite the historic usefulness of PVCs, its use continues to cause major problems in hospitalized patients.[2,3] The failure of PVC, defined as an unscheduled dysfunction of vascular catheter derived from phlebitis, thrombosis, extravasation, or suspected infection is a common complication. Replacement of the catheter entails a new invasive procedure, increases the risk for health workers and raises hospital costs. Although the rate of PVC failure is highly variable, the rate of phlebitis remains around 30%–60% in several studies.[4–7]

There are various interventions to prevent PVC failure. These include aseptic insertion technique, skin antisepsis, catheter-skin stabilization, and use of semipermeable transparent dressing to better evaluate the catheter insertion site.[8,9] Although it seems to be an important step during catheter care, flushing catheter is infrequently addressed in preventive infection guidelines. Flushing the catheter before and after the administration of intravenous medication maintains catheter patency, and prevents contact between incompatible fluids and medications that can promote thrombosis and phlebitis and may decrease the formation of biofilm by reducing fibrin buildup within the catheter lumen.[10] All these elements could help to reduce the complications of the catheters and prolong their dwell time.

Although flushing is highly advisable, compliance in daily routine care is low and it is not usually documented. Pre-filled saline syringes used for routine flushing of PVC offer several advantages: On one hand, they provide a convenient unit-of-use dose, saving nursing time by avoiding having to draw up the flush solution from other fluid bag or ampule. On the other hand, they could prevent interruption in aseptic technique and potential contamination and cross contamination from repetitive use of multiple-dose vials and large-volume bags of normal saline. Thus, a proper use of pre-filled saline syringes could be a convenient way to enhance patient safety while saving nursing time and costs.[11]

The primary objective of our research was to demonstrate the impact of pre-filled saline flushing syringes on the incidence of PVC failure and to assess the associated risk factors of this complication.

Methods

Study design

Quasi-experimental study

Pre-intervention observational period: Patients with a PVC inserted on study wards during the pre-intervention period and submitted to flushing practices according to usual hospital protocols were included. PVCs were prospectively followed daily by a member of the infection control team.

Intervention period: introduction of 3-mL/0.9% saline pre-filled syringes (BD PosiFlush™) for flushing PVCs. All consecutive patients with a PVC at study wards during the intervention period were included.

Flushing the PVC with the pre-filled saline syringes was promoted according to good clinical practice guidelines before and after medication. PVCs were prospectively followed daily by a member of the infection control team.

Surveillance

All the adverse events associated with any catheter being monitored for the study and reasons of PVC withdrawal/replacement were recorded.

PVC surveillance included the occurrence of mechanical and/or clinical PVC failures. The latter were first recorded as suspected events based on daily collection of the presence/absence of signs and/or symptoms during dwell time to up to 48 h after catheter removal.

Setting

Multicenter study conducted in medical and surgical wards of three European hospitals (2 in Spain and 1 in Italy) for a 9-month period (4 months pre-intervention period, 5 months intervention period) from September 2016 to May 2017. Patients were monitored in the following study hospitals: hospital I: Hospital Universitari Sant Joan de Reus (Reus, Spain), 32 beds in trauma ward and 100 beds in an internal medicine ward; hospital II: Parc Sanitari Sant Joan de Déu (Sant Boi de Llobregat, Spain), 36 beds in internal medicine ward and 24 beds in general surgery ward; and hospital III: National Institute for Infectious Diseases "Lazzaro Spallanzani" (Rome, Italy), 152 beds in the entire hospital. The fourth hospital (Bellvitge University Hospital/

BUH), where pre-filled saline syringes (BD PosiFlush™) have been in use for a decade, was considered as a control hospital in the study.

The pre-intervention practice in the three study hospitals was based on the use of manually filled saline syringes for flushing. The pre-intervention practice in the three study hospitals was based on the use of manually filled saline syringes for flushing and locking. The manual flushing policy consists of flushing PVCs with manually filled syringes with 3–5 mL of normal saline to assess the patency of the peripheral catheter before usage and to lock it when not in use. Locking of PVC is defined as the injection of a limited volume of saline following the catheter flush, for the period of time when the catheter is not used, to prevent intraluminal clot formation.[12] Needle-free connectors (NFCs) or needleless connectors are changed all along with catheter removal or replacement according to hospital guidelines.

Participants

Inclusion criteria: Patients admitted in the study wards during the study period and having one or more PVC during their hospitalization were considered eligible for the study. Patients were followed-up from the day of admission until the day of discharge from the study wards. All PVC and PVC-related events during this period were prospectively followed according to surveillance program previously described.

Exclusion criteria: patients under palliative treatment or with a life expectancy lower than 48 h.

Variables

The main outcome of the study was PVC failure, defined as an unscheduled dysfunction of PVC because of any of the following conditions: clinical failure (phlebitis, occlusion) and mechanical failure (extravasation and/or accidental removal). Phlebitis was defined as the simultaneous presence of two or more of the following criteria: (1) pain and/or tenderness with a severity of two or more on a 10-point scale (with 0 defined as no pain and 10 defined as the worst imaginable pain), (2) erythema extending to at least 1 cm from the insertion site, (3) swelling extending to at least 1 cm from the insertion site, (4) purulent discharge from the insertion site, and (5) a palpable venous cord beyond the tip of the catheter.[13] Extravasation injury was defined as the damage caused by the efflux of solutions from a vessel into the surrounding tissue spaces during intravenous infusion.[14] Occlusion was defined as any circumstance in which the PVC was still in place, but it was not possible to flush the catheter or infuse fluids (relatively synonymous terms included blockage). Accidental removal was defined as a catheter dislodgment that was not planned.[13]

Four types of PVCs have been used during the study period. The characteristics of the syringes in use are described in the supplemental table (Annex I).

Statistical analysis

The chi-square or Fisher's exact tests were used to compare categorical data, and the Student's t-test or Mann–Whitney U-test for continuous data, as appropriate. Cox regression analysis was performed to identify independent variables associated with catheter failure. Variables with $p < 0.05$ in univariate analysis were included in the multivariate Cox model to assess the association of these variables as independent risk factors with PVC failure. All tests were two-tailed, and a p value < 0.05 was considered statistically significant.

Ethics

This study was approved by the Clinical Research Ethics Committee of Bellvitge University Hospital (reference number AC092/15) and by the Ethics Committee of the National Institute for Infectious Diseases Lazzaro Spallanzani–IRCCS (reference number 21/2016). Patient data were anonymized for the purposes of this analysis. Information that could identify patients was protected according to the national normative approach.

Results

Data were collected from 3853 PVCs in 1915 patients among the three hospitals included in the study, excluding the control hospital. In this group, the mean age of patients was 61, and 60% of patients were males, while the Charlson score was of 1.4 (Table 1). In total, PVC failure was observed in 57% in the pre-intervention period, while the PVC failure after the implementation of the pre-filled syringes decreased to 43.4% ($p < 0.001$).

All three hospitals showed a decrease in the failure rates between pre-intervention period versus intervention period: hospital I (30% vs 26%), hospital II (70% vs 41%), and hospital III (71% vs 62%). Among the three participating hospitals, hospital II had the highest number of patients included during the study. A total of 2152 of catheters were used in hospital II with a decrease in PVC failure from 70% in pre-intervention period to 41% during the intervention period (Table 1). Our results showed that 25% of PVC failures registered were mechanical versus 23.1% clinical, with hospital III showing the highest failure rate in period 1 and period 2 with 33.2% versus 32.3% respectively (Annex II). A slight non-significant decrease in PVC failure rate in the control hospital was observed during the study period (Annex III).

A univariate analysis of the risk factors associated with PVC failure showed that PVC failure was more frequently

Table 1. Distribution of patients and catheters among the three participating hospitals: comparison between periods.

	Hospital I		Hospital II		Hospital III		Total	
	Period 1	Period 2	Period 1	Period 2	Period 1	Period 2	Period 1	Period 2
Number of patients (N)	309	302	515	498	120	171	944	971
Age (mean)	68.3	68.4	71.3	73.5	45.4	42	61.6	61.3
Gender (% male)	52.7%	51.7%	56%	50%	73%	74%	60.6%	58.6%
Charlson score (mean)	1.2	1.3	2.3	2.3	2	1.45	1.8	1.7
Mean days of hospital stay	11.1	10.9	11.6	9.6	12.2	11.4	11.6	10.6
Mean days of ward stay	10.2	9.7	10	8.3	11.1	10.1	10.4	9.3
Number of catheters	481	460	1251	901	300	460	2032	1821
Rate of PVC failure	30%	26%	70%	41%	70%	62%	57%	43.4%

Period 1 refers to pre-intervention period, and period 2 refers to intervention period. PVC: peripheral venous catheters.

Table 2. Univariate and multivariate analysis of the risk factors associated with PVC failure.

	Univariate analysis			Multivariate analysis	
	Non-catheter failure, N = 1906	Catheter failure, N = 1947	p value	Hazard ratio	95% CI
Age ⩾65	1176 (61.7%)	1190 (61.1%)	0.716		
Gender (male)	1071 (56.2%)	1116 (57.3%)	0.495		
Charlson score ⩾4	871 (45.7%)	1097 (56.3%)	0.000	1.644	1.069–2.527
Days of hospitalization ⩾10	713 (37.4%)	1289 (66.2%)	0.000	1.468	1.172–1.837
Days of catheterization ⩾4	993 (52.1%)	712 (36.6%)	0.000		
Unit of hospitalization					
Trauma	324 (17%)	86 (4.4%)	0.000	0.431	0.219–0.851
Type of catheter					
Catheter A	1587 (83.3%)	1475 (75.8%)	0.000		
Catheter B	129 (6.8%)	104 (5.3%)	0.037		
Catheter C	33 (1.7%)	75 (3.9%)	0.000		
Catheter D	157 (8.2%)	293 (15%)	0.000	1.758	1.058–2.913
Unit of catheterization					
Hospital	1118 (58.7%)	1181 (60.7%)	0.212		
Emergency unit	599 (31.4%)	661 (33.9%)	0.051		
Others	189 (9.9%)	105 (5.4%)	0.000		
Intervention period	974 (51.1%)	791 (40.6%)	0.000	0.761	0.630–0.919

PVC: peripheral venous catheter; CI: confidence interval.

observed among patients with a hospitalization longer than 10 days, having a catheter for ⩾4 days, admitted to trauma wards, catheterized in the emergency department, having any of the four PVC types used, and with a Charlson score ⩾4 points, while the PVC failure incidence was not significantly different according to age nor gender (Table 2). Multivariate analysis showed that the independent risk factors associated with PVC failure were as follows: Charlson score ⩾4 points (hazard ratio (HR): 1.64; 95% confidence interval [CI]: 1.069–2.527), ⩾10 days of hospital stay (HR: 1.468; 95% CI: 1.172–1.837), and use of "catheter D" (HR: 1.758; 95% CI: 1.058–2.919). On the other hand, the intervention period (HR: 0.761; 95% CI: 0.630–0.919) and the insertion of PVC at traumatology wards (HR: 0.431; 95% CI: 0.219–0.851) were protective factors.

The Kaplan–Meier curve (Figure 1) shows the difference in the dwell time of PVC between both periods. At 5 days of catheterization, 40% of PVC did not fail in the pre-intervention period, while 60% of them did not fail in the intervention period.

Discussion

This study sought to determine the impact of flushing with pre-filled saline syringes on the incidence of PVC failure. Our work was based on a multicenter quasi-experimental study performed among three European hospitals with a large number of PVCs and patients involved during the study period, and with a main finding that the implementation of pre-filled syringes reduced the rate of PVC failures and prolonged the catheter dwell time.

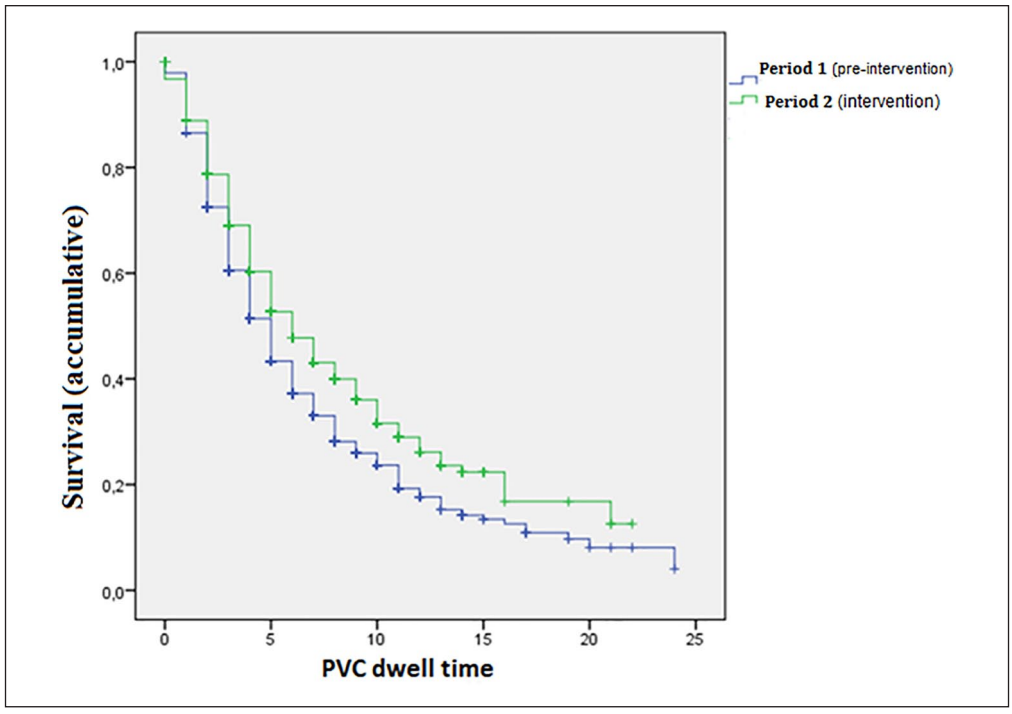

Figure 1. Kaplan–Meier curve showing the difference in the PVC dwell time between period 1 and period 2.

PVCs are the most common medical device used in hospitals in modern medicine;[15] however, 50% could fail ultimately.[16,17] The results of our study align with this figure, showed a rate of PVC failure in more than 50% of the catheters in use during the study period. This result is consistent with that reported in other studies,[18,19] even though comparisons should be made with caution because of the heterogeneity of definition criteria. Our results showed that the most frequent type of PVC failure was mechanical and mainly observed in hospital III. The change of the type of catheter in use (from type B to type D) in hospital III during the period 2 of the study could be associated with the PVCs failure rate registered, as pointed out by the multivariate analysis. Yet, literature has cited the contribution of many catheter characteristics such as materials or performance that can contribute to PVC failure.[20] PVC failure entails a replacement of catheters and thus an additional cost. According to a study conducted in Australia, an adjusted maintenance of catheter and replacement prevention could have a remarkable economic impact.[21]

Catheter failure could be associated with many risk factors. Our findings showed that an independent risk factor for catheter failure was length of hospital stay ($\geqslant$10 days), a result consistent with other published studies highlighting the period of hospitalization as a risk factor.[22] Other risk factor in our study was a Charlson score of comorbidity $\geqslant$4. The comorbidity of patients having venous catheters, measured in our cohort using the Charlson index or score, has been associated with a higher failure rate in PVCs.[23] Although this association is not clearly reflected in the literature, it could be speculated that those patients with higher comorbidity may require a more frequent use of these catheters for infuse drugs, they may have greater vascular fragility because of aging or have received corticoid treatment, or they may have interstitial edema in the case of patients with heart disease, cirrhosis, or nephropathy, all situations that are likely to impact the duration of a well-inserted and permeable PVC.

Various efforts have been made to decrease PVC failure. A number of interventions have been applied to reduce PVC complications, from scheduled replacement to aseptic techniques[24] and the introduction of an integrated system of peripheral catheters.[25]

Flushing is still one of the controversial measures applied to reduce PVC failure. While some studies have reinforced the importance of the implementation of flushing technique in reducing catheter colonization failure,[26,27] including occlusion of PVCs,[12] one study showed that neither the increased flushing volume nor its frequency significantly altered the risk of PVC failure.[10]

Little information exists in literature regarding the impact of using pre-filled syringes versus the use of manually saline filled syringes for flushing. Manually prepared syringes are subject to longer manipulation due to the process of filling which put them under higher contact with the healthcare team and put the PVC and the patient under higher risk of contamination, whereas the pre-filled syringes could prevent that easily. In addition, the change from standard syringes to the non-rebound pre-filled syringes, which avoids the reflux of blood with each disconnection, could have contributed in the reduction of the incidence of occlusion. Our study showed that using the pre-filled syringes for flushing was a protective independent factor for catheter failure. These results align with a

previous single-center pilot study on totally implantable venous access devices[28] and with a meta-analysis study conducted in China,[29] showing that the use of pre-filled versus manually filled syringes for flushing reduced PVC-related complications and extended PVCs survival. The ease of use of the pre-filled syringes encourage the healthcare team to use them and thus increase the frequency of flushing PVC and indirectly decrease the rate of PVC failure as demonstrated by our research.

An analysis of this type is inherently limited by the heterogeneity of different factors. First, the quasi-experimental design of this study lacks random assignment and leads to non-equivalent test groups which can limit the generalizability of the results to a larger population. Second, the heterogeneity of the patient populations in the study, the protocols for catheter insertion and site care, and the different types of catheters used along with the type of needleless connector in the participating hospitals could be considered as one of our study's limitations. And finally, in our study it was not possible to evaluate the frequency of flushing in both periods because these data are not recorded by the healthcare team in the nurse chart. We have assumed that the ease of use of the pre-filled syringes could have increased the frequency of flushing during the intervention period.

To conclude, the implementation of pre-filled saline syringes was able to reduce PVC failure in our study. The type of catheter in use, the Charlson score of the patient, and the length of its hospital stay can affect the rate of PVC failure and catheter-related complications. The decrease of the rate of PVC failure due to the implementation of the pre-filled saline syringes could lead to less frequent replacement of catheters, decreasing the risk for patients, improving the safety of healthcare workers, and finally contributing to reduce the associated costs.

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Supplemental material

Supplemental material for this article is available online.

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